STRATFORD PUBLIC SCHOOLS
Stratford, Connecticut

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Only The Educated Are Free

AP Physics 1 / UConn PHYS 1201Q
Grades 11-12

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<u>Advanced Placement Physics 1/UConn PHYS 1201Q</u>

AP Physics 1 is the equivalent of the first semester of an introductory, non-calculus based college physics course, taught over one school year. This College Board course is co-aligned to UConn PHYS 1201Q through the UConn Early College Experience (ECE) program. The primary textbook for the course is College Physics, 7th edition 2006 by Serway/Faughn (ISBN 0-534-99723-6)

In *AP Physics 1/UConn PHYS 1201Q*, students will explore principles of Newtonian mechanics (including rotational motion); work, energy, and power; mechanical waves and sound; thermodynamics, fluids, and introductory, simple circuits. The course is based on seven Big Ideas (BI), which encompass core scientific principles, theories, and processes that cut across traditional boundaries and provide a broad way of thinking about the physical world. The following are Big Ideas:

- Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)
- Fields existing in space can be used to explain interactions. (BI2)
- The interactions of an object with other objects can be described by forces. (BI3)
- Interactions between systems can result in changes in those systems. (BI4)
- Changes that occur as a result of interactions are constrained by conservation laws. (BI5)
- 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. (BI6)
- The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems. (BI7)

Throughout the units in this course, students will establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena, promoting an engaging and rigorous experience for AP/ECE physics students. Such Science Practices (SP) require that students:

SP1: 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 *reexpress key elements of natural phenomena across multiple representations* in the domain.

SP2: 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.

SP3: Engage in scientific questioning to extend thinking or to guide investigations within the context of the 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.*

SP4: Plan and implement data collection strategies in relation to a particular scientific question

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.

SP5: 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.

SP6: 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*.

SP7: 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.

These Science Practices developed by the College Board parallel the eight practices of science and engineering found in the NRC's *A Science Framework for K-12 Science Education*, upon which the *Next Generation Science Standards* (NGSS) are based. The importance of combining science and engineering practices with disciplinary core ideas is stated in the Framework as follows:

> "…students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. At the same time, they cannot learn or show competence in practices except in the context of specific content." (NRC Framework, 2012, p. 218)

The eight practices of science and engineering that the Framework identifies as essential for all students to learn (and describes in detail in Chapter 3 of the Framework) are listed below:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

In this course, students will also become familiar with the three components of scientific argumentation:

1) The Claim - an explanation or prediction for what, why or how something happens
2) The Evidence – the data or reasoning that supports the claim
3) The Questioning – the process through which claims are examined and defended

Throughout the year, as a result of the scientific argumentation process, students will expected revise their claims and make revisions as appropriate to their scientific thinking. Opportunities to engage in scientific argumentation will occur during class discussions (including peer questioning), laboratory work and data analysis presentations (peer critique/questions), project write-ups and presentations (peer critique/questions), and also on in-class assessments (quizzes and tests). Students will regularly be expected to explain not only the "what's", but also the "why's" and "how's" of the content learning in this course through the sighting of both qualitative and quantitative evidence. During lab time in particular, students should expect to engage regularly in peer critique and questioning of experimental procedures, data collection and analysis, and experimental conclusions.

Students will be provided opportunities to apply the Science Practices and demonstrate growth in their scientific argumentation skills through laboratory work and projects. At least twenty-five percent of instructional time in this course is devoted to such work, with an emphasis on inquiry-based investigations that will require students to ask questions, make observations and predictions, design experiments, analyze data, and construct arguments in a collaborative setting. The objective of the course is to have students develop the skills and intuition to be able to understand physics problems and, along with mathematical reasoning, to be able to solve college-level physics problems. The lab experiments parallel and support the core concepts of the curriculum. Ultimately most of the lab experimental designs lead to the collection of data that is analyzed through graphical methods to draw conclusions about scientific phenomena, and all have written components to them. Students are expected to record their observations, data, and data analyses as part of their *Lab Portfolio*. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate.

The lab work in this course supports the following Common Core English Language Arts Standards in Science and Technical Subjects:

CCSS.ELA-LITERACY.RST.11-12.3
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

CCSS.ELA-LITERACY.RST.11-12.7
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

CCSS.ELA-LITERACY.RST.11-12.8
Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

CCSS.ELA-LITERACY.RST.11-12.9
Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

CCSS.ELA-LITERACY.WHST.11-12.1.B
Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.

CCSS.ELA-LITERACY.WHST.11-12.1.D
Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

CCSS.ELA-LITERACY.WHST.11-12.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

CCSS.ELA-LITERACY.WHST.11-12.2.E
Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).

CCSS.ELA-LITERACY.WHST.11-12.4
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

In *AP Physics 1/UConn PHYS 1201Q*, students will cultivate their understanding of Big Ideas and Science Practices as they explore the following topics:

- Kinematics (*#)
- Newton's laws (*#)
- Circular motion and Universal Law of Gravitation (*#)
- Work, energy, and conservation of energy (*#)
- Impulse, linear momentum, and conservation of linear momentum (*#)
- Simple harmonic motion: simple pendulum and mass-spring systems (*#)
- Rotational motion: torque; rotational kinematics, dynamics and energy, and conservation of angular momentum (*#)
- Electrostatics: electric charge and electric force (*)
- DC circuits: resistors only (*)
- Mechanical waves and sound (*#)
- Thermodynamics: thermal energy, ideal gases, kinetic theory (#)
- Fluids (#)

* AP Physics 1 Topic #UConn PHYS 1201Q Topic

Topics that are UConn PHYS 1201Q specific will be taught as part of the course summer assignment and/or after the AP Physics 1 College Board examination. It is intended that the first semester of the course will cover thermodynamics, kinematics, Newton's Laws, circular motion, gravitation, work, energy and conservation of energy. All students will take a common District Midterm Exam covering those units of study. The student's final grade for this course will be determined by the grading policy of the UConn Physics Department: *Course Work 75%, Final Exam 25%*. All students will take the final exam for the course provided by the UConn Physics Department. There are no final exam exemptions in this course.

References:

AP Physics 1 Course Overview; College Board; New York, NY; 2014

AP Physics 1 and AP Physics 2 Course and Exam Description Including the Curriculum Framework; College Board; New York, NY; 2014

AP Physics 1/UConn PHYS 1201Q Concepts At a Glance
(Adapted from Appendix A of The College Board's 2014 Curriculum Framework)

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

Enduring Understanding 1.A: The internal structure of a system determines many properties of the system.	**Essential Knowledge 1.A.1:** A system is an object or a collection of objects. Objects are treated as having no internal structure.
	Essential Knowledge 1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an *object*.
Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.	**Essential Knowledge 1.B.1:** Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
	Essential Knowledge 1.B.2: There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.
	Essential Knowledge 1.B.3: The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
Enduring Understanding 1.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.	**Essential Knowledge 1.C.1:** Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems.
	Essential Knowledge 1.C.2: Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.
	Essential Knowledge 1.C.3: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

Enduring Understanding 1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.	**Essential Knowledge 1.E.1:** Matter has a property called density.
	Essential Knowledge 1.E.2: Matter has a property called resistivity.
	Essential Knowledge 1.E.3: Matter has a property called thermal conductivity.

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

Enduring Understanding 2.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.	**Essential Knowledge 2.A.1:** A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.
Enduring Understanding 2.B: A gravitational field is caused by an object with mass.	**Essential Knowledge 2.B.1:** A gravitational field g at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.
	Essential Knowledge 2.B.2: The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object.

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

Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.	**Essential Knowledge 3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
	Essential Knowledge 3.A.2: Forces are described by vectors.
	Essential Knowledge 3.A.3: A force exerted on an object is always due to the interaction of that object with another object.
	Essential Knowledge 3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.

Enduring Understanding 3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using a = F/m .	**Essential Knowledge 3.B.1:** If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.
	Essential Knowledge 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
	Essential Knowledge 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum, mass- spring oscillator.
Enduring Understanding 3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.	**Essential Knowledge 3.C.1:** Gravitational force describes the interaction of one object that has mass with another object that has mass.
	Essential Knowledge 3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
	Essential Knowledge 3.C.4: Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring, and buoyant.
Enduring Understanding 3.D: A force exerted on an object can change the momentum of the object.	**Essential Knowledge 3.D.1:** The change in momentum of an object is a vector in the direction of the net force exerted on the object.
	Essential Knowledge 3.D.2: The change in momentum of an object occurs over a time interval.
Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.	**Essential Knowledge 3.E.1:** The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted.
Enduring Understanding 3.F: A force exerted on an object can cause a torque on that object.	**Essential Knowledge 3.F.1:** Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.
	Essential Knowledge 3.F.2: The presence of a net torque along any axis will cause a rigid

	system to change its rotational motion or an object to change its rotational motion about that axis.
	Essential Knowledge 3.F.3: A torque exerted on an object can change the angular momentum of an object.
Enduring Understanding 3.G: Certain types of forces are considered fundamental.	**Essential Knowledge 3.G.1:** Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.

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

Enduring Understanding 4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system, where a = F/m .	**Essential Knowledge 4.A.1:** The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.
	Essential Knowledge 4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.
	Essential Knowledge 4.A.3: Forces that systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.
Enduring Understanding 4.B: Interactions with other objects or systems can change the total linear momentum of a system.	**Essential Knowledge 4.B.1:** The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.
	Essential Knowledge 4.B.2: The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted.
Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.	**Essential Knowledge 4.C.1:** The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy.

