AP Physics -1 Curriculum
2018-2019

Curriculum Requirements		Page(s)
CR1	Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.	3
CR2a	The course design provides opportunities for students to develop understanding of the foundational principles of kinematics in the context of the big ideas that organize the curriculum framework.	3
CR2b	The course design provides opportunities for students to develop understanding of the foundational principles of dynamics in the context of the big ideas that organize the curriculum framework.	4
CR2c	The course design provides opportunities for students to develop understanding of the foundational principles of gravitation and circular motion in the context of the big ideas that organize the curriculum framework.	7
CR2d	The course design provides opportunities for students to develop understanding of the foundational principles of simple harmonic motion in the context of the big ideas that organize the curriculum framework.	9
CR2e	The course design provides opportunities for students to develop understanding of the foundational principles of linear momentum in the context of the big ideas that organize the curriculum framework.	5
CR2f	The course design provides opportunities for students to develop understanding of the foundational principle of energy in the context of the big ideas that organize the curriculum framework.	5
CR2g	The course design provides opportunities for students to develop understanding of the foundational principles of rotational motion in the context of the big ideas that organize the curriculum framework.	7
CR2h	The course design provides opportunities for students to develop understanding of the foundational principles of electrostatics in the context of the big ideas that organize the curriculum framework.	12
CR2i	The course design provides opportunities for students to develop understanding of the foundational principles of electric circuits in the context of the big ideas that organize the curriculum framework.	12
CR2j	The course design provides opportunities for students to develop understanding of the foundational principles of mechanical waves in the context of the big ideas that organize the curriculum framework.	10
CR3	Students have opportunities to apply AP Physics 1 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.	5, 13
CR4	The course provides students with opportunities to apply their knowledge of physics principles to realworldquestionsorscenarios(includingsocietalissuesortechnologicalinnovations)tohelpthem become scientifically literatecitizens.	6, 7, 13
CR5	Students are provided with the opportunity to spend a minimum of 25 percent of instructional time engaging in hands-on laboratory work with an emphasis on inquiry-based investigations.	2
CR6a	The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.	3
CR6b	The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.	4, 5, 6, 7, 8, 9, 10, 11
CR7	The course provides opportunities for students to develop their communication skills by recording evidence of their research of literature or scientific investigations through verbal, written, and graphic presentations.	2, 5, 8, 10
CR8	The course provides opportunities for students to develop written and oral scientific argumentation skills.	2, 7

COURSE OVERVIEW

AP Physics 1 is an algebra-based, introductory college physics course that explores topics such as Newtonian mechanics (one- and two- dimensional motion, projectile motion, forces, and gravitation); work, energy, and power; mechanical waves and electromagnetic waves; magnetism and circuits. Through inquiry-based learning, students will develop scientific critical thinking and reasoning skills. The AP Physics student must be familiar with Algebra II and trigonometry. Calculus is useful but not necessary for this course. In most colleges, a similar course would be used as a foundation in physics for students in life sciences, pre-med, and some applied sciences, as well as other fields not directly related to science.

The course focuses on the interconnections between the various strands and units contained in the course syllabus and how each contributes to the "Big Ideas" that provide a core foundation for this course. Problem solving techniques and strategies are fine-tuned throughout the year, and students are continually tasked with connecting physics applications in different units in order to synthesize solutions to complex problems.

Students will have the opportunity to meet the learning objectives in a variety of ways and to apply their knowledge to real world experiences and societal issues. Instructional time involves a variety of student-centered activities such as student-led discussions, STEAM group projects, and class demonstrations; students also have the opportunity to work cooperatively to solve challenging problems and to present their solutions to the class. Laboratory work, described below, offers frequent opportunities to work cooperatively, explore ideas, and present information. Outside of class students read the assigned text and complete homework assignments that support and reinforce each lesson as well as what has been learned in the laboratory setting. Unit exams take place at the end of each block of instruction. Students also attend tutorial sessions, offered during school in sessions called "Wildcat Wednesdays," where they can receive individual assistance from the instructor and work with their peers.

