Students explore principles of Newtonian mechanics (including rotational motion); work, energy, and power; mechanical waves and sound; and introductory, simple circuits. The course is based on six Big Ideas, which encompass core scientific principles, theories, and processes that cut across traditional boundaries and provide a broad way of thinking about the physical world.

BIG IDEA 1: *Objects and systems have properties such as mass and charge. Systems may have internal structure.*

The student is able to model verbally or visually the properties of a system based on its substructure and to relate this to changes in the system properties over time as external variables are changed. These properties include mass and charge (resistivity). [SP 1.1, 4.1, 7.1]

The student is able to make claims, discuss, explain, and make predictions about natural phenomena (such as charging process and simple circuits) based on conservation of electric charge. [SP 1.5, 6.1, 6.2, 6.4, 7.2]

The student is able to design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration and to distinguish between inertial and gravitational mass. [SP 4.2]

BIG IDEA 2: *Fields existing in space can be used to explain interactions.*

The student is able to apply $F=mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. [SP 2.2, 7.2]

The student is able to apply $g = G\frac{M}{r^2}$ to calculate the gravitational field due to an object with mass M, where the field is a vector directed toward the center of the object of mass M. [SP 2.2]

BIG IDEA 3: *The interactions of an object with other objects can be described by forces.*

The student is able to design an experimental investigation and analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations. [SP 1.5, 2.1, 2.2, 4.2, 5.1]

The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object and the object’s resulting motion. [SP 1.1, 6.4, 7.2]

The student is able to analyze, discuss, and predict the motion of an object subject to forces exerted by one or several objects using an application of Newton's three laws in a variety of physical situations including translational motion and oscillating systems. [SP 1.1, 1.4, 1.5, 2.2, 6.4, 7.2]

The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces in a variety of physical situations including translational motion and oscillating systems. [SP 4.2, 5.1]

The student is able to use Newton's law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in a variety of contexts including orbital motion. [SP 2.2]

The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges. [SP 2.2, 6.4]

The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. [SP 7.2]

The student is able to make claims and explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [SP 6.1, 6.2]

The student is able to 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. [SP 2.1]

The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time. [SP 4.2]

The student is able to justify the selection of data, analyze data, and 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. [SP 2.1, 4.1, 5.1, 6.4]

The student is able to make predictions about the changes in kinetic energy of an object based on the net force on the object and the displacement vector of the object. [SP 1.4, 2.2, 6.4, 7.2]

The student is able to use representations, compare, and calculate the torques on an object caused by various forces. [SP 1.4, 2.2, 2.3]

The student is able to design an experiment and analyze data about torques and motion in a rigid system (balanced or unbalanced). [SP 4.1, 4.2, 5.1]

The student is able to analyze, discuss, and make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis. [SP 6.4]

The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum. [SP 2.1, 6.4, 7.2]

The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object. [SP 4.1, 4.2, 5.1, 5.3]

The student is able to articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored. [SP 7.1]

BIG IDEA 4: *Interactions between systems can result in changes in those systems.*

The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and quantitatively using Newton's second law. [SP 1.2, 1.4, 2.2, 2.3, 6.4]

The student is able to create mathematical models and analyze graphical relationships for force, acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system. [SP 1.4, 2.2, 5.3]

The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.) or from data. [SP 1.4, 2.2, 5.1]

The student is able to apply mathematical routines to calculate the change in momentum of a system by analyzing a force-time graph, a mathematical expression of force with respect to time, or given the average force exerted over a certain time on the system. [SP 2.2, 5.1]

The student is able to calculate and predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. [SP 1.4, 2.1, 2.2, 6.4]

The student is able to calculate and make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass. [SP 6.4]

The student is able to 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. [SP 1.4, 2.2, 7.2]

The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system. [SP 1.2, 1.4]

The student is able to plan data collection strategies designed to investigate torque, angular velocity, angular acceleration, and angular momentum. [SP 3.2, 4.1, 4.2, 5.1, 5.3]

The student is able to use appropriate models and mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum. [SP 1.2, 1.4, 2.2]

The student is able to plan a data collection strategy designed to measure the change in angular momentum of a system and relate it to interactions with other objects or the average torque applied to the system and the time interval during which the torque is exerted. [SP 4.1, 4.2]

BIG IDEA 5: *Changes that occur as a result of interactions are constrained by conservation laws*.

