Content Area:Physics
Grade:

Unit	Enduring Understandings	Essential Questions	Objectives	Skills
Kinematics	**Students will understand that:** All forces share certain common characteristics when considered by observers in inertial reference frames. The acceleration of the center of mass of a system is related to the net force exerted on the system, where acceleration is directly proportional to the mass and inversely to the net applied force of the system	How can the motion of objects be predicted and/or explained? Can equations be used to answer questions regardless of the questions' specificity? How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports? How can we use models to help lus understand motion? Why is the general rule for stopping your car "when you double your speed, you must give yourself four times as much distance to stop?"	Express the motion of an object using narrative, mathematical, and graphical representations. Design and/or conduct an experimental investigation of the motion of an object. Analyze experimental data describing the motion of an object and be able to express the results of the analysis using narrative, mathematical, and graphical representations. Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-qualitatively.	Express key elements of natural phenomena across multiple representations in the domain. Describe representations and models of natural or man-made phenomena and systems of domains. Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Justify the selection of a mathematical routine to solve problems. Apply mathematical routines to quantities that describe natural phenomena.

				Estimate quantities that describe natural phenomena. Collect data to answer a particular scientific question. Analyze data to identify patterns or relationships. Make claims and predictions about natural phenomena based on scientific theories and models
Dynamics	**Students will understand that:** The internal structure of a system determines many properties of that system. The gravitational field is caused by an object with mass. At the macroscopic level, forces can be categorized as either long-ranged “field” forces or contact forces.	How can the properties of internal and gravitational mass be experimentally verified to be the same? How do you decide what to believe about scientific claims? How does something we cannot see determine how an object behaves? How do objects with mass respond when	Model verbally or visually the properties of a system based on its substructure and relate this to changes in the system properties over the time as external variables are changed. Apply F=mg to calculate the gravitational force on an object with mass, m in a gravitational field, g in the context of the effects of a net force on objects and systems.	Describe representations and models of natural or man-made phenomena and systems of domains. Apply mathematical routines to quantities that describe natural phenomena. Connect concepts in and across domain(s) to generalize across enduring understandings

	Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles All forces share certain common characteristics when considered by observers in inertial reference frames. The acceleration of an object interacting with another object can be predicted using Newton's second law. The acceleration of the center of mass of a system is related to the net force exerted on the system, where acceleration is directly proportional to the mass and inversely to the net applied force of the system	placed in a gravitational field? Why is acceleration due to gravity constant on Earth's surface? Are different kinds of forces really different? How can Newton's laws of motion be used to predict the behavior of particles? Why does the same push change the motion of a shopping cart more than the motion of a car?	Make claims about various contact forces between objects based on the microscopic cause of these forces. Explain contact forces and how they have certain directions. Perform an experiment to determine the relationship between the net force exerted on an object, its inertial mass and its acceleration. Design a plan for collecting data to measure gravitational mass and inertial mass and to distinguish between the two experiments (honors and advanced). Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units. Analyze a scenario and make claims about the	Justify claims with evidence. Construct explanations of phenomena based on evidence produced through scientific practices. Design a plan for collecting data. Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Make claims and predictions about natural phenomena based on scientific theories and models. Analyze data to identify patterns or relationships

			forces exerted on an object by other objects for different types of forces or components of forces. Describe a force as an interaction between two objects, and identify both objects for any force. Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact Analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces	

			Predict the motion of an object subject to forces exerted by several objects using Newton's second law in a variety of situations. Conduct activities to determine the relationship between the net force and the vector sum of the individual forces.	
Circular Motion and Gravitation	**Students will understand that:** A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance as well as a variety of other physical phenomena. Certain types of forces are considered fundamental. Forces can be categorized as either long-range forces or contact forces.	How does changing the mass of an object affect the gravitational force? Why is a refrigerator hard to push in space? Why do we feel pulled toward the Earth but not towards a pencil? How can the acceleration due to gravity be modified? How can Newton's laws of motion be used to predict the behavior of objects?	Describe situations when the gravitational force is the dominant force and when other forces can be ignored. Use Newton's law of gravitation to calculate the gravitational force that two objects exert on each other and use that force in contexts other than orbital motion. Connect the concepts of gravitational force and electric force to compare similarities	Connect phenomena and models across spatial and temporal scales. Apply mathematical routines to quantities that describe natural phenomena. Connect concepts in and across domain(s) to generalize across enduring understandings Design a plan for collecting data Evaluate the evidence provided by data sets in