Students will spend 25% of instructional time engaged in laboratory work **[CR5]**. Experiments designed by the instructor are used to demonstrate procedural guidelines and to learn how to use specific laboratory equipment. The majority of labs are inquiry-based where students are given an objective and a set of materials. They are tasked with designing a procedure and collecting data to determine specific quantities, determine the relationship between variables, and/or to derive fundamental physics equations through modeling techniques. Laboratory design, experimentation, data gathering, data presentation, analysis, drawing conclusions, and experimental error analysis are important elements in these labactivities.

Laboratory work is presented in written reports and oral presentations; which students may present to teachers or to their peers. All aspects of the laboratory work including any pre-lab work, question/hypothesis, experimental procedure, data, analysis, graphs, conclusion, and error analysis will be recorded **[CR7]**. Additional information as indicated in the following pages will also be included in the lab notebook. Oral presentations require students to present their method, data and conclusions on whiteboards, PowerPoints, or Tri-Folds. The class will then engage in peer critique of each group's results, and discuss strategies to improve experimental methodology. **[CR8]**

Evaluation:

Students will get grades on homework, quizzes, laboratory work, projects, and exams.Exams are typically worth 100 points and will consist of questions similar to one's studentswill see on the AP Exam. Homework assignments and quizzes will consist of problemsfrom the textbook, supplements, and old AP Exams. Projects are long-term, and typicallywill involve groups of students developing a plan, collecting data and/or research, andpresenting conclusions in a meaningful way. Laboratory work is student centered andinquiry based and is discussed below.Grades will be determined by taking the number of points a student has earned anddividing it by the total number of points that the student could have achieved. Thisdecimal is multiplied by 100, and that will be the student's grade.

RESOURCES

TEXTBOOK [CR1]

Wilson, Buffa, Lou. *College Physics, 6th ed*. Upper Saddle River, New Jersey; Prentice Hall, 2007.
Serway, Vullie, College Physics, 10th ed

TEACHING RESOURCES [CR1]

Cutnell, Johnson. *Physics, 7th ed*. Hoeboken, NJ; Wiley, 2006.

Hieggelke, Curtis, David Maloney, and Stephen Kanim. *Newtonian Tasks Inspired by Physics Education Research: nTIPERs*. Upper Saddle River, NJ: Pearson, 2012.

Hieggelke, Curtis, David Maloney, Tomas O'Kuma, and Stephen Kanim. *E&M TIPERs: Electricity & Magnetism Tasks*. Upper Saddle River, NJ: Pearson, 2006.

O'Kuma, Maloney, Hieggelke. *Ranking Task Exercises in Physics: Student Edition*. San Francisco, CA; Addison-Wesley, 2003.

Google Sites and Drive and Remind will be used to communicate with students regularly and distribute course materials, including video help, study guides, electronic resources, etc.

COURSE SYLLABUS

UNIT 1. KINEMATICS [CR2a]

- Kinematics in one-dimension: constant velocity and uniform acceleratedmotion
- Vectors: vector components andresultant vector
- Kinematics in two-dimensions: projectilemotion

Big Idea 3: The interactions of an object with other objects can be described by forces.
Big Idea 4: Interactions between systems can result in changes in those systems.
Learning Objectives: 3.A.1.1, 3.A.1.2, 3.A.1.3

Course Sequence	Student Labs and Activities [CR6a]
Course Introduction Physics Conventions Measurements Significant figures	Read 1.1 to 1.7 and 2.1 to 2.5 and 3.1 to 3.4 Groups discuss how a system, such as a bicycle, a car, the solar system, an atom, etc., can be viewed as a particle(s), an object(s), and as a system in different situations. (EU 1.A)
Orientation Intro to center of mass Objects and systems Inertial Frames Coordinate System Scalars and vectors Kinematic variables and rates	*Lab 1: Constant velocity. Structured lab to demonstrate lab format and expectations. Record and graph displacement versus time data. Generate velocity and acceleration graphs.* (EU 3.A, 4.A) (SP 2, 5) *Lab 2: [Guided-Inquiry] Design an experiment. Given a track (capable of being inclined to a measureable angle), a low friction cart, a meter stick, and a timing device; students will design a lab to determine the acceleration of the cart. Students will describe the observed motion qualitatively, organize the data into a meaningful table, and construct a graph that can be used to determine the acceleration of theobject.*

