

AP Physics 1

Curriculum/Content Area: Science	Course Length: 2 Terms
Course Title: AP Physics 1	Date last reviewed: 2018
Prerequisites:	Board approval date: May 2018
Primary Resource: Giancoli, Douglas C. (2005) Physics :principles with applications Upper Saddle River, N.J. : Pearson/Prentice Hall, Urone, P., & Hinrichs, R. (2016). College Physics. Houston, Texas: OpenStax College.	

Desired Results

Course description and purpose: Course description and purpose: AP Physics 1 is the equivalent to a first-semester algebra- based college physics course. The course covers Newtonian mechanics, work, energy, power, rotational motion, momentum, mechanical waves, sound and an introduction to electric circuits. The ability to develop and use physics knowledge by using scientific inquiry and reasoning is at the heart of this course. It is recommended that students who take this course follow it with AP Physics 2 for a complete coverage of physics topics and adequate preparation for college science courses. Students interested in Engineering and the physical science may follow this course with AP Physics C: Calculus-Based.

AP Physics Big Ideas
Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
Big Idea 2: Fields existing in space can be used to explain interactions.
Big Idea 3: The interactions of an object with other objects can be described by forces.
Big Idea 4: Interactions between systems can result in changes in those systems.
Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
Big Idea 6: 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.

Kinematics	
AP Big Ideas Big Idea 3: The interactions of an object with other objects can be described by forces.	
Standards	
AP Physics Enduring Understandings EU3.A: All forces share certain common characteristics when considered by observers in inertial reference frames. EU4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system.	
Advanced Placement Science Practices SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems. SP2 The student can use mathematics appropriately. SP4 The student can plan and implement data collection strategies in relation to a particular scientific question. SP5 The student can perform data analysis and evaluation of evidence.	
Learning Targets	
<ul style="list-style-type: none"> • I can express the motion of an object using narrative, mathematical, and graphical representations. [SP 1, 2] • I can design an experimental investigation of the motion of an object. [SP 4] • I can 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 5] 	
Assessment Evidence	
Performance Assessment Options <i>May include, but are not limited to the following:</i> <ul style="list-style-type: none"> • 	Other assessment options <i>May include, but are not limited to the following:</i> <ul style="list-style-type: none"> •
Digital Tools & Supplementary Resources	

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Newton's Laws & Dynamics

AP Big Ideas

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Big Idea 2: Fields existing in space can be used to explain interactions.

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 4: Interactions between systems can result in changes in those systems.

Standards

AP Physics Enduring Understandings

EU1.A: The internal structure of a system determines many properties of the system.

EU1.C: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

EU2.B: A gravitational field is caused by an object with mass.

EU3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.

EU3.B: Classically, the acceleration of an object interacting with other objects can be predicted.

EU3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a distance) forces or contact forces.

EU4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets:

Big Idea 1

- I can design an experiment for collecting data to determine the relationship between the net force exerted on an object its inertial mass and its acceleration. **[SP 4]**
- I can design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. **[SP 4]**

Big Idea 2

- I can 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, 7]**

Big Idea 3

- I can represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. **[SP 1]**
- I can analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. **[SP 6, 7]**
- I can challenge a claim that an object can exert a force on itself. **[SP 6]**
- I can describe a force as an interaction between two objects and identify both objects for any force. **[SP 1]**
- I can construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. **[SP 1, 6]**
- I can use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. **[SP 6, 7]**
- I can analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. **[SP 1]**
- I can predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. **[SP 6, 7]**
- I can design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. **[SP 4, 5]**
- I can re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. **[SP 1, 2]**
- I can create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. **[SP 1, 1, 2]**
- I can make claims about various contact forces between objects based on the microscopic cause of those forces. **[SP 6]**

- 3.C.4.2: I can explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. **[SP 6]**

Big Idea 4

- I can use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semiquantitatively. **[SP 1, 1, 2, 6]**
- I can make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time. **[SP 6]**
- I can evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified. **[SP 5]**
- I can create mathematical models and analyze graphical relationships for 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, 2.]**
- I can apply Newton's second law to systems to calculate the change in the center-of-mass velocity when an external force is exerted on the system. **[SP 2]**
- I can use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system. **[SP 1]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Digital Tools & Supplementary Resources

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Circular Motion & Gravitation

AP Big Ideas

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Big Idea 2: Fields existing in space can be used to explain interactions.

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 4: Interactions between systems can result in changes in those systems..

Standards: AP Enduring Understandings & Practices

AP Physics Enduring Understandings

EU1.C: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

EU2.A: 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 (long-range forces) as well as a variety of other physical phenomena.

EU.B: A gravitational field is caused by an object with mass.

EU3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.

EU3.B: Classically, the acceleration of an object interacting with other objects can be predicted.

EU3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.

EU3.G: Certain types of forces are considered fundamental.

EU4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system.