	Essential Knowledge 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work.
	Essential Knowledge 4.C.3: Energy is transferred spontaneously from a higher temperature system to a lower temperature system. This process of transferring energy is called heating. The amount of energy transferred is called heat.
Enduring Understanding 4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.	**Essential Knowledge 4.D.1:** Torque, angular velocity, angular acceleration, and angular momentum are vectors and can be characterized as positive or negative depending upon whether they give rise to or correspond to counterclockwise or clockwise rotation with respect to an axis.
	Essential Knowledge 4.D.2: The angular momentum of a system may change due to interactions with other objects or systems.
	Essential Knowledge 4.D.3: The change in angular momentum is given by the product of the average torque and the time interval during which the torque is exerted.

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

Enduring Understanding 5.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.	**Essential Knowledge 5.A.1:** A system is an object or a collection of objects. The objects are treated as having no internal structure.
	Essential Knowledge 5.A.2: For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.
	Essential Knowledge 5.A.3: An interaction can be either a force exerted by objects outside the system or the transfer of some quantity

	with objects outside the system.
	Essential Knowledge 5.A.4: The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.
Enduring Understanding 5.B: The energy of a system is conserved.	**Essential Knowledge 5.B.1:** Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.
	Essential Knowledge 5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. [includes mass-spring oscillators and simple pendulums and examining changes in internal energy with changes in configuration.]
	Essential Knowledge 5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
	Essential Knowledge 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.
	Essential Knowledge 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. [A piston filled with gas getting compressed or expanded is treated as a part of thermodynamics.]
	Essential Knowledge 5.B.6: Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer is called heat.

	Essential Knowledge 5.B.7: The first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. Examples should include P-V diagrams — isovolumetric processes, isothermal processes, isobaric processes, and adiabatic processes. No calculations of internal energy change from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative.
	Essential Knowledge 5.B.9: Kirchhoff's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.]
	Essential Knowledge 5.B.10: Bernoulli's equation describes the conservation of energy in fluid flow.
Enduring Understanding 5.C: The electric charge of a system is conserved.	**Essential Knowledge 5.C.3:** Kirchhoff's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel. [Covers circuits with resistors in series, with at most one parallel branch, one battery only.]
Enduring Understanding 5.D: The linear momentum of a system is conserved.	**Essential Knowledge 5.D.1:** In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
	Essential Knowledge 5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
	Essential Knowledge 5.D.3: The velocity of the center of mass of the system cannot be changed by an interaction within the system. [Includes no calculations of centers of mass; the equation is not provided until Physics 2.

	However, without doing calculations, students are expected to be able to locate the center of mass of highly symmetric mass distributions, such as a uniform rod or cube of uniform density, or two spheres of equal mass.]
Enduring Understanding 5.E: The angular momentum of a system is conserved.	**Essential Knowledge 5.E.1:** If the net external torque exerted on the system is zero, the angular momentum of the system does not change.
	Essential Knowledge 5.E.2: The angular momentum of a system is determined by the locations and velocities of the objects that make up the system. The rotational inertia of an object or system depends upon the distribution of mass within the object or system. Changes in the radius of a system or in the distribution of mass within the system result in changes in the system's rotational inertia, and hence in its angular velocity and linear speed for a given angular momentum. Examples should include elliptical orbits in an Earth-satellite system. Mathematical expressions for the moments of inertia will be provided where needed. Students will not be expected to know the parallel axis theorem.
Enduring Understanding 5.F: Classically, the mass of a system is conserved.	**Essential Knowledge 5.F.1:** The continuity equation describes conservation of mass flow rate in fluids. Examples should include volume rate of flow and mass flow rate.

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.

Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.	**Essential Knowledge 6.A.1:** Waves can propagate via different oscillation modes such as transverse and longitudinal.
	Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.

	Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.
	Essential Knowledge 6.A.4: Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.
Enduring Understanding 6.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.	**Essential Knowledge 6.B.1:** For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.
	Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.
	Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.
	Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.
Enduring Understanding 6.D: Interference and superposition lead to standing waves and beats.	**Essential Knowledge 6.D.1:** Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.
	Essential Knowledge 6.D.2: Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave.
	Essential Knowledge 6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string and sound waves in both closed and open tubes.
	Essential Knowledge 6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.

	Essential Knowledge 6.D.5: Beats arise from the addition of waves of slightly different frequency.

Big Idea 7: The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.

Enduring Understanding 7.A: The properties of an ideal gas can be explained in terms of a small number of macroscopic variables including temperature and pressure.	**Essential Knowledge 7.A.1:** The pressure of a system determines the force that the system exerts on the walls of its container and is a measure of the average change in the momentum, the impulse, of the molecules colliding with the walls of the container. The pressure also exists inside the system itself, not just at the walls of the container.
	Essential Knowledge 7.A.2: The temperature of a system characterizes the average kinetic energy of its molecules.
	Essential Knowledge 7.A.3: In an ideal gas, the macroscopic (average) pressure (P), temperature (T), and volume (V), are related by the equation $PV = nRT$.
Enduring Understanding 7.B: The tendency of isolated systems to move toward states with higher disorder is described by probability.	**Essential Knowledge 7.B.1:** The approach to thermal equilibrium is a probability process.
	Essential Knowledge 7.B.2: The second law of thermodynamics describes the change in entropy for reversible and irreversible processes. Only a qualitative treatment is considered in this course.

Throughout the course, at least one assignment or activity outside the laboratory experience will be designed to apply learning objectives connecting across two or more enduring understandings.

Additional information about the Big Ideas, Enduring Understandings, Essential Knowledge and Learning Objectives found in the following unit plans can be found on pages 17 – 109 of the Fall 2014 edition of the College Board's *AP Physics 1 and AP Physics 2 Course and Exam Description Including the Curriculum Framework.*

Unit Name: Thermodynamics Est. # of Weeks: Summer Assignment & 2 weeks of 1st semester

Synopsis: Thermal physics is the study of heat, temperature, and how they affect matter. Heat leads to changes in internal energy and this to changes in temperature, which cause the expansion or contraction of matter. The kinetic theory of gases helps us to understand how processes on the atomic scale affect macroscopic properties such as pressure, temperature, and internal energy. Energy transfers between a system and its surroundings explain phase changes. This unit is required content for UConn Physics 1201Q and AP Physics 2, thus is will be taught in both the first and second year physics courses. In this course, it is expected that the unit will be covered as part of the course summer assignment or after the AP Physics 1 (since the content is UConn 1201Q specific) to the level sufficient to meet the assessment criteria of the UConn 1201Q Final Exam provided each year by the UConn Physics Department. Further, it is assumed that the content of the unit will be expanded upon and covered in more depth in the subsequent course to meet the AP Physics 2 exam requirements.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

- Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)
- Interactions between systems can result in changes in those systems. (BI4)
- Changes that occur as a result of interactions are constrained by conservation laws. (BI5)
- 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. (BI6)
- The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems. (BI7)

AP Physics Enduring Understandings (College Board Curriculum Framework)

1.A: The internal structure of a system determines many properties of the system.
1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.
4.C: Interactions with other objects or systems can change the total energy of a system.
5.B: The energy of a system is conserved.
7.A: The properties of an ideal gas can be explained in terms of a small number of macroscopic variables including temperature and pressure.
7.B: The tendency of isolated systems to move toward states with higher disorder is described by probability.

Key Vocabulary

absolute temperature
absolute zero
Avagadro's number
Boil
Boltzmann's constant
Calorie
Calorimetry
Condense
Conduction
Convection
Freeze
Fusion
Gas
Heat
ideal gas
internal energy
Kelvin
kinetic theory of gases
latent heat
linear coefficient of thermal expansion

<table>
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<td></td>
<td>Liquid
Melt
molar mass
Mole
phase change
Plasma
Pressure
Radiation
root-mean-square speed
Solid
specific heat
thermal contact
thermal equilibrium
universal gas constant
Vaporization
volume coefficient of thermal expansion

As time permits, topics from the thermodynamics unit in AP Physics 2 may also be taught during this course.

adiabatic
Carnot cycle
cycle
entropy
heat engine
irreversible
isobaric
isothermal
isovolumetric
laws of thermodynamics (zeroth, 1st, and 2nd)
reversible
thermodynamic efficiency
work</td>
</tr>
<tr>
<td>AP Physics Essential Knowledge (College Board Curriculum Framework)
1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an object.
1.E.3: Matter has a property called thermal conductivity.
a. The thermal conductivity is the measure of a material's ability to transfer thermal energy.
4.C.3: Energy is transferred spontaneously from a</td>
<td>Guiding Questions (College Board Course Planning Guides)

How are heat and temperature explained on a molecular level?

How do we know thermal energy is transferred or exchanged?

How is the ideal gas law modeled to demonstrate the relationships among temperature, pressure, and volume of gases?</td>
</tr>
</table>

higher temperature system to a lower temperature system. This process of transferring energy is called heating. The amount of energy transferred is called heat.

1. Conduction, convection, and radiation are mechanisms for this energy transfer.
2. At a microscopic scale the mechanism of conduction is the transfer of kinetic energy between particles.
3. During average collisions between molecules, kinetic energy is transferred from faster molecules to slower molecules.

5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy.

5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.

1. Since energy is constant in a closed system, changes in a system's potential energy can result in changes to the system's kinetic energy.
2. The changes in potential and kinetic energies in a system may be further constrained by the construction of the system.

