CONCEPTUAL PHYSICS

Standards Category	Anchor	Big Idea	Concepts	Pennsylvania State Standards/Eligible Content
Physical Sciences: Physics	Introduction to Physics	What is physics?	What is physics? What concepts does physics cover? Students will study the scientific method and how scientific models are created. They will also analyze contrasting scientific models. Students will learn to conduct experiments and evaluate experimental data as well as drawing conclusions. How does physics relate to the other sciences that students study? Who studies physics? What kinds of jobs do they have? Where do they work? What units are used in physics? (kilogram, meter, Newton, etc.)	3.1.P.A9: • Compare and contrast scientific theories. • Know that both direct and indirect observations are used by scientists to study the natural world and universe. • Identify questions and concepts that guide scientific investigations. • Formulate and revise explanations and models using logic and evidence. • Recognize and analyze alternative explanations and models. • Explain the importance of accuracy and precision in making valid measurements. • Examine the status of existing theories. • Evaluate experimental information for relevance and adherence to science processes. • Judge that conclusions are consistent and logical with experimental conditions. • Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. • Communicate and defend a scientific argument.
Physical Sciences: Physics	Astronomy and the Cosmos	Astronomy is the study of the universe. The cosmos is the idea that the universe is governed by predictable laws.	Astronomy has played an import role in the actions of civilizations throughout history. Students will study and discover how the observations of the universe have helped to shape civilizations. The universe is predictable, and the laws that govern the actions of the universe are measurable. Students will study Kepler's Laws of Planetary motion, Newton's Law of Universal Gravitation, and see how these are connected. Students will study star formation and evolution; galaxies; the expansion of the universe; the origins of the universe and the Big Bang Theory; black holes; etc…	**3.3.12.B1:** • Describe the **life cycle** of stars based on their mass. • Analyze the influence of **gravity** on the formation and **life cycles** of galaxies, including our own Milky Way **galaxy**; stars; planetary **systems**; and residual material left from the creation of the **solar system.** • Relate the **nuclear processes** involved in energy production in stars and supernovas to their **life cycles.** **3.3.12.B2:** • Apply mathematical models and computer simulations to study evidence collected relating to the extent and composition of the universe. • Analyze the evidence supporting theories of the origin of the universe to predict its future.
	Principles of Motion and Force	Objects that move in translational motion are described in terms of position, velocity, and acceleration.	The position, velocity, and acceleration of an object can be measured and quantified (in magnitude and direction), using appropriate tools and units, in a reference frame. Position, velocity and acceleration are examples of vectors, quantities relying on both direction and magnitude that combine with other velocity and	

	Principles of Motion and Force	All forces arise from the interactions between different objects.	acceleration vectors according to specific mathematical rules. Vectors allow the formulation of Physical Laws independent of a particular coordinate system. The motion of a projectile can be represented and analyzed as two different motions, a vertical motion with constant acceleration and a horizontal motion with constant speed. Position, velocity, and acceleration describe the motion of objects at every scale from the motion of subatomic particles to the motion of entire galaxies. These concepts are used in the design and evaluation of many technologies.	3.2.P.B1 • Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. • Use force and mass to explain translational motion or simple harmonic motion of objects. • Relate torque and rotational inertia to explain rotational motion. 3.2.P.B7 • Compare and contrast scientific theories. • Know that both direct and indirect observations are used by scientists to study the natural world and universe. • Identify questions and concepts that guide scientific investigations. • Formulate and revise explanations and models using logic and evidence. • Recognize and analyze alternative explanations and models. • Explain the importance of accuracy and precision in making valid measurements. • Examine the status of existing theories. • Evaluate experimental information for relevance and adherence to science processes. • Judge that conclusions are consistent and logical with experimental conditions. • Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. • Communicate and defend a scientific argument.
Physical Sciences: Physics	Reasoning and Analysis		Four fundamental forces of nature dominate at different scales: the strong and weak forces acting within the nucleus opposing proton-proton repulsion, the electrical force dominates in biological and chemical processes, and gravitational force dominates at astronomical scales. Forces may result from contact or action at a distance in the case of gravitational, electrostatic, or magnetic fields. Solids, liquids and gases can exert forces on surfaces which can be quantified as pressure. When two surfaces of objects are in contact with each other, the force of friction between them depends on the nature of the materials in contact and the normal force.	
Physical Sciences: Physics	Principles of Motion and Force		Newton's Law of Universal Gravitation Newton's Law of Universal Gravitation computes the gravitational force between two masses separated by some distance. Coulomb's Law computes the force between two electrically charged objects separated by some distance. Inertial mass is a measure of the resistance of an object to changes in translation motion (Newton's First Law of Motion).	3.2.P.B1 • Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. • Use force and mass to explain translational motion or simple harmonic motion of objects. • Relate torque and rotational inertia to explain rotational motion. 3.2.P.B7 • Compare and contrast scientific theories. • Know that both direct and indirect observations are used by scientists to study the natural world and universe. • Identify questions and concepts that guide scientific investigations. • Formulate and revise explanations and models using logic and evidence. • Recognize and analyze alternative explanations and models. • Explain the importance of accuracy and precision in making valid measurements.