	A gravitational field is caused by an object with mass. Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. Acceleration of the center of mass of a system is related to the net force exerted under the system and its acceleration. All forces share certain common characteristics when considered by observers in inertial reference frames.	How can we use forces to predict the behavior of objects and keep us safe? How is the acceleration of the center of mass of a system related to the net force exerted on the system? Why is it more difficult to stop a fully loaded dump truck than a small passenger car?	and differences between forces. Apply F= mg to calculate the gravitational force on an object of mass m in a gravitational field of strength g. Calculate the gravitational field due to an object with mass m. Approximate a numerical value of the gravitational field near the surface of an object from its radius and mass relative to those of Earth or other reference object. Design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. Evaluate whether all the forces on a system or whether all the parts of a system have been identified.	relation to a particular scientific question. Create representations and models of natural or man-made phenomena and systems in the domain. Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Analyze data to identify patterns or relationships. Justify the selection of a mathematical routine to solve problems. Construct explanations of phenomena based on evidence produced through scientific practices. Make claims and predictions about natural phenomena based on scientific theories and models.

			Design a plan to collect and analyze data for motion from force measurements Create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. Express the motion of an object using narrative, mathematical and graphical representations. Design an experimental investigation of the motion of an object, analyze the data, and express the results using narrative, mathematical and graphical representations. Represent forces in diagrams or mathematically. Analyze a scenario and make claims about the	

			forces exerted on an object by other objects. Describe a force and an interaction between two objects. Use Newton's third law to make claims and predictions, construct explanations, and analyze situations involving two object interactions.	
Energy	**Students will understand that:** Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. A force exerted on an object can change in the kinetic energy of the object. Interactions with other objects or systems can	How does pushing something give it energy? How is energy exchanged and transformed within or between systems? How does the choice of system influence how energy is stored or how work is done? How does energy conservation allow the riders in the back car of a rollercoaster to have a thrilling ride?	Define open and closed systems for everyday situations and apply conservation concepts for energy and linear momentum to those situations. Make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves. Use net force and velocity vectors to determine whether the	Make claims and predictions about natural phenomena based on scientific theories and models. Connect concepts in and across domain(s) to generalize across enduring understandings Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Justify the selection of a mathematical routine to solve problems.

	change the total energy of a system. The energy of a system is conserved.	How can the idea of potential energy be used to describe the work done to move celestial bodies? How is energy transferred between objects or systems? How does the law of conservation of energy govern the interactions between objects and systems?	kinetic energy of an object would change Apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object. Calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy with the system whose sum is the total energy. Predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. Make predictions about the changes in the mechanical energy of a system when a component of an external force acts	Apply mathematical routines to quantities that describe natural phenomena. Design a plan for collecting data Analyze data to identify patterns or relationships Make claims and predictions about natural phenomena based on scientific theories and models

			parallel or antiparallel to the direction of the displacement of the center of mass. Apply the concepts of conservation of energy and the work-energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system. Create a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy. Translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both	

			kinetic and potential energies. Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. Make calculations of the internal potential energy of a system. escribe and make predictions about the internal energy of systems. Conduct experiments and analyze data to determine how a force exerted on an object or system does work on the object or system as is moves through a distance. Predict and calculate the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.	

Momentum	**Students will understand that:** A force exerted on an object can change the momentum of the object. Interactions with other objects or systems can change the total linear momentum of a system. Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. The linear momentum of a system is conserved.	How does pushing an object change its momentum? How do interactions with other objects or systems change the linear momentum of a system? How is the physics definition of momentum different from how momentum is used to describe things in everyday life? How does the law of the conservation of momentum govern interactions between objects or systems? How can momentum be used to determine fault in car crashes?	Justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force. Justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction. Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. Analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.	Justify the selection of a mathematical routine to solve problems. Design a plan for collecting data. Analyze data to identify patterns or relationships Make claims and predictions about natural phenomena based on scientific theories and models. Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Apply mathematical routines to quantities that describe natural phenomena. Connect concepts in and across domain(s) to generalize across enduring understandings Refine scientific questions..