Distance, Displacement Speed, Velocity Acceleration Deriving kinematic equations and problem solving techniques One-dimensional kinematics Qualitatively describing motion associated with experimental results and real world examples Graphical motion analysis Position, velocity, and acceleration time graphs Free fall Acceleration of gravity Two-dimensional kinematics Vector components Vector Addition Relative motion Projectile motion	(EU 3.A, 4.A) (SP 2, 3, 4, 5) **[CR6b]** *Lab 3: Free fall. Structured lab to demonstrate computer data acquisition. Using computer-based data collection, students will record the time for a free falling object from various heights. Students will graph results in order to determine the value of the acceleration of gravity.* (EU 3.A, 4.A) (SP 2, 5) Compare and contrast the graphs of constant velocity and acceleration. Record results. (EU 3.A) (SP 5) Describe the trip from home to school in terms of distance, displacement, speed, velocity, and acceleration. Generate a matching velocity-time graph for the motion described. (EU 3.A) (SP 1) *Lab 4: Projectile motion. Students will fire a projectile horizontally and mathematically use the results to determine the launch velocity. Subsequently students will fire the projectile at several launch angles while experimentally determining maximum height and maximum range. Results will be compared to calculated values. Students will also construct a variety of graphs involving displacement, velocity, andacceleration.* (EU 3.A, 4.A) (SP 2, 4, 5)

UNIT 2. DYNAMICS [CR2b]

- Forces, types, and representation(FBD)
- Newton's FirstLaw
- Newton's SecondLaw
- Applications of Newton's SecondLaw
- Friction
- Interacting objects: ropes andpulleys

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
Big Idea 2: Fields existing in space can be used to explain interactions
Big Idea 3: The interactions of an object with other objects can be described by forces.
Big Idea 4: Interactions between systems can result in changes in those systems.

Learning Objectives: 1.C.1.1, 1.C.1.3, 2.B.1.1, 3.A.2.1, 3.A.3.1, 3.A.3.2, 3.A.3.3, 3.A.4.1, 3.A.4.2, 3.A.4.3, 3.B.1.1, 3.B.1.2, 3.B.1.3, 3.B.2.1, 3.C.4.1, 3.C.4.2, 4.A.1.1, 4.A.2.1, 4.A.2.2, 4.A.2.3, 4.A.3.1, 4.A.3.2

Inertial mass, Law of Inertia Force Agent and object Contact forces	Read 4.1 to 4.6 Define inertia and its connection to mass. Given several examples of motion of objects, all having differing masses, assess the general effect of mass on motion. (EU 3.A)