The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [SP 6.4, 7.2]

The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that includes objects, which may have both kinetic and potential energies. [SP 1.4, 1.5, 2.2]

The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system. [SP 1.4, 2.1]

The student is able to describe and make qualitative and/or quantitative calculations and/or predictions about narrative or diagrams of systems with kinetic, potential, and internal energy. [SP 1.4, 2.2, 6.4, 7.2]

The student is able to predict and calculate from graphical data 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. [SP 1.4, 2.2, 6.4]

The student is able to design an experiment and analyze data (numerically and graphically) to examine how a force exerted on an object or system does work on the object or system as it moves through a distance. [SP 4.2, 5.1]

The student is able to make claims, analyze, discuss, and predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance. [SP 2.2, 6.4, 7.2]

The student is able to 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. [SP 4.2, 6.4, 7.2]
The student is able to apply conservation of energy (Kirchhoff's loop rule) using graphs or calculations involving simple circuits with resistors only. [SP 1.1, 1.4, 2.2, 6.4, 7.2]

The student is able to design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed. [SP 4.1, 4.2, 5.1]

The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. [SP 1.4, 2.2]

The student is able to make predictions and reconcile a situation based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. [SP 2.2, 3.2, 5.1, 5.3, 6.4, 7.2]

The student is able to predict, justify, and apply mathematical routines appropriately to problems involving elastic and inelastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy. [SP 2.1, 2.2, 6.4, 7.2]

The student is able to design an experiment to test the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data numerically or graphically, and evaluate any discrepancy between the prediction and the outcome. [SP 4.1, 4.2, 5.1, 5.3, 6.4]

The student is able to predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force).
[SP 6.4]

The student is able to make predictions and calculations related to the angular momentum and rotational inertia of a system whether the external net torque is zero or nonzero. [SP 2.1, 2.2, 6.4, 7.2]

<u>BIG IDEA 6</u>: *Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.*

The student is able to describe and interpret representations of transverse and longitudinal waves. [SP 1.2, 1.4, 2.2, 6.2]

The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples. [SP 6.4, 7.2]

The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example. [SP 6.4]

The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. [SP 4.2, 5.1, 7.2]

The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer. [SP 1.4]

The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses. [SP 1.1, 1.4]

The student is able to design a suitable experiment and analyze data illustrating the superposition of waves (only for wave pulses or standing waves). [SP 4.2, 5.1]

The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively. [SP 2.1, 3.2, 4.2]

The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. [SP 6.4]

The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air. [SP 3.2, 4.1, 5.1, 5.2, 5.3]

The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region. [SP 1.2]

The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments. [SP 2.2]

The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats. [SP 1.2]

Science Practices for AP Physics I

Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

1.1. The student can create representations and models of natural or man-made phenomena and systems in the domain.
1.2. The student can describe representations and models of natural or man-made phenomena and systems in the domain.
1.3. The student can refine representations and models of natural or man-made phenomena and systems in the domain.
1.4. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
1.5. The student can re-express key elements of natural phenomena across multiple representations in the domain.

Science Practice 2: The student can use mathematics appropriately.

2.1 The student can justify the selection of a mathematical routine to solve problems.
2.2 The student can apply mathematical routines to quantities that describe natural phenomena.
2.3 The student can estimate numerically quantities that describe natural phenomena.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

3.1 The student can pose scientific questions.
3.2 The student can refine scientific questions.
3.3 The student can evaluate scientific questions.

Science Practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question. [Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction, and/or archived data.]

4.1 The student can justify the selection of the kind of data needed to answer a particular scientific question.
4.2 The student can design a plan for collecting data to answer a particular scientific question.
4.3 The student can collect data to answer a particular scientific question.

4.4 The student can evaluate sources of data to answer a particular scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence.

5.1 The student can analyze data to identify patterns or relationships.
5.2 The student can refine observations and measurements based on data analysis.
5.3 The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

Science Practice 6: The student can work with scientific explanations and theories.

6.1 The student can justify claims with evidence.
6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices.
6.3 The student can articulate the reasons that scientific explanations and theories are refined or replaced.
6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.
6.5 The student can evaluate alternative scientific explanations.

Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

7.1 The student can connect phenomena and models across spatial and temporal scales.
7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.