EU4.C: Interactions with other objects or systems can change the total energy of a system.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets:

Big Idea 1

- I can design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. **[SP 4]**

Big Idea 2

- I can 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, 7]**

- I can apply $g = GM/r^2$ 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]**
- I can approximate a numerical value of the gravitational field (g) near the surface of an object from its radius and mass relative to those of the Earth or other reference objects. **[SP 2]**

Big Idea 3

- I can represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. **[SP 1]**
- I can analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. **[SP 6, 7]**
- I can describe a force as an interaction between two objects and identify both objects for any force. **[SP 1]**
- I can construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. **[SP 1, 6]**
- I can use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. **[SP 6, 7]**
- I can analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. **[SP 1]**
- I can design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. **[SP 4, 5]**
- I can re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. **[SP 1, 2]**
- I can create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. **[SP 1, 2]**
- I can use Newton's law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in contexts other than orbital motion. **[SP 2]**
- I can use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion **[SP 2]**
- I can connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. **[SP 7]**
- I can articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored. **[SP 7]**

Big Idea 4:

- I can evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified. **[SP 5]**

Assessment Evidence:**Performance Assessment Options**

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Digital Tools & Supplementary Resources:

Tools and resources that can augment the learning experience for students

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Energy**AP Big Ideas**

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 4: Interactions between systems can result in changes in those systems.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Standards**AP Physics Enduring Understandings**

EU3.E: A force exerted on an object can change the kinetic energy of the object.

EU.C: Interactions with other objects or systems can change the total energy of a system.

EU5.A: 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.

EU5.B: The energy of a system is conserved.

EU5.D: The linear momentum of a system is conserved.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP3 The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets:

Big Idea 3:

- I can 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. **[SP 6, 7]**
- I can use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged. **[SP 1]**
- I can use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged. **[SP 1, 2]**
- I can 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. **[SP 2]**

Big Idea 4:

- I can calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy. **[SP 1, 2]**
- I can 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 6]**
- I can 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]**
- I can 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, 2, 7]**

Big Idea 5:

- I can define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. **[SP 6, 7]**
- I can set up 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. **[SP**

1, 2]

- I can 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. **[SP 1]**
- I can 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, 2]**
- I can describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. **[SP 2, 6, 7]**
- I can make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. **[SP 1, 2]**
- I can apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. **[SP 1, 2]**
- I can describe and make predictions about the internal energy of systems. **[SP 6, 7]**
- I can calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. **[SP 1, 2, 2]**
- I can design an experiment and analyze data 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, 5]**
- I can design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system. **[SP 4, 5]**
- I can 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, 2, 6]**
- I can make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). **[SP 6, 7]**
- I can 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, 6]**
- I can make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. **[SP 6, 7]**
- I can apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for

one-dimensional situations and only qualitatively in two-dimensional situations. **[SP 2, 3, 5]**

- I can 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. **[SP 2]**
- I can 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 whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome. **[SP 4, 5, 6]**
- I can 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 principles for analyzing an elastic collision, solve for missing variables, and calculate their values. **[SP 2]**
- I can 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. **[SP 6, 7]**
- I can apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. **[SP 6, 7]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Digital Tools & Supplementary Resources

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Momentum

AP Big Ideas

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 4: Interactions between systems can result in changes in those systems.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Standards:

AP Physics Enduring Understandings

EU3.D: A force exerted on an object can change the momentum of the object.

EU4.B: Interactions with other objects or systems can change the total linear momentum of a system.

EU5.A: 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.

EU5.D: The linear momentum of a system is conserved.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP3 The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets

Big Idea 3

- I can 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. **[SP 4]**
- I can 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]**
- I can 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 6]**
- I can 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. **[SP 5]**
- I can 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]**

Big Idea 4:

- I can 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.). **[SP 1,**

2]

- I can 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. **[SP 5]**
- I can apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system. **[SP 2]**
- I can perform analysis on data presented as a force-time graph and predict the change in momentum of a system. **[SP 5]**

Big Idea 5

- I can define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. **[SP 6, 7]**
- I can make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. **[SP 6, 7]**
- I can apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations. **[SP 2, 3, 5]**
- I can 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. **[SP 2]**
- I can 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 whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome. **[SP 4, 5, 6]**
- I can 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 principles for analyzing an elastic collision, solve for missing variables, and calculate their values. **[SP 2]**
- I can 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. **[SP 6,7]**
- I can 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. **[SP 4,5]**
- I can apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. **[SP 6,7]**
- I can analyze data that verify conservation of momentum in collisions with and without an external friction force. **[SP 4,5]**
- I can classify a given collision situation as elastic or inelastic, justify the selection of

conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. **[SP 2]**

- I can 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]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Simple Harmonic Motion

AP Big Ideas

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Standards

AP Physics Enduring Understandings

EU3.B: Classically, the acceleration of an object interacting with other objects can be predicted.