Long-range forces Gravity field Identifying forces Weight Tension Normal force Force of springs Friction Drag Objects and systems Force vectors Free-body diagrams Newton's Second Law Newton's Third Law Problem solving Net force Statics Dynamics Inclines Compound bodies Advanced equilibrium and dynamics problems involving a variety of forces and interacting objects	Groups research weight, tension, normal force, restoring force, friction, drag, and applied forces. Identify the agent, the magnitude of the force, and the direction of the force. Share the results with the class. (EU 2.A, 3.A, 3.C) (SP 6) List the requirements for an object to experience a force. Explain why there must be an action-reaction pair, and explain why objects cannot place a force on themselves. Share your explanation with a partner. (EU 3.A) (SP 6) *[Connecting Across Enduring Understandings]* – Students will be given various scenarios (e.g. equilibrium on an incline, non-equilibrium with friction, etc.) and told to find pictures of common objects in real world settings; they will identify one object and one system. For each object/system, they will identify the forces acting on the object and system, identify the corresponding action-reaction pairs, construct a free-body diagram, and predict the motion of the object and the system. They will then share the results with another student and critique each other. (LO 1.A.5.1, 3.A.4.3, 3.B.1.1) (SP 1, 6, 7) **[CR3] [CR7]** Given a variety of scenarios, students will construct a free body diagram, assess the type of motion experienced by the object, determine the magnitude and direction of the sum of the force vectors, and determine the objects acceleration. (EU 3.B, 4.A) *Lab 5: Statics. Using masses, strings, and spring scales, students will suspend the masses in several configurations, including various angles, while recording the tension in each string. The results will also be compared to free-body diagrams of each suspended mass.* (EU 3.A, 3.B) (SP 1, 2, 5, 7) Groups will be given diagrams consisting of compound bodies in various configurations. Identify objects/systems and prepare free-body diagram. (LO 1.A.5.1, 3.A.4.3) (SP 1) *Lab 6: [Guided-Inquiry] Atwood's Machine. Determine the acceleration of gravity using two masses, a string, a pulley, a meter stick, and a timer.* (EU 1.A, 1.C, 3.A, 3.B) (SP 2, 4, 5) **[CR6b]** *Lab 7: [Guided-Inquiry] Given a ramp, a pulley, a string, unequal masses, a meter stick, a timer, and a spring scale, design a series of experiments to determine the coefficients of static and kinetic friction between felt: wood and wood: wood. In addition, determine the acceleration of the object when forces are unbalanced.* (EU 1.A, 1.C, 3.A, 3.B) (SP 1, 2, 3, 4, 5, 6, 7) **[CR6b]**

UNIT 3. CONSERVATION LAWS [CR2e] [CR2f]

- Work
- Power
- Kinetic energy
- Potential energy: gravitational andelastic
- Conservation ofenergy
- Impulse
- Momentum
- Conservation ofmomentum

• Elastic and inelasticcollisions **Big Ideas 3:** The interactions of an object with other objects can be described by forces. **Big Ideas 4:** Interactions between systems can result in changes in those systems. **Big Ideas 5:** Changes that occur as a result of interactions are constrained by conservation laws. **Learning Objectives:** 3.D.1.1, 3.D.2.1, 3.D.2.2, 3.D.2.3, 3.D.2.4, 3.E.1.1, 3.E.1.2, 3.E.1.3, 3.E.1.4, 4.B.1.1, 4.B.1.2, 4.B.2.1, 4.B.2.2, 4.C.1.1, 4.C.1.2, 4.C.2.1, 4.C.2.2, 5.A.2.1, 5.B.1.1, 5.B.1.2, 5.B.2.1, 5.B.3.1, 5.B.3.2, 5.B.3.3, 5.B.4.1, 5.B.4.2, 5.B.5.1, 5.B.5.2, 5.B.5.3, 5.B.5.4, 5.B.5.5, 5.D.1.1, 5.D.1.2, 5.D.1.3, 5.D.1.4, 5.D.1.5, 5.D.2.1, 5.D.2.2, 5.D.2.3, 5.D.2.4, 5.D.2.5, 5.D.3.1	
Energy Energy model Internal energy Total mechanical energy Kinetic energy Potential Energy Gravitational Elastic	Read 5.1 to 5.6 and 6.1 to 6.4 *Lab 8: [Real World Application] Students will research, design, build, and test a roller coaster out of cardstock for a marble. Students will design a data collection method to determine the effect on internal energy due to non-conservative forces by examining various points along the track. Data collected will be presented graphically in order to determine the work done. In addition, students will calculate changes in kinetic energy to the work done. Students will share the results with the class and discuss whether or not the results are consistent with the work energy theorem.* (EU 3.E, 4.C, 5.B) (SP 1, 2, 4, 5, 6) **[CR4] [CR6b]**
Work Dot product of Vectors Conservative Forces Non-conservative forces Constant force Variable force	Class Discussion: Class will create an energy model to visualize the relationships between energies within a system. The conditions for both an open and closed system will be established, and examples of each will be discussed. Given specific examples, students will use the model to suggest the source of a change in energy and the resulting effect on both the system and the environment. (4.C, 5.A, 5.B) (SP 1, 2)
Work Kinetic Energy Theorem	Students will be given a variety of diagrams showing systems in various positions. Students will access the energies comprising the system's internal energy. Students will qualitatively and quantitatively determine changes to these energies as a result of changes within the system. (EU 4.C, 5.B) (SP 1, 2, 6)
Conservation of energy Conservative Forces Non-Conservative Forces	Students will categorize previously learned forces as either conservative or non-conservative. (EU 5.B) (SP 1)
Power Graphing energy, work, and power	Work will be demonstrated by applying a variety of forces to various objects. Students will make predictions regarding the resulting motion. Students will use their observations to determine how a force must be applied to change the internal energy of a system. (EU 4.C, 5.B) (SP 1)
Linear momentum Impulse Open and closed systems	Students will make qualitative predictions on changes in kinetic energy given force and velocity vectors. Students will also solve quantitative problems using the work-kinetic energy theorem. Students will compare the work values obtained with their qualitative observations and with the results obtained using force and distance to determine work. (EU 3.E, 4.C) (SP 2)
Conservation of linear momentum Elastic collisions	Given a variety of systems, students will use conservation of energy to determine key data at various locations for a moving object or changing system. (EU 5.A, 5.B) (SP 2)