5.B.6: Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer is called heat.

5.B.7: The first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat.

7.A.2: The temperature of a system characterizes the average kinetic energy of its molecules.

1. The average kinetic energy of the system is an average over the many different speeds of the molecules in the system that can be described by a distribution curve.
2. The root mean square speed corresponding to the average kinetic energy for a specific gas at a given temperature can be obtained from this distribution.

7.A.3: In an ideal gas, the macroscopic (average) pressure (P), temperature (T), and volume (V) are related by the equation $PV = nRT$.

7.B.1: The approach to thermal equilibrium is a probability process.

1. The amount of thermal energy needed to change the temperature of a system of particles depends both on the mass of the system and on the temperature change of the system.
2. The details of the energy transfer depend upon interactions at the molecular level.

3. Since higher momentum particles will be involved in more collisions, energy is most likely to be transferred from higher to lower energy particles. The most likely state after many collisions is that both systems of particles have the same temperature. * As time permits EKs from the Thermodynamics unit in AP Physics 2 may also be taught.	

AP Physics Learning Objectives (College Board Curriculum Framework)

1.A.5.1:
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. [See **Science Practices 1.1 and 7.1**]

1.A.5.2:
The student is able to construct representations of how the properties of a system are determined by the interactions of its constituent substructures.

1.E.3.1:
The student is able to design an experiment and analyze data from it to examine thermal conductivity.
[See **Science Practices 4.1**, **4.2**, **and 5.1**]

4.C.3.1:
The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level. [See **Science Practice 6.4**]

5.B.2.1:
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.

5.B.4.1:
The student is able to describe and make predictions about the internal energy of systems. [See **Science Practices 6.4 and 7.2**]

5.B.6.1:
The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation. [See **Science Practice 1.2**]

5.B.7.1:
The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.

5.B.7.2:
The student is able to create a plot of pressure versus volume for a thermodynamic process from given data.
[See **Science Practice 1.1**]

7.A.2.1:
The student is able to qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system. [See **Science Practice 7.1**]

7.A.2.2:
The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes. [See **Science Practice 7.1**]

7.A.3.1:
The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. [See **Science Practices 6.4 and 7.2**]

7.A.3.2:
The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables.
[See **Science Practices 3.2 and 4.2**]

7.A.3.3:
The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$. [See **Science Practice 5.1**]

7.B.1.1:
The student is able to construct an explanation, based on atomic-scale interactions and probability, of how a system approaches thermal equilibrium when energy is transferred to it or from it in a thermal process.

* As time permits LOs from the Thermodynamics unit in AP Physics 2 may also be taught.

ASSESSMENT PLAN

Summative Assessment(s)	**Formative and Diagnostic Assessment(s)**
• Teacher designed quizzes and unit test aligned to Essential Knowledge • Midterm (Common District Exam) • UCONN PHYS 1201Q Exit Exam (to be provided each year by UConn Physics Department)	• Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)

States of Matter PhET Simulation Lab
Specific Heat Calrimetry Lab
Heat of Fusion of Ice Lab
Gas Laws PhET Simulation Lab

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Kinematics   Est. # of Weeks: 4 weeks 1st semester

Synopsis: Any motion involves the concepts of displacement, velocity, and acceleration. This unit involves learning concepts related to one and two-dimensional kinematics, including vectors and free-fall.

STUDENT LEARNING GOALS	
AP Physics Big Ideas (College Board Curriculum Framework) • Fields existing in space can be used to explain interactions. (BI2) • The interactions of an object with other objects can be described by forces. (BI3) • Interactions between systems can result in changes in those systems. (BI4)	**AP Physics Enduring Understandings (College Board Curriculum Framework)** **2.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. **3.A:** All forces share certain common characteristics when considered by observers in inertial reference frames. **4.A:**The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\mathbf{a} = \mathbf{F}/m$ **Key Vocabulary** air resistance average acceleration average speed average velocity coordinate system displacement distance frame of reference freefall gravity horizontal instantaneous acceleration instantaneous speed instantaneous velocity kinematics magnitude mass metric prefix position projectile Pythagorean theorem quantity range resultant right-triangle trig formulas scalar slope systeme internationale (SI)

	uncertainty uniform unit vector vector component vertical

AP Physics Essential Knowledge (College Board Curriculum Framework)	**Guiding Questions (College Board Course Planning Guides)**
2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector. 1. Vector fields are represented by field vectors indicating direction and magnitude. 2. When more than one source object with mass or electric charge is present, the field value can be determined by vector addition. 3. Conversely, a known vector field can be used to make inferences about the number, relative size, and location of sources. **3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. **4.A.1:** The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. **4.A.2:** The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.	How is velocity fundamentally different from speed, and why is this difference important? How can accelerated motion in one and two dimensions be described qualitatively, quantitatively, and graphically? Why is free fall considered a special case of accelerated motion? How do variables such as launch angle, velocity, and altitude affect the maximum height and range of a launched projectile?

AP Physics Learning Objectives (College Board Curriculum Framework)

3.A.1.1:
The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
[See **Science Practices 1.5**, **2.1**, **and 2.2**]

3.A.1.2:
The student is able to design an experimental investigation of the motion of an object. [See **Science Practice 4.2**]

3.A.1.3:
The student is able to 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. [See **Science Practice 5.1**]

4.A.2.1:
The student is able to 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. [See **Science Practice 6.4**]

4.A.2.3
The student is able to 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.
[See **Science Practices 1.4 and 2.2**]

ASSESSMENT PLAN	
Summative Assessment(s) • Teacher designed quizzes and unit test aligned to Essential Knowledge • Midterm (Common District Exam) • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	**Formative and Diagnostic Assessment(s)** • AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)

Moving Man PhET Simulation Lab

Determining "g" Lab

Projectile Motion Lab (determine muzzle velocity and/or landing point)

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Dynamics: Newton's Laws of Motion Est. # of Weeks: 5 weeks 1st semester

<table>
<tr><td colspan="2">Synopsis: Dynamics is the study of motion and physical concepts such as force and mass. Newton's Laws provides the basis of Classical Mechanics, and describe the relationship between the motion of objects found in our everyday world and the forces acting on them.</td></tr>
<tr><td colspan="2">STUDENT LEARNING GOALS</td></tr>
<tr><td rowspan="2">AP Physics Big Ideas (College Board Curriculum Framework)

• Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)

• Fields existing in space can be used to explain interactions. (BI2)

• The interactions of an object with other objects can be described by forces. (BI3)

• Interactions between systems can result in changes in those systems. (BI4)

• Changes that occur as a result of interactions are constrained by conservation laws. (BI5)</td>
<td>AP Physics Enduring Understandings (College Board Curriculum Framework)
1.A:The internal structure of a system determines many properties of the system.
1.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.
2.B: A gravitational field is caused by an object with mass.
3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using $\mathbf{a} = \mathbf{F}/m$
3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
4.A:The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\mathbf{a} = \mathbf{F}/m$
5.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.</td></tr>
<tr><td>Key Vocabulary

action/reaction
coefficient of kinetic friction
coefficient of static friction
contact
dynamics
equilibrium
field
force
free-body diagram
fundamental forces
gravitational field
gravitational mass
gravity
inertia
inertial frame of reference
inertial mass
kinetic friction
net force
newton
Newton's laws
normal
static friction
tension
weight</td></tr>
</table>

AP Physics Essential Knowledge (College Board Curriculum Framework)	**Guiding Questions (College Board Course Planning Guides)**
1.A.1: A system is an object or a collection of objects. Objects are treated as having no internal structure. **1.C.1:** Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems. **1.C.3:** Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. **2.B.1:** A gravitational field at the location of an object with mass *m* causes a gravitational force of magnitude *m***g** to be exerted on the object in the direction of the field. 1. On Earth, this gravitational force is called weight. 2. The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force. 3. If the gravitational force is the only force exerted on the object, the observed free-fall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in newtons/kilogram) at that location. **3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. **3.A.2:** Forces are described by vectors. **3.A.3:** A force exerted on an object is always due to the interaction of that object with another object. **3.A.4:** If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. **3.B.1:** If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. **3.B.2:** Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. **3.C.4:** Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring, and buoyant. **4.A.1:** The linear motion of a system can be described by the displacement, velocity, and	How is knowledge of the net force essential to understanding an object's motion? How can a free-body diagram be used to describe and/or create a mathematical representation of the forces acting on an object?

acceleration of its center of mass. **4.A.2:** The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time. 1. The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system. 2. Force and acceleration are both vectors, with acceleration in the same direction as the net force. **4.A.3:** Forces that systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system. **5.A.1:** A system is an object or a collection of objects. The objects are treated as having no internal structure. **5.A.3:** An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system. **5.A.4:** The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.	

