Indiana Academic Standards for Physics II
Standards Resource Guide Document

This Teacher Resource Guide has been developed to provide supporting materials to help educators successfully implement the Indiana Academic Standards fo Physics II. These resources are provided to help you in your work to ensure all students meet the rigorous learning expectations set by the Academic Standards. 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: Energy and Momentum in Two Dimensions			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.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.		Net external force – overall force exerted on an object by another object Qualitatively – observation/description Quantitatively – numerical data Linear momentum – vector quantity defined as the product of an object's mass and its velocity Impulse momentum theorem – net force acts on an object, impulse of the net force is equal to the change in momentum of the object Translational kinetic energy – the energy due to motion from one location to another Work – energy theorem – work done by all forces acting on a particle equals the change in the particle's kinetic energy	Energy and matter

PII.1.2 For a system consisting of a 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.		Two- dimensional – having only two dimensions (such as length and width or the x and y axis for movement).	Energy and matter Scale, proportion, and quantity
PII.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.		Mechanical energy – ability to do work Velocity – speed and direction Kinetic energy – energy that a body possesses by virtue of being in motion	Energy and matter Scale, proportion, and quantity
PII.1.4 Classify interactions between two objects moving in two dimensions as elastic, inelastic and completely inelastic.		Inelastic – part of the kinetic energy is changed to some other form of energy Elastic – no loss of kinetic energy Completely inelastic – maximum amount of kinetic energy of a system is converted into other energy	Energy and matter Scale, proportion, and quantity

Standard 2: Temperature and Thermal Energy Transfer			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.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.		Temperature – degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch Thermal energy – internal energy of an object due to the kinetic energy of its atoms and/or molecules 1. Kinetic molecular theory –Gases are composed of a large number of particles that behave like hard, spherical objects in a state of constant, random motion. 2. These particles move in a straight line until they collide with another particle or the walls of the container. 3. These particles are much smaller than the distance between particles. Most of the volume of a gas is therefore empty space. 4. There is no force of attraction between gas particles or between the particles and the walls of the container. 5. Collisions between gas particles or collisions with the walls of the container are perfectly elastic. None of the energy of a gas particle is lost when it collides with another particle or with the walls of the container. 6. The average kinetic energy of a collection of gas particles depends on the temperature of the gas and nothing else. Motion – action or process of moving or being moved	Energy and matter Systems and system models

		Molecules – group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction	
PII.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.		Solid – definite shape and volume Gas – takes the volume and shape of the container Molecular motion – movement of microscopic particles	Energy and matter Systems and system models
PII.2.3 Cite evidence from everyday life to describe the transfer of thermal energy by conduction, convection, and radiation.		Conduction – process by which heat energy is transmitted through collisions between neighboring molecules Convection – heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it Radiation – Heat transfer due to emission of electromagnetic waves	Energy and matter Pattern
PII.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.		Volume – space a sample occupies Number of molecules – value of individual particles in a sample Ideal gas – theoretical gas composed of many randomly moving point particles that do not interact except when they collide elastically Closed system – physical system that doesn't exchange any matter with its surroundings, and isn't subject to any force whose source is external to the system Pressure – force applied perpendicular to the surface of an object per unit area over which that force is distributed	Energy and matter Scale, proportion, and quantity

PII.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.			Energy and matter
PII.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.		PV graphs – graphical representation of the relationship between pressure and volume	Systems and system models Scale, proportion, and quantity

Standard 3: Fluids			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.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.		Incompressible fluid – fluid with a constant density Density – mass/volume relationship for a sample	Systems and system models

PII.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.		Buoyancy – upward force exerted by a fluid that opposes the weight of an immersed object Floating – rest or move on or near the surface of a liquid without sinking Submerged – cause to be under water Archimedes principle – upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces	Systems and system models
PII.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.		Flow rate – volume of fluid which passes per unit time Pipe – tube of metal, plastic, or other material used to convey water, gas, oil, or other fluid substances Velocity – speed of something in a given direction	Energy and matter Scale, proportion, and quantity
PII.3.4 Develop and apply Bernoulli's principle and continuity equations to predict changes in the speed and pressure of a moving incompressible fluid.		Bernoulli's principle – increase in the velocity of a stream of fluid results in a decrease in pressure Continuity equations – volume of water flowing through the hose per unit time (i.e. the flow rate at the left must be equal to the flow rate at the right or in fact anywhere along the hose/pipe	Energy and matter Scale, proportion, and quantity
PII.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.		Pascal's Principle – pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid Mechanical advantage – the ratio of output force to the input force applied to a mechanism	Energy and matter Scale, proportion, and quantity

Standard 4: Electricity			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.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.			Energy and matter
PII.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.		Distance - amount of space between two things or people	Energy and matter Pattern

PII.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.		Coulomb's law – force of attraction or repulsion acting along a straight line between two electric charges is directly proportional to the product of the charges and inversely to the square of the distance between them	Energy and matter Scale, proportion, and quantity
PII.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.			Energy and matter Scale, proportion, and quantity
PII.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.		Equipotential lines – every point in it is at the same potential	Energy and matter Pattern

PII.4.6 Distinguish between electric potential energy and electric potential (i.e. voltage).			Energy and matter Scale, proportion, and quantity
PII.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.		Conservation of energy – energy cannot be created or destroyed, but can be altered from one form to another.	Energy and matter Scale, proportion, and quantity

