Indiana Academic Standards for Physics I
Standards Resource Guide Document

This Teacher Resource Guide has been developed to provide supporting materials to help educators successfully implement the Indiana Academic Standards for Physics I. These resources are provided to help you in your work to ensure all students meet the rigorous learning expectations set by the Academic Standards. Use of these resources is optional – teachers should decide which resource will work best in their school for their students.
This resource document is a living document and will be frequently updated.
Please send any suggested links and report broken links to:

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The resources, clarifying statements, and vocabulary in this document are for illustrative purposes only, to promote a base of clarity and common understanding. Each item illustrates a standard but please note that the resources, clarifying statements, and vocabulary are not intended to limit interpretation or classroom applications of the standards.

Standard 1: Constant Velocity			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.		Time – amount of time/how long it takes to accomplish a task as measured in hours and minutes

Position – location of an object in relation to a scale or other objects
Uniform rate – identical or uniform motion per unit time
Qualitatively – using observations and descriptions
Quantitatively – numerical observations/data
Motion – movement of an object in relation to its surroundings | Scale, proportion, and quantity

Systems and system models |

PI.1.2 Describe the slope of the graphical representation of position vs. clock reading (time) in terms of the velocity of the object.		Velocity – speed with direction	Scale, proportion, and quantity
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.		System – defined boundaries encompassing things/parts in a complex whole Magnitude – numerical quantity or value Slope – number that measures its "steepness", usually denoted by the letter m. It is the change in y for a unit change in x along the line	Scale, proportion, and quantity
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.		Distance - scalar quantity that refers to "how much ground an object has covered" during its motion. Displacement - vector quantity that refers to "how far out of place an object is"; it is the object's overall change in position.Speed – how fast an object is moving Velocity – the rate at which an object changes its position Average speed – distance traveled divided by the time elapsed Average velocity – displacement divided by the time.	Scale, proportion, and quantity

Standard 2: Constant Acceleration			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.			Scale, proportion, and quantity Systems and system models
PI.2.2 Describe the slope of the graphical representation of velocity vs. clock reading (time) in terms of the acceleration of the object.		Acceleration - increase in the rate or speed of something.	Cause and effect
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.			Scale, proportion, and quantity

Indiana Academic Standard	Clarifying Statement	Highlighted Vocabulary Words from the Standard Defined	Crosscutting Concept
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.			Cause and effect
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.		Constant velocity – no change in speed or direction as time progresses Constant acceleration – change in velocity by the same amount each second Free fall – downward movement under the force of gravity only	Scale, proportion, and quantity

Standards 3: Forces			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.		Newton's first law of motion – body remains at rest or in uniform motion in a straight line unless acted upon by a force Net external force – sum of force(s) applied on an object by something other than the object	Scale, proportion, and quantity Energy and matter

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.		Inertial mass – mass of a body as determined by the second law of motion from the acceleration of the body when it is subjected to a force that is not due to gravity One dimension – ability to move in only one dimension, linear movement	Cause and effect
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.		Vectors – quantity having direction as well as magnitude Magnitude – numerical quantity or value Direction – course along which something moves Units – scale in which a numerical value is expressed Forces – strength or energy as an attribute of physical action or movement	Scale, proportion, and quantity Energy and matter
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.		Newton's third law of motion – when a force acts on a body due to another body, then an equal and opposite force acts simultaneously on that body Action-reaction pairs – for every action force, there is an equal and opposite reaction force	Scale, proportion, and quantity Systems and system models

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.		Gravitational mass – mass of a body as measured by its gravitational attraction for other bodies	Systems and system models Energy and matter
PI.3.6 Describe the slope of the force due to gravity vs. gravitational mass graphical representation in terms of gravitational field.		Gravitational field –the attractive effect, considered as extending throughout space, of matter on other matter	Cause and effect
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.		Independent – is not determined by or relying on another variable Mass – measure of the number of atoms in a sample	Scale, proportion, and quantity

Standard 4: Energy			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.		Translational kinetic – the energy due to motion from one location to another Gravitational potential – energy an object possesses because of its position in a gravitational field Elastic potential energies – energy stored as a result of deformation of an elastic object, such as the stretching of a spring	Scale, proportion, and quantity
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.		Potential energy – energy possessed by a body as a result of its position or condition rather than its motion	Cause and effect Energy and matter
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.		Work – when acting on a body, there is a displacement of the point of application in the direction of the force Energy – power derived from the utilization of physical or chemical resources, especially to provide light and heat or to work machines Area – amount of space inside the boundary of a flat (2-dimensional) object	Systems and system models Energy and matter

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.		Unbalanced force – Forces that cause a change in the motion of an object	Systems and system models
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.		Conservation of energy – principle stating that energy cannot be created or destroyed, but can be altered from one form to another Mechanical energy – ability to do work Closed system – region that is isolated from its surroundings by a boundary that admits no transfer of matter or energy across it Dissipative – scatter in various directions; disperse	Scale, proportion, and quantity Energy and matter
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.		Speed – measure of the rate of movement of a body expressed either as the distance travelled divided by the time taken	Cause and effect Stability and change.