AP Physics Learning Objectives (College Board Curriculum Framework)
1.C.1.1:
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. [See **Science Practice 4.2**]
The student is able to design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. [See **Science Practice 4.2**]
1.C.3.1:
The student is able to design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. [See **Science Practice 4.2**]
2.B.1.1:
The student is able to apply 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. [See **Science Practices 2.2 and 7.2**]
2.B.1.1:
The student is able to apply $\mathbf{F} = m\mathbf{g}$ 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. [See **Science Practices 2.2 and 7.2**]
3.A.1.1:
The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
[See **Science Practices 1.5**, **2.1**, **and 2.2**]
3.A.1.2:
The student is able to design an experimental investigation of the motion of an object. [See **Science Practice 4.2**]
3.A.1.3:
The student is able to 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. [See **Science Practice 5.1**]
3.A.2.1:
The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See **Science Practice 1.1**]
3.A.3.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]
3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself. [See **Science Practice 6.1**]
3.A.3.3:
The student is able to describe a force as an interaction between two objects and identify both objects for any force. [See **Science Practice 1.4**]
3.A.4.1:
The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [See **Science Practices 1.4 and 6.2**]
3.A.4.2:
The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. [See **Science Practices 6.4 and 7.2**]
3.A.4.3:
The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [See **Science Practice 1.4**]
3.B.1.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]
3.B.1.2:
The student is able to 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. [See **Science Practices 4.2 and 5.1**]
3.B.1.3:
The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See **Science Practices 1.5 and 2.2**]
3.B.2.1:
The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See **Science Practices 1.1**, **1.4**, **and 2.2**]
3.C.4.1:
The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [See **Science Practice 6.1**]
3.C.4.2:
The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [See **Science Practice 6.2**]
4.A.1.1:
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 semiquantitatively. [See **Science Practices 1.2**, **1.4**, **2.3**, **and 6.4**]
4.A.2.1:
The student is able to 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. [See **Science Practice 6.4**]
4.A.2.2
The student is able to evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified. [See **Science Practice 5.3**]
4.A.2.3
The student is able to 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. [See **Science Practices 1.4 and 2.2**]
4.A.3.1:
The student is able to 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. [See **Science Practice 2.2**]
4.A.3.2:
The student is able to 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. [See **Science Practice 1.4**]

ASSESSMENT PLAN	
Summative Assessment(s) • Teacher designed quizzes and unit test aligned to Essential Knowledge • Midterm (Common District Exam) • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	**Formative and Diagnostic Assessment(s)** • AP Physics 1 practice exam • Teacher designed homework problem sets
Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment) Interial and Graviational Mass Lab Determine the Coefficient of Friction Lab Atwood Machine Lab AP Physics 1 Sample Lab #1	

LEARNING PLAN COMPONENTS
➢ Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create: • Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6 • Reference textbooks: College-level textbooks as selected by teacher • AP Central – AP Physics 1 Course Homepage Resources • Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site • PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Circular Motion and Gravitation   Est. # of Weeks: 3 weeks 1st semester

<table>
<tr><td colspan="2">Synopsis: Concepts related to circular motion are an extension of Newton's laws of motion. Newton knew from his 1st Law of Motion that a force had to be acting on the moon since it had an almost circular path around the earth. Newton named this earth-moon force "gravity". Kepler's three laws of planetary motion formed the foundation of Newton's approach to universal gravitation.</td></tr>
<tr><th colspan="2">STUDENT LEARNING GOALS</th></tr>
<tr><td>AP Physics Big Ideas (College Board Curriculum Framework)
• Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)

• Fields existing in space can be used to explain interactions. (BI2)

• The interactions of an object with other objects can be described by forces. (BI3)</td><td>AP Physics Enduring Understandings (College Board Curriculum Framework)
1.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.
2.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.
2.B: A gravitational field is caused by an object with mass.
3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using a = F/m.
3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
3.G: Certain types of forces are considered fundamental.

Key Vocabulary

centripetal acceleration
centripetal force
circumference
clockwise
counterclockwise
gravitational constant
gravity
period
radius</td></tr>
<tr><td>AP Physics Essential Knowledge (College Board Curriculum Framework)

1.C.2: Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.
1. The gravitational mass of an object determines the amount of force exerted on the object by a gravitational field.
2. Near the Earth's surface, all objects fall (in a vacuum) with the same acceleration, regardless of their inertial mass.
2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.
1. Vector fields are represented by field vectors indicating direction and magnitude.</td><td>Guiding Questions (College Board Course Planning Guides)

Why do you stay in your seat on a roller coaster when it goes upside down in a vertical loop?

What does it mean for a force to be fundamental?

How can Newton's second law of motion be related to the universal law of gravitation?

Why does a person's weight vary at various locations throughout the universe?</td></tr>
</table>

2. When more than one source object with mass or electric charge is present, the field value can be determined by vector addition. 3. Conversely, a known vector field can be used to make inferences about the number, relative size, and location of sources. **2.B.1:** A gravitational field at the location of an object with mass *m* causes a gravitational force of magnitude *mg* to be exerted on the object in the direction of the field. 1. On Earth, this gravitational force is called weight. 2. The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force. 3. If the gravitational force is the only force exerted on the object, the observed free-fall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in newtons/kilogram) at that location. **2.B.2:** The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object. a. The gravitational field caused by a spherically symmetric object is a vector whose magnitude outside the object is equal to GM/r^2. b. Only spherically symmetric objects will be considered as sources of the gravitational field. **3.A.2:** Forces are described by vectors. 1. Forces are detected by their influence on the motion of an object. 2. Forces have magnitude and direction. **3.A.3:** A force exerted on an object is always due to the interaction of that object with another object. 1. An object cannot exert a force on itself. 2. Even though an object is at rest, there may be forces exerted on that object by other objects. 3. The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects. **3.A.4:** If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. **3.B.1:** If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. **3.B.2:** Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. 1. An object can be drawn as if it was extracted	

from its environment and the interactions with the environment identified.

2. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
3. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free- body diagram to the algebraic representation.

3.C.1: Gravitational force describes the interaction of one object that has mass with another object that has mass.

1. The gravitational force is always attractive.
1. The magnitude of force between two spherically symmetric objects of mass m_1 and m_2 is $G(m_1m_2/r^2)$ where r is the center-to center distance between the objects.
2. In a narrow range of heights above the Earth's surface, the local gravitational field, **g**, is approximately constant.

3.C.4: Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant.

3.G.1: Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.

AP Physics Learning Objectives (College Board Curriculum Framework)

2.B.1.1:

The student is able to apply $\mathbf{F} = m\mathbf{g}$ 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. [See **Science Practices 2.2 and 7.2**]

2.B.2.1:

The student is able to 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. [See **Science Practice 2.2**]

2.B.2.2:

The student is able to 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. [See **Science Practice 2.2**]

3.A.2.1:

The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See **Science Practice 1.1**]

3.A.3.1:

The student is able to 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. [See **Science Practices 6.4 and 7.2**]

3.A.3.3:

The student is able to describe a force as an interaction between two objects and identify both objects for any force. [See **Science Practice 1.4**]

3.A.4.1:

The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [See **Science Practices 1.4 and 6.2**]

3.B.1.1:

The student is able to 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. [See **Science Practices 6.4 and 7.2**]

3.B.1.3:

The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See **Science Practices 1.5 and 2.2**]
3.B.2.1:
The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See **Science Practices 1.1**, **1.4**, **and 2.2**]
3.C.1.1:
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 contexts other than orbital motion. [See **Science Practice 2.2**]
3.C.1.2:
The student is able to use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1). [See **Science Practice 2.2**]
3.C.4.1:
The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [See **Science Practice 6.1**]
3.C.4.2:
The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [See **Science Practice 6.2**]
3.G.1.1:
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. [See **Science Practice 7.1**]

ASSESSMENT PLAN

Summative Assessment(s)	Formative and Diagnostic Assessment(s)
• Teacher designed quizzes and unit test aligned to Essential Knowledge • Midterm (Common District Exam) • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)
Centripetal Force Lab
Gravitation PhET Simulation Lab

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Work and Energy   Est. # of Weeks: 4 weeks 1st semester

Synopsis: Energy is present in many forms – mechanical energy (kinetic and potential) is considered in this unit. In an isolated system, a collection of objects can exchange energy with each other but the total amount of energy must remain constant. Energy and forces are linked through the concept of work.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

• Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)

• The interactions of an object with other objects can be described by forces. (BI3)

• Interactions between systems can result in changes in those systems. (BI4)

• Changes that occur as a result of interactions are constrained by conservation laws. (BI5)

AP Physics Enduring Understandings (College Board Curriculum Framework)

1.A: The internal structure of a system determines many properties of the system.
3.E: A force exerted on an object can change the kinetic energy of the object.
4.C: Interactions with other objects or systems can change the total energy of a system.
5.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.
5.B: The energy of a system is conserved.

Key Vocabulary

conservation law
conservation of energy
conservation of mechanical energy
conservative force
dissipative force
escape velocity
gravitational potential
gravitational potential energy
joule
kilowatt-hour
kinetic energy
mechanical energy
nonconservative force
power
reference level
system
watt
work
work-energy theorem

AP Physics Essential Knowledge (College Board Curriculum Framework)

1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an *object*.
3.E.1: The change in the kinetic energy of an object

Guiding Questions (College Board Course Planning Guides)

How are Newton's Laws related to energy through the concept of work?

How can energy be represented with graphs and equations?