EU5.B: The energy of a system is conserved.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets

Big Idea 3:

- I can predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. **[SP 6,7]**
- I can design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force. **[SP 4]**
- The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown. **[SP 2,5]**
- I can construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. **[SP 2,6]**

Big Idea 5:

- I can 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, 2]**
- I can describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. **[SP 2, 6, 7]**
- I can make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. **[SP 1, 2]**
- I can apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. **[SP 1, 2]**
- I can describe and make predictions about the internal energy of systems. **[SP 6, 7]**
- I can calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. **[SP 1, 2]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Digital Tools & Supplementary Resources

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Torque and Rotational Motion

AP Big Ideas

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 4: Interactions between systems can result in changes in those systems.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Standards

AP Physics Enduring Understandings

EU3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.

EU3.F: A force exerted on an object can cause a torque on that object.

EU4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.

EU5.E: The angular momentum of a system is conserved.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets

Big Idea 3:

- I can use representations of the relationship between force and torque. **[SP 1]**
- I can compare the torques on an object caused by various forces. **[SP 1]**
- I can estimate the torque on an object caused by various forces in comparison to other situations. **[SP 2]**

- I can design an experiment and analyze data testing a question about torques in a balanced rigid system. **[SP 4, 5]**
- I can calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction). **[SP 1, 2]**
- I can 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]**
- I can 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 that object about an axis. **[SP 4, 5.]**
- I can 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 6, 7]**
- In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object. **[SP 2]**
- I can 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., 5]**

Big Idea 4:

- I can use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semiquantitatively. **[SP 1 2, 6]**
- I can 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]**
- I can plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data. **[SP 3, 4, 5]**
- I can describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems. **[SP 1]**
- I can plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems. **[SP 4]**
- I can use appropriate 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 2]**

- I can plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted. **[SP 4]**

Big Idea 5:

- I can make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque. **[SP 6, 7]**
- I can make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero. **[SP 2]**
- I can describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system. Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses. **[SP 2]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Electric Charge and Electric Force

AP Big Ideas

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Standards

AP Physics Enduring Understandings

EU1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.

EU3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a- distance) forces or contact forces.

EU5.A: 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.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets

Big Idea 1:

- I can make claims about natural phenomena based on conservation of electric charge. **[SP 6]**
- I can make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. **[SP 6, 7]**
- I can construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices. **[SP 6]:**
- I can challenge the claim that an electric charge smaller than the elementary charge has been isolated. **[SP 1, 6, 7]**

Big Idea 3:

- I can use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges. **[SP 2, 6]**
- I can connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. **[See SP 7]**

Big Idea 5:

- I can define open and closed systems for everyday situations and apply conservation concepts for energy, charge and linear momentum to those situations. **[SP 6, 7]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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DC Circuits

AP Big Ideas

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Standards

AP Physics Enduring Understandings

EU1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.

EU1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.

EU5.B: The energy of a system is conserved.

EU5.C: The electric charge of a system is conserved.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets

Big Idea 1:

- I can make claims about natural phenomena based on conservation of electric charge.
[SP 6]
- I can make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes,

including conservation of charge in simple circuits. [SP 6, 7]

- I can choose and justify the selection of data needed to determine resistivity for a given material. [SP 4]

Big Idea 5:

- I can construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff's loop rule). [SP 1]
- I can 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, 6, 7]
- I can apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [SP 2, 6, 7]
- I can apply conservation of electric charge (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. [SP 6, 7]
- I can 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, 5]
- I can 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, 2]

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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Mechanical Waves and Sound

AP Big Ideas

Big Idea 6: 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.

Standards

AP Physics Enduring Understandings

EU6.A: A wave is a traveling disturbance that transfers energy and momentum.

EU6.B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.

EU6.D: Interference and superposition lead to standing waves and beats.

Advanced Placement Science Practices

SP1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.

SP2 The student can use mathematics appropriately.

SP3 The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

SP4 The student can plan and implement data collection strategies in relation to a particular scientific question.

SP5 The student can perform data analysis and evaluation of evidence.

SP6 The student can work with scientific explanations and theories.

SP7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Learning Targets

Big Idea 6:

- I can use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave. **[SP 6]**
- I can describe representations of transverse and longitudinal waves. **[SP 1]**
- I can describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples. **[SP 6,7]**
- I can use graphical representation of a periodic mechanical wave to determine the amplitude of the wave. **[SP 1]**
- I can 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]**
- I can design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. **[SP 4, 5, 7]**
- I can 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]**

- I can 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]**
- I can design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves). **[SP 4, 5]**
- I can design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium. **[SP 4]**
- I can analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes. **[SP 5]**
- I can 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, 3, 4]**
- I can 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]**
- I can 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, 4, 5]**
- I can 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]**
- I can challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region. **[SP 1, 6]**
- I can 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]**
- I can use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats. **[SP 1]**

Assessment Evidence

Performance Assessment Options

May include, but are not limited to the following:

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Other assessment options

May include, but are not limited to the following:

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