			Design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time. Calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system. Analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass. Apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time of the system. Perform an analysis on data presented as a force-time graph and	Evaluate sources of data to answer a particular scientific question. Evaluate the evidence provided by data sets in relation to a particular scientific question

			predict the change in momentum of a system. Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. Make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. Apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy. Design an experimental test of an application of the principle of the conservation of linear	

			momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment. Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principle for analyzing an elastic collision. Solve for missing variables, and calculate their values. Qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic. Plan data-collection strategies to test the law of conservation of momentum in a two-object collision that	

			is elastic or inelastic and analyze the resulting data graphically. Apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. Analyze data that verify conservation of momentum in collisions with and without an external friction force	
Simple Harmonic Motion	**Students will understand that:** The acceleration of an object interacting with other objects can be predicted using Newton's second law. The energy of a system is conserved	How does a restoring force differ from a "regular" force? How does the presence of restoring forces predict and lead to harmonic motion? How does a spring cause an object to oscillate? How can oscillations be used to make our lives easier?	Predict which properties determine the motion of a simple harmonic oscillator. Design a plan (honors/advanced) and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.	Apply mathematical routines to quantities that describe natural phenomena. Design a plan for collecting data. Analyze data to identify patterns or relationships Construct explanations of phenomena based on evidence produced through scientific practices.

		How does the energy conservation law govern the interactions between objects and systems? How can energy stored in a spring be used to create motion?	Analyze data to identify relationships between given values and variables associated with objects in oscillatory motion and use those data to determine the value of an unknown. Construct a qualitative and/or quantitative explanation of oscillatory behavior given evidence of restoring force. Calculate the expected behavior of a system using the principles of energy conservation. Describe and make predictions about everyday examples of systems with internal potential energy. Make calculations of the internal potential energy of a system. Apply mathematical reasoning to create a description of the	Make claims and predictions about natural phenomena based on scientific theories and models. Connect concepts in and across domain(s) to generalize across enduring understandings Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Justify the selection of a mathematical routine to solve problems

			internal potential energy of a system. Calculate changes in kinetic energy and potential energy of an oscillating system	
Torque (and Rotational Motion - honors/advanced)	**Students will understand that:** All forces share certain common characteristics when considered by observers in inertial reference frames. A force exerted on an object can cause a torque on that object. A net torque exerted on a system by other objects or systems will change the angular momentum of the system (honors/advanced). The angular momentum of a system is conserved (honors/advanced)	How does a system at rotational equilibrium compare to a system in translational equilibrium? How does the choice of system and rotation point affect the forces that can cause a torque on an object or a system? How can balanced forces cause rotation? Why are long wrenches more effective? How can an external net torque change the angular momentum of a system? Why is a rotating bicycle wheel more stable than a stationary one?	Express the motion of an object using narrative, mathematical and graphical representations. Use representations of the relationship between force and torque. Compare the torques on an object caused by various forces. Design an experiment and analyze data pertaining to torques in a balanced rigid system. Calculate torques on a two-dimensional system in static equilibrium. Make predictions about the change in the angular velocity about	Use representations and models to analyze situations or solve problems qualitatively and quantitatively. Justify the selection of a mathematical routine to solve problems. Apply mathematical routines to quantities that describe natural phenomena. Estimate quantities that describe natural phenomena. Justify the selection of a mathematical routine to solve problems. Collect data to answer a particular scientific question.

		How does the conservation of angular momentum govern interactions between objects and systems?	an axis for an object when forces exerted on the object cause a torque about that axis. (honors/advanced) Plan data-collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of the object about an axis	Analyze data to identify patterns or relationships. Make claims and predictions about natural phenomena based on scientific theories and models. Connect concepts in and across domain(s) to generalize across enduring understandings