What does it mean for energy to be conserved?

depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted. 1. Only the component of the net force exerted on an object parallel or antiparallel to the displacement of the object will increase (parallel) or decrease (antiparallel) the kinetic energy of the object. 2. The magnitude of the change in the kinetic energy is the product of the magnitude of the displacement and of the magnitude of the component of force parallel or antiparallel to the displacement. 3. The component of the net force exerted on an object perpendicular to the direction of the displacement of the object can change the direction of the motion of the object without changing the kinetic energy of the object. This should include uniform circular motion and projectile motion. **4.C.1:** The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy. **5.A.1:** A system is an object or a collection of objects. The objects are treated as having no internal structure. **5.A.2:** For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. **5.A.3:** An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system. **5.A.4:** The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis. **5.B.1:** Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects. **5.B.3:** A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces. 1. The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system. 2. Changes in the internal structure can result in changes in potential energy. Examples should include mass-spring oscillators and objects	

falling in a gravitational field. 3. The change in electric potential in a circuit is the change in potential energy per unit charge. [Physics 1: only in the context of circuits.] **5.B.4:** The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system. 1. Since energy is constant in a closed system, changes in a system's potential energy can result in changes to the system's kinetic energy. 2. The changes in potential and kinetic energies in a system may be further constrained by the construction of the system. **5.B.5:** Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.	

AP Physics Learning Objectives (College Board Curriculum Framework)

1.A.5.1:
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. [See **Science Practices 1.1 and 7.1**]
3.E.1.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]
3.E.1.2:
The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged. [See **Science Practice 1.4**]
3.E.1.3:
The student is able to 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.
[See **Science Practice 1.4 and 2.2**]
3.E.1.4:
The student is able to 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. [See **Science Practice 2.2**]
4.C.1.1:
The student is able to 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. [See **Science Practices 1.4**, **2.1**, **and 2.2**]
4.C.1.2:
The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. [See **Science Practice 6.4**]
5.A.2.1:
The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [See **Science Practices 6.4 and 7.2**]
5.B.1.1:
The student is able to 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. [See **Science Practices 1.4 and 2.2**]
5.B.1.2:
The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that

includes the object, which may have both kinetic and potential energies. [See **Science Practice 1.5**]

5.B.3.1:
The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. [See **Science Practices 2.2**, **6.4**, **and 7.2**]

5.B.3.2:
The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. [See **Science Practices 1.4 and 2.2**]

5.B.3.3:
The student is able to 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. [See **Science Practices 1.4 and 2.2**]

5.B.4.1:
The student is able to describe and make predictions about the internal energy of systems. [See **Science Practices 6.4 and 7.2**]

5.B.4.2:
The student is able to calculate changes in kinetic energy and potential energy of a system using information from representations of that system. [See **Science Practices 1.4**, **2.1**, **and 2.2**]

5.B.5.1:
The student is able to 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. [See **Science Practices 4.2 and 5.1**]

5.B.5.2:
The student is able to 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. [See **Science Practices 4.2 and 5.1**]

5.B.5.3:
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 distance. [See **Science Practices 1.4**, **2.2**, **and 6.4**]

5.B.5.4:
The student is able to 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). [See **Science Practices 6.4 and 7.2**]

5.B.5.5:
The student is able to 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. [See **Science Practices 2.2 and 6.4**]

ASSESSMENT PLAN

Summative Assessment(s)	**Formative and Diagnostic Assessment(s)**
• Teacher designed quizzes and unit test aligned to Essential Knowledge • Midterm (Common District Exam) • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)

Pendulum/Projectile Lab
Hot-wheels Lab
AP Physics 1 Sample Lab #2

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Momentum   Est. # of Weeks: 3 weeks 2nd semester

Synopsis: This unit introduces the idea of momentum. Newton's laws are connected to momentum through the concept of an impulse. Collisions are examined through the conservation of momentum and types are collisions are classified according to whether or not energy is conserved.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

- Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)
- The interactions of an object with other objects can be described by forces. (BI3)
- Interactions between systems can result in changes in those systems. (BI4)
- Changes that occur as a result of interactions are constrained by conservation laws. (BI5)

AP Physics Enduring Understandings (College Board Curriculum Framework)

1.A: The internal structure of a system determines many properties of the system.
3.D: A force exerted on an object can change the momentum of the object.
4.B: Interactions with other objects or systems can change the total linear momentum of a system.
5.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.
5.D: The linear momentum of a system is conserved.

Key Vocabulary

center of mass/gravity
collision
conservation of linear momentum
elastic collision
explosion
impulse-momentum theorem
inelastic collision
linear impulse
linear momentum

AP Physics Essential Knowledge (College Board Curriculum Framework)

1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an *object*.
3.D.1: The change in momentum of an object is a vector in the direction of the net force exerted on the object.
3.D.2: The change in momentum of an object occurs over a time interval.

1. The force that one object exerts on a second object changes the momentum of the second object (in the absence of other forces on the second object).
2. The change in momentum of that object depends on the impulse, which is the product of the average force and the time interval during which the interaction occurred.

4.B.1: The change in linear momentum for a constant-

Guiding Questions (College Board Course Planning Guides)

How are Newton's laws related to momentum?

What does it mean for momentum to be conserved?

How can the outcome of a collision be used to characterize a collision as elastic or inelastic?

How can changes in momentum be utilized to determine the forces applied to an object?

<table>
<tr><td>mass system is the product of the mass of the system and the change in velocity of the center of mass.
4.B.2: The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted.
1. The units for momentum are the same as the units of the area under the curve of a force versus time graph.
2. The changes in linear momentum and force are both vectors in the same direction.
5.A.1: A system is an object or a collection of objects. The objects are treated as having no internal structure.
5.A.2: For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.
5.A.3: An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system.
5.A.4: The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.
5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
1. In an isolated system, the linear momentum is constant throughout the collision.
2. In an isolated system, the kinetic energy after an elastic collision is the same as the kinetic energy before the collision.
5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
1. In an isolated system, the linear momentum is constant throughout the collision.
2. In an isolated system, the kinetic energy after an inelastic collision is different from the kinetic energy before the collision.</td><td></td></tr>
<tr><td colspan="2">AP Physics Learning Objectives (College Board Curriculum Framework)
1.A.5.1:
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. [See Science Practices 1.1 and 7.1]
3.D.1.1:
The student is able to 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. [See Science Practice 4.1]
3.D.2.1:
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. [See Science Practice 2.1]
3.D.2.2:
The student is able to 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. [See Science Practice 6.4]</td></tr>
</table>

3.D.2.3:
The student is able to 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. [See **Science Practice 5.1**]
3.D.2.4:
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. [See **Science Practice 4.2**]
4.B.1.1:
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.). [See **Science Practices 1.4 and 2.2**]
4.B.1.2:
The student is able to 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. [See **Science Practice 5.1**]
4.B.2.1:
The student is able to 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. [See **Science Practice 2.2**]
4.B.2.2:
The student is able to perform analysis on data presented as a force-time graph and predict the change in momentum of a system. [See **Science Practice 5.1**]
5.A.2.1:
The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [See **Science Practices 6.4 and 7.2**]
5.D.1.1:
The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. [See **Science Practices 6.4 and 7.2**]
5.D.1.2:
The student is able to 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. [See **Science Practices 2.2**, **3.2**, **5.1**, **and 5.3**]
5.D.1.3:
The student is able to 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. [See **Science Practices 2.1 and 2.2**]
5.D.1.4:
The student is able to 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. [See **Science Practices 4.2**, **5.1**, **5.3**, **and 6.4**]
5.D.1.5:
The student is able to 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. [See **Science Practices 2.1 and 2.2**]
5.D.2.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]
5.D.2.2:
The student is able to 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. [See **Science Practices 4.1**, **4.2**, **and 5.1**]
5.D.2.3:
The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. [See **Science Practices 6.4 and 7.2**]
5.D.2.4:
The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force. [See **Science Practices 4.1**, **4.2**, **4.4**, **5.1**, **and 5.3**]

5.D.2.5:
The student is able to 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.
[See **Science Practices 2.1 and 2.2**]

ASSESSMENT PLAN

Summative Assessment(s)	**Formative and Diagnostic Assessment(s)**
• Teacher designed quizzes and unit test aligned to Essential Knowledge • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)
PASSCar Conservation Lab
Ballistic Pendulum Lab
Accident Reconstruction Lab

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Rotational Motion Est. # of Weeks: 4 weeks 2nd semester

Synopsis: Important concepts in the study of linear motion have an analog in rotational motion. The concepts of angular speed and angular acceleration are central to understanding rotational motion. Rotational motion, when combined with Newton's laws of motion and universal gravitation, can also explain certain facts about satellite motion. Students learn how the application point of a force affects the motion of an object by creating torques, which tell us how the force affects an object's equilibrium and rate of rotation.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

• The interactions of an object with other objects can be described by forces. (BI3)

• Interactions between systems can result in changes in those systems. (BI4)

• Changes that occur as a result of interactions are constrained by conservation laws. (BI5)

AP Physics Enduring Understandings (College Board Curriculum Framework)

3.F: A force exerted on an object can cause a torque on that object.
4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.
5.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.
5.E: The angular momentum of a system is conserved.

Key Vocabulary

angular acceleration
angular displacement
angular momentum
angular velocity
axis of rotation
center of mass/gravity
clockwise
counterclockwise
equilibrium
moment of inertia
radian
revolution
rigid
rolling
rotational kinetic energy
tangential
torque

AP Physics Essential Knowledge (College Board Curriculum Framework)

3.F.1: Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.

1. The lever arm is the perpendicular distance from the axis of rotation or revolution to the line of application of the force.
2. The magnitude of the torque is the product of the magnitude of the lever arm and the magnitude of the force.

Guiding Questions (College Board Course Planning Guides)

In what ways are rotational motion and linear motion related?

How can Newton's law be applied to rotating systems?

How does a net torque affect the angular momentum of a rotating system?

What does it mean for angular momentum to be conserved?