Standard 5: Linear Momentum In One Dimension			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.		Linear momentum – product of an object's mass and its velocity	Scale, proportion, and quantity Stability and change.
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.		Impulse – change in momentum	Scale, proportion, and quantity
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.		Collision – instance of one moving object or person striking against another Separation – the action or state of moving or being moved apart	Scale, proportion, and quantity Energy and matter

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.			Systems and system models Patterns
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.		Elastic – no loss of kinetic energy in the collision Inelastic – part of the kinetic energy is changed to some other form of energy in the collision	Scale, proportion, and quantity Structure and function
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.		Center of mass – point at which the entire mass of a body may be considered concentrated for some purpose	Systems and system models

Standard 6: Simple Harmonic Oscillating Systems			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.		Stretch – made or be capable of being made longer or wider without tearing or breaking Spring – elastic object used to store mechanical energy Restoring force – any one of the forces or torques that tend to restore a system or parts thereof to equilibrium Compression – the reduction in volume Ideal spring – force is proportional to the displacement, has no weight, mass, or damping losses	Scale, proportion, and quantity Patterns
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.		Elastic material – ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed Elastic constant – constant or coefficient that expresses the degree to which a material possesses elasticity	Scale, proportion, and quantity Structure and function
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.		Period – time needed for one complete cycle	Cause and effect Stability and change.

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.		Gravity – force that attracts a body toward any other physical body having mass Length – measurement or extent of something from end to end Amplitudes – length and width of waves	Cause and effect Energy and matter
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.		Harmonic oscillating systems – physical system in which some value oscillates above and below a mean value at one or more characteristic frequencies	Cause and effect Structure and function

Standard 7: Mechanical Waves and Sound			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PI.7.1 Differentiate between transverse and longitudinal modes of oscillation for a mechanical wave traveling in one dimension.		Transverse wave – wave vibrating at right angles to the direction of its propagation Longitudinal wave – wave vibrating in the direction of propagation Oscillation – movement back and forth at a regular speed Mechanical wave – wave that is an oscillation of matter, and therefore transfers energy through a medium	Scale, proportion, and quantity Patterns
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.		Medium – intervening substance, as air, through which a force acts or an effect is produced Electromagnetic wave – propagated by simultaneous periodic variations of electric and magnetic field intensity	Scale, proportion, and quantity Patterns
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.		Wavelength – distance between successive crests of a wave Frequency – rate at which a vibration occurs that constitutes a wave, either in a material (as in sound waves), or in an electromagnetic field (as in radio waves and light), usually measured per second	Cause and effect Energy and matter

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.			Systems and system models Stability and change.
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.		Doppler Effect – apparent change in the frequency of waves, as of sound or light, occurring when the source and observer are in motion relative to each other, with the frequency increasing when the source and observer approach each other and decreasing when they move apart	Systems and system models
PI.7.6 Qualitatively and quantitatively apply the principle of superposition to describe the interaction of two mechanical waves or pulses.		Pulses - disturbance that travel from one location to another location through a medium	Patterns
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.		Resonance – reinforcement or prolongation of sound by reflection from a surface or by the synchronous vibration of a neighboring object Sound waves – wave of compression and rarefaction, by which sound is propagated in an elastic medium such as air	Patterns Energy and matter

Standard 8: Simple Circuit Analysis			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
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.		Cross sectional area – section made by a plane cutting anything transversely Resistivity – measure of the resisting power of a specified material to the flow of an electric current Ohmic – standard unit of electrical resistance in the International System of Units (SI),	Scale, proportion, and quantity Stability and change.
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.			Scale, proportion, and quantity
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.		Voltage – electromotive force or potential difference expressed in volts	Energy and matter

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.			Energy and matter Structure and function
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.		Simple series circuit – closed circuit in which the current follows one path Current – time rate of flow of electric charge Power – rate at which electrical energy is transferred by an electric circuit Circuit – path in which electrons from a voltage or current source flow	Cause and effect
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.		Parallel circuit – circuit is divided into two or more paths	Cause and effect Stability and change.
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.		Conservation of energy – principle stating that energy cannot be created or destroyed, but can be altered from one form to another Kirchhoff's loop rule – sum of all the voltages around the loop is equal to zero Battery – container consisting of one or more cells, in which chemical energy is converted into electricity and used as a source of power	Scale, proportion, and quantity Structure and function

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.			Scale, proportion, and quantity Structure and function

Crosscutting Concepts

1. Patterns. Observed patterns of forms and events guide organization and classification, and they 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 determine 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.