Standard 5: Simple and Complex Circuits			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.5.1 Relate the idea of electric potential energy to electric potential (i.e. voltage) in the context of electric circuits.			Energy and matter
PII.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.			Energy and matter Scale, proportion, and quantity
PII.5.3 Describe the slope of the graphical representation of			Energy and matter

current vs. voltage or voltage vs. current in terms of the resistance of the device.			Scale, proportion, and quantity
PII.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.			Energy and matter
PII.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.		DC circuits – type of circuit with direct current	Energy and matter Scale, proportion, and quantity

Standard 6: Magnetism			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.6.1 Describe the magnetic properties of ferromagnetic, paramagnetic, and diamagnetic materials on a macroscopic scale and atomic scale.		Ferromagnetic – high susceptibility to magnetization Paramagnetic – very weakly attracted by the poles of a magnet Diamagnetic – tending to become magnetized in a direction at 180° to the applied magnetic field.	Energy and matter Scale, proportion, and quantity

PII.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.			Energy and matter
PII.6.3 Describe the motion of a charged or uncharged particle through a uniform magnetic field.			Energy and matter Pattern
PII.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.		Right hand rule – rule in electricity: if the thumb, the forefinger, and the middle finger of the right hand are bent at right angles to one another with the thumb pointed in the direction of motion of a conductor relative to a magnetic field and the forefinger in the direction of the field, then the middle finger will point in the direction of the induced electromotive force	Energy and matter Pattern
PII.6.5 Describe the practical uses of magnetism in motors, electronic devices, mass spectroscopy, MRIs, and other applications.		Mass – measure of amount of matter in a sample Spectroscopy – branch of science concerned with the investigation and measurement of spectra produced when matter interacts with or emits electromagnetic radiation. MRIs –Magnetic resonance imaging (MRI) is a technique that uses a magnetic field and radio waves to create detailed images of the organs and tissues within your body	Structure and function Cause and effect

Standard 7: Electromagnetic Induction			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**

PII.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.			Energy and matter Scale, proportion, and quantity
PII.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.			Energy and matter Scale, proportion, and quantity
PII.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.		Ohm's Law – law relating the voltage difference between two points, the electric current flowing between them, and the resistance of the path of the current. Faraday's Law – induction is a basic law of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force Lenz's Law – principle stating that an electric current, induced by a source such as a changing magnetic field, always creates a counterforce opposing the force inducing it. Magnetic flux – number of magnetic field lines passing through a closed sur	Energy and matter Cause and effect

Standard 8: Geometric Optics			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.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.		Planar – mirror with a flat (planar) reflective surface Converging – reflecting surface that bulges inward Diverging mirrors – curved mirror in which the reflective surface bulges toward the light source	Energy and matter Cause and effect
PII.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.		Angles of incidence – angle that an incident line or ray makes with a perpendicular to the surface at the point of incidence Angles of refraction – angle made by a refracted ray with a perpendicular to the refracting surface	Energy and matter Cause and effect

PII.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.		Focal length – distance between the center of a lens or curved mirror and its focus Lens –piece of glass or other transparent substance with curved sides for concentrating or dispersing light rays, used singly (as in a magnifying glass) or with other lenses (as in a telescope).	Energy and matter Cause and effect
PII.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.		Real image – reproduction of an object via light that can be formed on a surface Virtual image – optical image formed from the apparent divergence of light rays from a point, as opposed to an image formed from their actual divergence	Energy and matter Cause and effect

Standard 9: Particle and Wave Nature of Light			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.9.1 Develop the relationship among frequency, wavelength, and energy for electromagnetic waves across the entire spectrum.			Energy and matter Cause and effect
PII.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.			Energy and matter Cause and effect

PII.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.		Photon – particle representing a quantum of light or other electromagnetic radiation. A photon carries energy proportional to the radiation frequency but has zero rest mass Photoelectron - electron emitted from an atom by interaction with a photon, especially an electron emitted from a solid surface by the action of light Planck's Constant – constant that gives the unvarying ratio of the energy of a quantum of radiation to its frequency and that has an approximate value of 6.626×10^{-34} joule second—symbol h	Energy and matter Cause and effect
PII.9.4 Describe the slope of the graphical representation of the kinetic energy of a photoelectron vs. frequency in terms of Planck's constant.			Energy and matter Cause and effect
PII.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.		Monochromatic light – light of a single wavelength Slits – a long, narrow cut or opening Interference pattern – pattern that results when two or more waves interfere with each other, generally showing regions of constructive and of destructive interference	Energy and matter Cause and effect

PII.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.		Unpolarized light - light waves in which the vibrations occur in more than a single plane	Energy and matter Cause and effect

Standard 10: Modern Physics			
Indiana Academic Standard	**Clarifying Statement**	**Highlighted Vocabulary Words from the Standard Defined**	**Crosscutting Concept**
PII.10.1 Describe the Standard Model and explain the composition and decay of subatomic particles using the Standard Model and Feynman diagrams.		Subatomic particles – particle smaller than an atom Standard model –mathematical description of the elementary particles of matter and the electromagnetic, weak, and strong forces by which they interact Feynman diagrams – diagram showing electromagnetic interactions between subatomic particles	Stability and change Structure and function
PII.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.		Electromagnetic repulsion – acts between charged particles and is the combination of all electrical and magnetic forces Nucleus – positively charged central core of an atom, consisting of protons and neutrons and containing nearly all its mass	Stability and change

PII.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.		Fission – action of dividing or splitting something into two or more parts Fusion – process or result of joining two or more things together to form a single entity	Stability and change
PII.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.		Conservation of mass – principle stating that mass cannot be created or destroyed Conservation of charge – principle stating that the total electric charge of an isolated system is fixed Linear momentum – vector quantity defined as the product of an object's mass and its velocity Radioactive particle – emission of elementary particles by some atoms when their unstable nuclei disintegrate	Stability and change

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.