3. The net torque on a balanced system is zero. **3.F.2:** The presence of a net torque along any axis will cause a rigid system to change its rotational motion or an object to change its rotational motion about that axis. 1. Rotational motion can be described in terms of angular displacement, angular velocity, and angular acceleration about a fixed axis. 2. Rotational motion of a point can be related to linear motion of the point using the distance of the point from the axis of rotation. 3. The angular acceleration of an object or rigid system can be calculated from the net torque and the rotational inertia of the object or rigid system. **3.F.3:** A torque exerted on an object can change the angular momentum of an object. 1. Angular momentum is a vector quantity, with its direction determined by a right-hand rule. 2. The magnitude of angular momentum of a point object about an axis can be calculated by multiplying the perpendicular distance from the axis of rotation to the line of motion by the magnitude of linear momentum. 3. The magnitude of angular momentum of an extended object can also be found by multiplying the rotational inertia by the angular velocity. 4. The change in angular momentum of an object is given by the product of the average torque and the time the torque is exerted. **4.D.1:** Torque, angular velocity, angular acceleration, and angular momentum are vectors and can be characterized as positive or negative depending upon whether they give rise to or correspond to counterclockwise or clockwise rotation with respect to an axis. **4.D.2:** The angular momentum of a system may change due to interactions with other objects or systems. 1. The angular momentum of a system with respect to an axis of rotation is the sum of the angular momenta, with respect to that axis, of the objects that make up the system. 2. The angular momentum of an object about a fixed axis can be found by multiplying the momentum of the particle by the perpendicular distance from the axis to the line of motion of the object. 3. Alternatively, the angular momentum of a system can be found from the product of the system's rotational inertia and its angular velocity. **4.D.3:** The change in angular momentum is given by the product of the average torque and the time interval during which the torque is exerted. **5.A.2:** For all systems under all circumstances, energy,	

charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. **5.E.1:** If the net external torque exerted on the system is zero, the angular momentum of the system does not change. **5.E.2:** The angular momentum of a system is determined by the locations and velocities of the objects that make up the system. The rotational inertia of an object or system depends upon the distribution of mass within the object or system. Changes in the radius of a system or in the distribution of mass within the system result in changes in the system's rotational inertia, and hence in its angular velocity and linear speed for a given angular momentum. Examples should include elliptical orbits in an Earth-satellite system. Mathematical expressions for the moments of inertia will be provided where needed. Students will not be expected to know the parallel axis theorem.	

AP Physics Learning Objectives (College Board Curriculum Framework)

3.F.1.1:
The student is able to use representations of the relationship between force and torque. [See **Science Practice 1.4**]

3.F.1.2:
The student is able to compare the torques on an object caused by various forces. [See **Science Practice 1.4**]

3.F.1.3:
The student is able to estimate the torque on an object caused by various forces in comparison to other situations. [See **Science Practice 2.3**]

3.F.1.4:
The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system. [See **Science Practices 4.1**, **4.2**, **and 5.1**]

3.F.1.5:
The student is able to calculate torques on a two-dimensional system in static equilibrium by examining a representation or model (such as a diagram or physical construction). [See **Science Practices 1.4 and 2.2**]

3.F.2.1:
The student is able to 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. [See **Science Practice 6.4**]

3.F.2.2:
The student is able to 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. [See **Science Practices 4.1**, **4.2**, **and 5.1**]

3.F.3.1:
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. [See **Science Practices 6.4 and 7.2**]

3.F.3.2:
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. [See **Science Practice 2.1**]

3.F.3.3:
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. [See **Science Practices 4.1**, **4.2**, **5.1**, **and 5.3**]

4.D.1.1:
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.
[See **Science Practices 1.2 and 1.4**]

4.D.1.2:
The student is able to 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.
[See **Science Practices 3.2**, **4.1**, **4.2**, **5.1**, **and 5.3**]

4.D.2.1:
The student is able to 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. [See **Science Practices 1.2 and 1.4**]

4.D.2.2:
The student is able to 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. [See **Science Practice 4.2**]

4.D.3.1:
The student is able to 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. [See **Science Practice 2.2**]

4.D.3.2:
The student is able to 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.
[See **Science Practices 4.1 and 4.2**]

5.A.2.1:
The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [See **Science Practices 6.4 and 7.2**]

5.E.1.1:
The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque. [See **Science Practices 6.4 and 7.2**]

5.E.1.2:
The student is able to make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero. [See **Science Practices 2.1 and 2.2**]

5.E.2.1:
The student is able to 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. [See **Science Practice 2.2**]

ASSESSMENT PLAN

Summative Assessment(s)	**Formative and Diagnostic Assessment(s)**
• Teacher designed quizzes and unit test aligned to Essential Knowledge • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)
Equilibrium of Rigid Body (See-saw) Lab
Rotational Kinetic Energy Lab (Soup Can)

LEARNING PLAN COMPONENTS

➢ Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
- Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
- Reference textbooks: College-level textbooks as selected by teacher
- AP Central – AP Physics 1 Course Homepage Resources
- Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
- PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Simple Harmonic Motion Est. # of Weeks: 2 weeks 2nd semester

Synopsis: Periodic motion – from masses on springs, to pendulum motion, to atomic vibrations – is an important physical behavior. This unit explores Hooke's Law and the motion of a pendulum in the context of forces and conservation of energy. The periodic motion that explains sound waves will be further explored in the unit on Waves and Sound.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

• The interactions of an object with other objects can be described by forces. (BI3)

• Interactions between systems can result in changes in those systems. (BI4)

• Changes that occur as a result of interactions are constrained by conservation laws. (BI5)

AP Physics Enduring Understandings (College Board Curriculum Framework)

3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using **a** = **F**/*m*.
3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
3.E: A force exerted on an object can change the kinetic energy of the object.
4.C: Interactions with other objects or systems can change the total energy of a system.
5.B: The energy of a system is conserved.

Key Vocabulary

amplitude
angular frequency
elastic/spring potential energy
frequency
hertz
Hooke's law
period
restoring force
simple harmonic motion
simple pendulum
spring constant

AP Physics Essential Knowledge (College Board Curriculum Framework)

3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.

1. Displacement, velocity, and acceleration are all vector quantities.
2. Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.
3. A choice of reference frame determines the direction and the magnitude of each of these quantities.

3.A.2: Forces are described by vectors.

1. Forces are detected by their influence on the motion of an

Guiding Questions (College Board Course Planning Guides)

What factors affect the period of oscillation for a mass oscillating on a spring and for a simple pendulum?

How can oscillatory motion be represented graphically and mathematically?

How is conservation of energy applied in simple harmonic oscillators?

object. 2. Forces have magnitude and direction. **3.B.2:** Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. 1. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified. 2. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force. 3. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free- body diagram to the algebraic representation. **3.B.3:** Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum and mass-spring oscillator. 1. For a spring that exerts a linear restoring force, the period of a mass-spring oscillator increases with mass and decreases with spring stiffness. 2. For a simple pendulum, the period increases with the length of the pendulum and decreases with the magnitude of the gravitational field. 3. Minima, maxima, and zeros of position, velocity, and acceleration are features of harmonic motion. Students should be able to calculate force and acceleration for any given displacement for an object oscillating on a spring. **3.C.4:** Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2). **3.E.1:** The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted. 1. Only the component of the net force exerted on an object parallel or antiparallel to the displacement of the object will increase (parallel) or decrease (antiparallel) the kinetic energy of the object. 2. The magnitude of the change in the kinetic energy is the product of the magnitude of the displacement and of the magnitude of the component of force parallel or antiparallel to	

the displacement.

3. The component of the net force exerted on an object perpendicular to the direction of the displacement of the object can change the direction of the motion of the object without changing the kinetic energy of the object. This should include uniform circular motion and projectile motion.

4.C.1: The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy.

5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. [Physics 1: includes mass-spring oscillators and simple pendulums.]

5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.

1. The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system.
2. Changes in the internal structure can result in changes in potential energy. Examples should include mass-spring oscillators and objects falling in a gravitational field.
3. The change in electric potential in a circuit is the change in potential energy per unit charge. [Physics 1: only in the context of circuits.]