	Reasoning and Analysis	All changes in translational motion are due to forces.	The inertial mass and charge of an object and any forces acting on it can be measured and quantified using appropriate tools, units, frames of reference, and techniques. Newton's Laws of Motion empirically describe the motion of objects in terms of force interactions, mass, and acceleration in a non-accelerating, non-relativistic reference frame. For objects in a constant state of motion (including those at rest) the net force is zero.	• Examine the status of existing theories. 3.2.10.B1 • Analyze the relationships among the net forces acting on a body, the mass of the body, and the resulting acceleration using Newton's Second Law of Motion. • Apply Newton's Law of Universal Gravitation to the forces between two objects. • Use Newton's Third Law to explain forces as interactions between bodies. • Describe how interactions between objects conserve momentum. • Evaluate experimental information for relevance and adherence to science processes. • Judge that conclusions are consistent and logical with experimental conditions. • Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. • Communicate and defend a scientific argument.
Physical Sciences: Physics	Processes, Procedures, and Tools of Scientific Investigation Processes, Procedures, and Tools of Scientific Investigation	The rotational motion of objects is described in terms of angular position, angular velocity, and angular acceleration.	Given an understanding of all the forces acting on an object, its acceleration can be calculated. Given an understanding of an object's motion, its force(s) can be inferred. While many forces can act on an object, those forces can be represented and analyzed using a free body diagram. Forces can be mathematically combined together as a vector sum resulting in a single net force that causes the object to accelerate in the direction of that net force. An understanding of forces and their interactions is used to describe, explain, and design any number of natural and human-built objects and systems.	3.2.P.B1 • Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. • Use force and mass to explain translational motion or simple harmonic motion of objects. • Relate torque and rotational inertia to explain rotational motion. 3.2.P.B7 • Compare and contrast scientific theories. • Know that both direct and indirect observations are used by scientists to study the natural world and universe. • Identify questions and concepts that guide scientific investigations. • Formulate and revise explanations and models using logic and evidence. • Recognize and analyze alternative explanations and models. • Explain the importance of accuracy and precision in making valid measurements. • Examine the status of existing theories. • Evaluate experimental information for relevance and adherence to science processes. • Judge that conclusions are consistent and logical with experimental conditions. • Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. • Communicate and defend a scientific argument.
	Principles of Motion and Force		The angular position, angular velocity, and angular acceleration of an object are vectors and can be and quantified using appropriate tools, frames of reference, and units in reference to an axis of rotation. Angular position, angular speed, and angular acceleration are the rotational analogues of translational position, velocity, and acceleration. The rotation of objects gives rise to various rotation-related phenomena including gyroscopic stability and magnetic fields.	
Physical Sciences: Physics			A rotating reference frame can give the appearance of an object constrained to travel in a circular path, which gives	

Physical Sciences: Physics	Processes, Procedures, and Tools of Scientific Investigation Principles of Motion and Force Principles of Motion and Force Forms, Sources, Conversion, and Transfer of Energy	All changes in rotation motion are caused by torque. Objects that move in simple harmonic motion can be described in terms of position, velocity, and acceleration and can result in the production of waves that travel through space. All simple harmonic motion can be explained using force and/or torque.	a centripetal acceleration directed from the object toward the center of the rotating reference frame. These terms describe the rotation of objects at different scales from the motion very small particles to the movement of entire galaxies An object's rotational inertia is determined by the object's mass distribution around the axis of rotation; it is analogous to inertia for translational motion. Consequently, two objects with identical total masses but different mass distributions will have different rotational inertias. Torque is vector product of an applied force and the distance between the point of its application and an object's axis of rotation, resulting in the rotation of the object. The rotational mass/inertia of an object and the torques acting on it can be measured and quantified using appropriate tools, units, and techniques. Torque is the rotational analogue of force for translational motion. An object in equilibrium has vector sums of torques and forces both equal to zero. These concepts explain phenomena at different scales from particle interactions to galaxy formation. An understanding of these concepts is used to describe, explain, and design any number of natural and human-built objects and systems. The period, frequency, amplitude, position, velocity, and acceleration of an object in simple harmonic motion can be measured and quantified (in magnitude and direction), using appropriate tools and units, in a reference frame. Mechanical and electromagnetic waves are described in terms of wavelength, amplitude, velocity, and frequency and can be produced by objects in simple harmonic motion or electrical circuits.	3.2.P.B1 • Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. • Use force and mass to explain translational motion or simple harmonic motion of objects. • Relate torque and rotational inertia to explain rotational motion. 3.2.12.B1 • Analyze the principles of rotational motion to solve problems relating to angular momentum and torque. 3.2.P.B1 • Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. • Use force and mass to explain translational motion or simple harmonic motion of objects. • Relate torque and rotational inertia to explain rotational motion.