AP Physics Learning Objectives (College Board Curriculum Framework)

3.A.1.1:
The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See **Science Practices 1.5**, **2.1**, **and 2.2**]

3.A.1.2:
The student is able to design an experimental investigation of the motion of an object. [See **Science Practice 4.2**]

3.A.1.3:
The student is able to 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. [See **Science Practice 5.1**]

3.A.2.1:
The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See **Science Practice 1.1**]

3.B.2.1:
The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See **Science Practices 1.1**, **1.4**, **and 2.2**]

3.B.3.1:
The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. [See **Science Practices 6.4 and 7.2**]

3.B.3.2:
The student is able to 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. [See **Science Practice 4.2**]

3.B.3.3:
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. [See **Science Practices 2.2 and 5.1**]
3.B.3.4:
The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. [See **Science Practices 2.2 and 6.2**]
3.C.4.1:
The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [See **Science Practice 6.1**]
3.C.4.2:
The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [See **Science Practice 6.2**]
3.E.1.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]
3.E.1.3:
The student is able to 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.
[See **Science Practice 1.4 and 2.2**]
4.C.1.1:
The student is able to 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. [See **Science Practices 1.4**, **2.1**, **and 2.2**]
4.C.1.2:
The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. [See **Science Practice 6.4**]
5.B.2.1:
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.
[See **Science Practices 1.4 and 2.1**]
5.B.3.1:
The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. [See **Science Practices 2.2**, **6.4**, **and 7.2**]
Learning Objective 5.B.3.2:
The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. [See **Science Practices 1.4 and 2.2**]
5.B.3.3:
The student is able to 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. [See **Science Practices 1.4 and 2.2**]

ASSESSMENT PLAN

Summative Assessment(s)	**Formative and Diagnostic Assessment(s)**
• Teacher designed quizzes and unit test aligned to Essential Knowledge • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)
Hooke's Law Lab
Physical Pendulum Lab

LEARNING PLAN COMPONENTS
➢ Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create: • Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6 • Reference textbooks: College-level textbooks as selected by teacher • AP Central – AP Physics 1 Course Homepage Resources • Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site • PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Waves/Sound Est. # of Weeks: 2 weeks 2nd semester

Synopsis: Periodic vibrations can cause disturbances that move through a medium in the form different types of waves. Many types of waves occur in nature including sound and electromagnetic waves. The concepts and terms related to wave phenomena are introduced in this unit. The characteristics and properties of sound waves are explored in depth (how they are produced, how they travel through matter, and how they interfere with each other).	
STUDENT LEARNING GOALS	
AP Physics Big Ideas (College Board Curriculum Framework) • 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. (BI6)	**AP Physics Enduring Understandings (College Board Curriculum Framework)** **6.A:** A wave is a traveling disturbance that transfers energy and momentum. **6.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. **6.D:** Interference and superposition lead to standing waves and beats. **Key Vocabulary** amplitude antinode beats closed tube compression constructive interference continouus wave crest destructive interference Doppler effect electromagnetic wave fundamental frequency harmonic (noun) longitudinal wave mechanical wave node open tube overtone plane wave pressure wave rarefaction reflection resonance shock wave standing wave superposition transmission transverse wave

	trough wave wave pulse wave speed wavelength

AP Physics Essential Knowledge (College Board Curriculum Framework)	**Guiding Questions (College Board Course Planning Guides)**
6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal. 1. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves. 2. Electromagnetic waves are transverse waves. [Physics 2] 3. Transverse waves may be polarized. [Physics 2] **6.A.2:** For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum. **6.A.3:** The amplitude is the maximum displacement of a wave from its equilibrium value. **6.A.4:** Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves. **6.B.1:** For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time. **6.B.2:** For a periodic wave, the wavelength is the repeat distance of the wave. **6.B.4:** For a periodic wave, wavelength is the ratio of speed over frequency. **6.B.5:** The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only. **6.D.1:** Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition. **6.D.2:** Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave. **6.D.3:** Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string and sound waves in both closed and open tubes. **6.D.4:** The possible wavelengths of a standing wave are determined by the size of the region to which it is	How are waves energy transport phenomena? How are velocity, frequency, and wavelength used to describe a wave? What happens when two or more waves meet? How can wave boundary behavior be used to explain frequencies for standing waves in strings, open pipes, and closed pipes?

confined. 1. A standing wave with zero amplitude at both ends can only have certain wavelengths. Examples should include fundamental frequencies and harmonics. 2. Other boundary conditions or other region sizes will result in different sets of possible wavelengths. **6.D.5:** Beats arise from the addition of waves of slightly different frequency. 1. Because of the different frequencies, the two waves are sometimes in phase and sometimes out of phase. The resulting regularly spaced amplitude changes are called beats. Examples should include the tuning of an instrument. 2. The beat frequency is the difference in frequency between the two waves.	

AP Physics Learning Objectives (College Board Curriculum Framework)

6.A.1.1:
The student is able to 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. [See **Science Practice 6.2**]

6.A.1.2:
The student is able to describe representations of transverse and longitudinal waves. [See **Science Practice 1.2**]

6.A.2.1:
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. [See **Science Practices 6.4 and 7.2**]

6.A.3.1:
The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.
[See **Science Practice 1.4**]

6.A.4.1:
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. [See **Science Practice 6.4**]

6.B.1.1:
The student is able to use a graphical representation of a periodic mechanical wave (position vs. time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.
[See **Science Practices 1.4 and 2.2**]

6.B.2.1:
The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.
[See **Science Practice 1.4**]

6.B.4.1:
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. [See **Science Practices 4.2**, **5.1**, **and 7.2**]

6.B.5.1:
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. [See **Science Practice 1.4**]

6.D.1.1:
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. [See **Science Practices 1.1 and 1.4**]

6.D.1.2:
The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves). [See **Science Practices 4.2 and 5.1**]

6.D.1.3:
The student is able to 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. [See **Science Practice 4.2**]

6.D.2.1:
The student is able to 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. [See **Science Practice 5.1**]

6.D.3.1:
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. [See **Science Practices 2.1**, **3.2**, **and 4.2**]

6.D.3.2:
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. [See **Science Practice 6.4**]

6.D.3.3:
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.
[See **Science Practices 3.2**, **4.1**, **5.1**, **5.2**, **and 5.3**]

6.D.3.4:
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. [See **Science Practice 1.2**]

6.D.4.1:
The student is able to 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. [See **Science Practices 1.5 and 6.1**]

6.D.4.2:
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. [See **Science Practice 2.2**]

6.D.5.1:
The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats. [See **Science Practice 1.2**]

ASSESSMENT PLAN

Summative Assessment(s)	**Formative and Diagnostic Assessment(s)**
• Teacher designed quizzes and unit test aligned to Essential Knowledge • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)
Open/Closed Tube Resonance Lab
Boomwacker™ Lab
Vibrating String PhET Simulation Lab

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Electrostatics Est. # of Weeks: 2 weeks 2nd semester

Synopsis: This unit introduces elementary and fundamental particles, and properties of electric charge. Coulomb's Law, along with Newton's Laws, are used to explain the interactions of charged objects. Content from this unit is Physics 1 specific (not assessed on the UConn PHYS 1201Q Exit Exam) and will provide the basis for a more in-depth study of electrostatics in AP Physics 2/UConn 1202Q.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

• Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)

• Fields existing in space can be used to explain interactions. (BI2)

• The interactions of an object with other objects can be described by forces. (BI3)

• Changes that occur as a result of interactions are constrained by conservation laws. (BI5)

AP Physics Enduring Understandings (College Board Curriculum Framework)

1.A: The internal structure of a system determines many properties of the system.
1.B: Electric charge is
a property of an object or system that affects its interactions with other objects or systems containing charge.
3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using $\mathbf{a} = \mathbf{F}/m$.
3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
3.G: Certain types of forces are considered fundamental.
5.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.

Key Vocabulary

conduction
conductor
coulomb
Coulomb constant
Coulomb's law
electric charge
electron
elementary charge
induction
insulator
negative charge
neutral
neutron
polarization
positive charge
proton
quantization
superposition

AP Physics Essential Knowledge (College Board Curriculum Framework)

1.A.1: A system is an object or a collection of objects. Objects are treated as having no internal structure.

1. A collection of particles in which internal interactions change little or not at all, or in

Guiding Questions (College Board Course Planning Guides)

How can the charge model be used to explain electric phenomena?

How can knowledge of forces and energy be applied to processes

which changes in these interactions are irrelevant to the question addressed, can be treated as an object. 2. Some elementary particles are fundamental particles (e.g., electrons). Protons and neutrons are composed of fundamental particles (i.e., quarks) and might be treated as either systems or objects, depending on the question being addressed. 3. The electric charges on neutrons and protons result from their quark compositions. **1.A.5:** Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an *object*. **1.B.1:** Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system. **1.B.2:** There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge. 4. Like-charged objects and systems repel, and unlike- charged objects and systems attract. 5. Charged objects or systems may attract neutral systems by changing the distribution of charge in the neutral system. **1.B.3:** The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge. 1. The magnitude of the elementary charge is equal to 1.6×10^{-19} coulombs. 2. Electrons have a negative elementary charge; protons have a positive elementary charge of equal magnitude, although the mass of a proton is much larger than the mass of an electron. **3.A.3:** A force exerted on an object is always due to the interaction of that object with another object. 1. An object cannot exert a force on itself. 2. Even though an object is at rest, there may be forces exerted on that object by other objects. 3. The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects. **3.A.4:** If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. **3.B.1:** If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. **3.B.2:** Free-body diagrams are useful tools for	involving electrically charged objects?

visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

1. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
2. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
3. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free- body diagram to the algebraic representation.

3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.

1. Electric forces dominate the properties of the objects in our everyday experiences. However, the large number of particle interactions that occur make it more convenient to treat everyday forces in terms of nonfundamental forces called contact forces, such as normal force, friction, and tension.
2. Electric forces may be attractive or repulsive, depending upon the charges on the objects involved.

3.G.1: Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.

5.A.2: For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.

AP Physics Learning Objectives (College Board Curriculum Framework)

1.A.5.1:

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. [See **Science Practices 1.1 and 7.1**]

1.A.5.1:

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. [See **Science Practices 1.1 and 7.1**]

1.B.1.1:

The student is able to make claims about natural phenomena based on conservation of electric charge. [See **Science Practice 6.4**]

1.B.1.2:

The student is able to 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.
[See **Science Practices 6.4 and 7.2**]

1.B.2.1:

The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices. [See **Science Practice 6.2**]

1.B.3.1:

The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated.
[See **Science Practices 1.5, 6.1, and 7.2**]

3.A.3.1:

The student is able to 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. [See **Science Practices 6.4 and 7.2**]
3.A.3.2:
The student is able to challenge a claim that an object can exert a force on itself. [See **Science Practice 6.1**]
3.A.3.3:
The student is able to describe a force as an interaction between two objects and identify both objects for any force. [See **Science Practice 1.4**]
3.A.4.1:
The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [See **Science Practices 1.4 and 6.2**]
3.A.4.2:
The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. [See **Science Practices 6.4 and 7.2**]
3.A.4.3:
The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [See **Science Practice 1.4**]
3.B.1.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]
3.B.1.3:
The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See **Science Practices 1.5 and 2.2**]
3.B.2.1:
The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
3.C.2.1:
The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges (interactions between collections of electric point charges are not covered in Physics 1 and instead are restricted to Physics 2). [See **Science Practices 2.2 and 6.4**]
3.C.2.2:
The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. [See **Science Practice 7.2**]
3.G.1.1:
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. [See **Science Practice 7.1**]
5.A.2.1:
The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [See **Science Practices 6.4 and 7.2**]

ASSESSMENT PLAN	
Summative Assessment(s) • Teacher designed quizzes and unit test aligned to Essential Knowledge	**Formative and Diagnostic Assessment(s)** • AP Physics 1 practice exam • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)
Electroscope Lab
Scotch Tape Lab
Static Electricity PhET Simulation Lab
Coulomb's Law Lab

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 1 Course Homepage Resources
  - Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site
  - PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Electric Current and Circuits Est. # of Weeks: 3 weeks 2nd semester

Synopsis: In this unit, current is defined and factors contributing to the resistance to the flow of charge in conductors is discussed. Energy transformations in circuits are introduced. Energy and charge conservation are used to examine circuits with resistors in series, with at most one parallel branch, one battery only. Content from this unit is Physics 1 specific (not assessed on the UConn PHYS 1201Q exam) and will provide the basis for a more in-depth study of circuits in AP Physics 2/UConn 1202Q.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

• Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)

• Changes that occur as a result of interactions are constrained by conservation laws. (BI5)

AP Physics Enduring Understandings (College Board Curriculum Framework)

1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.
1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.
5.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.
5.B: The energy of a system is conserved.
5.C: The electric charge of a system is conserved.

Key Vocabulary

ammeter
ampere
battery
circuit
electric current
electric potential
electric potential difference
electric power
electromotive force
equivalent resistance
Kirchoff's laws: junction rule and loop rule
ohm
parallel
resistance
resistivity
resistor
series
volt
voltage
voltmeter

AP Physics Essential Knowledge (College Board Curriculum Framework)

1.B.1: Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.

1. An electrical current is a movement of charge through a conductor.
2. A circuit is a closed loop of electrical current.

Guiding Questions (College Board Course Planning Guides)

How do conservation laws apply to electric circuits?

What factors affect the resistance of a wire?

How are series and parallel circuits different from each other?

1.E.2: Matter has a property called resistivity. 1. The resistivity of a material depends on its molecular and atomic structure. 2. The resistivity depends on the temperature of the material. **5.A.2:** For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. **5.B.3:** A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces. 1. The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system. 2. Changes in the internal structure can result in changes in potential energy. Examples should include mass-spring oscillators and objects falling in a gravitational field. 3. The change in electric potential in a circuit is the change in potential energy per unit charge. [Physics 1: only in the context of circuits.] **5.B.9:** Kirchhoff 's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff 's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.] 1. Energy changes in simple electrical circuits are conveniently represented in terms of energy change per charge moving through a battery and a resistor. 2. Since electric potential difference times charge is energy, and energy is conserved, the sum of the potential differences about any closed loop must add to zero. 3. The electric potential difference across a resistor is given by the product of the current and the resistance. 4. The rate at which energy is transferred from a resistor is equal to the product of the electric potential difference across the resistor and the current through the resistor. 5. Energy conservation can be applied to combinations of resistors and capacitors in series and parallel circuits. [Physics 2 only] **5.C.3:** Kirchhoff 's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved	

at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel. [Physics 1: covers circuits with resistors in series, with at most one parallel branch, one battery only. Physics 2: includes capacitors in steady-state situations. For circuits with capacitors, situations should be limited to open circuit, just after circuit is closed, and a long time after the circuit is closed.]	

AP Physics Learning Objectives (College Board Curriculum Framework)

1.B.1.1:
The student is able to make claims about natural phenomena based on conservation of electric charge.
[See **Science Practice 6.4**]

1.B.1.2:
The student is able to 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.
[See **Science Practices 6.4 and 7.2**]

1.E.2.1:
The student is able to choose and justify the selection of data needed to determine resistivity for a given material.
[See **Science Practice 4.1**]

5.A.2.1:
The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [See **Science Practices 6.4 and 7.2**]

5.B.3.1:
The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. [See **Science Practices 2.2**, **6.4**, **and 7.2**]

5.B.3.2:
The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. [See **Science Practices 1.4 and 2.2**]

5.B.3.3:
The student is able to 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. [See **Science Practices 1.4 and 2.2**]

5.B.9.1:
The student is able to 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).
[See **Science Practices 1.1 and 1.4**]

5.B.9.2:
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 in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. [See **Science Practices 4.2**, **6.4**, **and 7.2**]

5.B.9.3:
The student is able to 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.
[See **Science Practices 2.2**, **6.4**, **and 7.2**]

5.C.3.1:
The student is able to 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. [See **Science Practices 6.4 and 7.2**]

5.C.3.2:
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. [See **Science Practices 4.1**, **4.2**, **and 5.1**]

5.C.3.3:
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. [See **Science Practices 1.4 and 2.2**]

ASSESSMENT PLAN	
Summative Assessment(s) • Teacher designed quizzes and unit test aligned to Essential Knowledge	**Formative and Diagnostic Assessment(s)** • AP Physics 1 practice exam • Teacher designed homework problem sets
Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment) Battery and Bulb Lab Qualitative Series and Parallel Circuits Lab Resistivity of Play-doh Lab Circuits PhET Simulation Lab	

LEARNING PLAN COMPONENTS
➢ Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create: • Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6 • Reference textbooks: College-level textbooks as selected by teacher • AP Central – AP Physics 1 Course Homepage Resources • Quest Learning and Assessment, Minds On Physics, and/or other similar online homework submission site • PhET Interactive Simulations https://phet.colorado.edu

Unit Name: Fluids Est. # of Weeks: 2 weeks 2nd semester

Synopsis: This unit covers topics related to density, pressure, Pascal's and Archimedes' principals, and fluids at rest. This unit is required content for UConn Physics 1201Q and AP Physics 2, thus is will be taught in both the first and second year AP Physics courses. In this course, it is expected that this unit will be covered after the AP Physics 1 (since the content is UConn 1201Q specific) to the level sufficient to meet the assessment criteria of the UConn 1201Q Final Exam provided each year by the UConn Physics Department. Further, it is assumed that the content of the unit will be covered in more depth in the subsequent AP Physics 2/UConn 1202Q course to meet the AP Physics 2 exam requirements.

STUDENT LEARNING GOALS

AP Physics Big Ideas (College Board Curriculum Framework)

• Objects and systems have properties such as mass and charge. Systems may have internal structure. (BI1)

• The interactions of an object with other objects can be described by forces. (BI3)

AP Physics Enduring Understandings (College Board Curriculum Framework)

1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.
3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using $\mathbf{a} = \mathbf{F}/m$.
3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.

Key Vocabulary

apparent weight
Archimedes' principle
Barometer
Buoyancy
Density
Fluid
Gas
Liquid
Pascal
Pascal's principle
Pressure

AP Physics Essential Knowledge (College Board Curriculum Framework)

1.E.1: Matter has a property called density.
3.A.2: Forces are described by vectors.
1. Forces are detected by their influence on the motion of an object.
2. Forces have magnitude and direction.

3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
1. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
2. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.

Guiding Questions (College Board Course Planning Guides)

Why does liquid pressure vary with depth when gas pressure does not?

How does Archimedes' principle help us to understand why certain objects float in fluids?

3. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free- body diagram to the algebraic representation. **3.C.4:** Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring, and buoyant.	

AP Physics Learning Objectives (College Board Curriculum Framework)

1.E.1.1:
The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction. [See **Science Practices 4.2 and 6.4**]

1.E.1.2:
The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. [See **Science Practices 4.1 and 6.4**]

3.A.2.1:
The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See **Science Practice 4.2**]

3.B.2.1:
The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See **Science Practices 1.1**, **1.4**, **and 2.2**]

3.C.4.1:
The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [See **Science Practice 6.1**]

3.C.4.2:
The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [See **Science Practice 6.2**]

ASSESSMENT PLAN

Summative Assessment(s)	Formative and Diagnostic Assessment(s)
• Teacher designed quizzes and unit test aligned to Essential Knowledge • UCONN PHYS 1201 Q Exit Exam (to be provided each year by UConn Physics Department)	• AP Physics 2 practice exam questions • Teacher designed homework problem sets

Possible Laboratory Work (teacher to select from list based on individual needs, facility, and equipment)

Buoyancy Lab

LEARNING PLAN COMPONENTS

- Identify those components that the district expects will provide the basis for major learning activities in the lesson designs that staff create:
  - Primary textbook: Serway/Faughn (2006). College Physics, 7th ed. Thomson Brooks/Cole. ISBN 0-534-99723-6
  - Reference textbooks: College-level textbooks as selected by teacher
  - AP Central – AP Physics 2 Course Homepage Resources
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