	Principles of Motion and Force		Traveling waves transfer energy exerted as force to distant objects that absorb or reflect the traveling waves. The waves produced by objects in simple harmonic motion interact with other waves and matter and result in the phenomena of wave superposition, interference, reflection, refraction, and resonance. These concepts are used in the design and evaluation of many technologies.	
Physical Sciences: Physics	Forms, Sources, Conversion, and Transfer of Energy			3.2.P.B5 • Explain how waves transfer energy without transferring matter. • Explain how waves carry information from remote sources that can be detected and interpreted. • Describe the causes of wave frequency, speed, and wavelength. 3.2.12.B5 • Research how principles of wave transmissions are used in a wide range of technologies. • Research technologies that incorporate principles of wave transmission.
Physical Sciences: Physics	Principles of Motion and Force	All motion can be explained using the laws of the conservation of energy, the conservation of momentum, and/or the conservation of angular momentum.	The simplest harmonic motion can be characterized by one part, an inertial mass, which remains in one vicinity while oscillating about an average position. The simple harmonic motion of an object can be quantitatively described using the sine and cosine trigonometric functions. The inertial mass and return force or torque of objects interacting in a system can be measured and quantified using appropriate tools, units, and techniques. The oscillatory behavior results from the interplay of two properties that have opposite tendencies: a return force or torque and an inertial mass. The return force or torque tries to return the inertial mass to the resting position while the internal mass resists changes in motion. Solids, liquids and gases behave as springs providing restoring force when displaced from equilibrium. The angular frequency of oscillation is related to the return force and inertial mass. Inductance is the electrical analog for inertial mass, and capacitance is the electrical analog for a returning force. Simple harmonic oscillators can be constructed out of inductors and capacitors to generate electromagnetic waves.	3.2.10.B2 • Explain how the overall energy flowing through a system remains constant. • Describe the work-energy theorem. • Explain the relationships between work and power. 3.2.10.B3 • Explain how heat energy will move from a higher temperature to a lower temperature until equilibrium is reached. • Analyze the processes of convection, conduction, and radiation between objects or regions that are at different temperatures.

	Principles of Force and Motion Processes, Procedures, and Tools of Scientific Investigation	Energy can be transferred between objects and/or can be converted into different forms.	These concepts are used in the design and evaluation of many technologies. The position and velocity of an object or interacting objects can be represented and quantified in terms of its momentum, angular momentum, kinetic energy, and potential energy. Rotational kinetic energy is the rotational analogue of translational kinetic energy. The total amount of energy in a closed system is conserved. In every transformation of energy from one form to another, some of the energy is converted into thermal energy. The rotational inertia and angular velocity of an object can be represented in terms of its angular momentum and kinetic energy. In an isolated system, the total momentum or angular momentum is conserved. In a closed system, the product of an object's angular speed and rotational inertia will remain constant. There are a number of situations in which an object will have both translational and rotational kinetic energy. In a closed system, the total work performed by objects may be calculated from the final kinetic energy minus the initial kinetic energy. The potential energy of an object in simple harmonic motion is at its maximum value when the object is at its maximum displacement and at its minimum when the object passes through its equilibrium position. The kinetic energy of an object in simple harmonic motion is at its minimum value when the object is at its maximum displacement and at its maximum when the object passes through its equilibrium position. The conservation laws apply at all scales from very small particles to entire universe.	3.2.P.B1 • Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. • Use force and mass to explain translational motion or simple harmonic motion of objects. • Relate torque and rotational inertia to explain rotational motion. 3.2.P.B2 • Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. • Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. • Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion. 3.2.10.B6 • Explain how the behavior of matter and energy follow predictable patterns that are defined by laws. 3.2.12.B2 • Explain how energy flowing through an open system can be lost.

			Energy can take many different forms including mechanical, thermal, chemical, and electromagnetic. Energy can be transferred thermally, mechanically, electrically or chemically in a system. Heat energy is transferred between objects or regions by the process of convection, conduction, or radiation Electricity is the result of converting one form of energy into another and the flow of electrons via a conductor.	• Demonstrate how the law of conservation of momentum and conservation of energy provide alternate approaches to predict and describe the motion of objects. 3.2.12.B3 • Describe the relationship between the average kinetic molecular energy, temperature, and phase changes. 3.2.P.B3 • Analyze the factors that influence convection, conduction, and radiation between objects or regions that are at different temperatures. 3.2.P.B4 • Explain how stationary and moving particles result in electricity and magnetism. • Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. • Explain how electrical induction is applied in technology. 3.2.10.B4 • Describe quantitatively the relationships between voltage, current, and resistance to electrical energy and power. • Describe the relationship between electricity and magnetism as two aspects of a single electromagnetic force. 3.2.12.B4 • Describe conceptually the attractive and repulsive forces between objects relative to their charges and the distance between them. 3.2.10.B7 • Compare and contrast scientific theories. • Know that both direct and indirect observations are used by scientists to study the natural world and universe. • Identify questions and concepts that guide scientific investigations. • Formulate and revise explanations and models using logic and evidence. • Recognize and analyze alternative explanations and models. 3.2.12.B7 • Examine the status of existing theories. • Evaluate experimental information for relevance and adherence to science processes.

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