Perfectly inelastic collisions Explosions Energy in collisions Graphing Impulse	Conceptual Round Robin: Students will be provided with several questions out of n TIPERS. In groups, they will construct a written argument. They will then rotate to the next station to respond to the previous group's argument, and so on. When finished, the original group will use the arguments provided by the rest of the class to construct an oral presentation with the answer to thequestion. [CR4] [CR8] Students will determine the change in momentum of various objects given their mass and initial velocity along with either: the objects resulting velocity; the force acting to change momentum and the time during which it acts; or graphical representation of force and time. (EU 3.D, 4.B) (SP 2, 5, 6) Given a real world scenario, students will design a plan to collect and organize data in order to determine the relationship between changes in momentum and average force. Articulate the difference between open and closed systems and their effect on conserved quantities. (EU 5.A) (SP 6, 7) Given various collisions students must identify them as elastic, inelastic, or perfectly elastic. Students must predict the resulting motion of colliding objects, and verify their predictions using the appropriate conservation of momentum calculations. When relevant, calculations may include kinetic energy lost. (EU 5.D) (SP 2, 3, 6, 7) *Lab 9: [Guided-Inquiry] Using low friction carts, capable of colliding elastically and in elastically, students will design experiments to verify conservation of momentum and kinetic energy for both types of collisions. Analysis will include graphing the motion of each cart before during and after the collision.* (EU 5.D) (SP 2, 3, 4, 5, 6, 7) **[CR6b]**

UNIT 4. CIRCULAR MOTION, GRAVITATION AND ROTATIONAL MOTION [CR2c] [CR2g]

- Uniform circularmotion
- Dynamics of uniform circularmotion
- Torque
- Center ofmass
- Rotationalkinematics
- Rotational dynamics and rotationalinertia
- Rotationalenergy
- Angularmomentum
- Conservation of angularmomentum

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
Big Idea 2: Fields existing in space can be used to explain interactions
Big Ideas 3: The interactions of an object with other objects can be described by forces.
Big Ideas 4: Interactions between systems can result in changes in those systems.
Big Ideas 5: Changes that occur as a result of interactions are constrained by conservation laws.
Learning Objectives: 3.A.3.1, 3.A.3.3, 3.B.1.2, 3.B.1.3, 3.B.2.1, 3.F.1.1, 3.F.1.2, 3.F.1.3, 3.F.1.4, 3.F.1.5, 3.F.2.1, 3.F.2.2, 3.F.3.1, 3.F.3.2, 3.F.3.3, 4.A.1.1, 4.A.2.2, 4.D.1.1, 4.D.1.2, 4.D.2.1, 4.D.2.2, 4.D.3.1, 4.D.3.2, 5.E.1.1, 5.E.1.2, 5.E.2.1

Uniform Circular Motion Period Tangential velocity Centripetal	Read 6.5 and 7.1 to 7.4 and 8.1 to 8.5 Groups given scenarios involving actual uniform circular motions will draw vectors representing tangential velocity and centripetal acceleration. For each scenario, the

acceleration Uniform circular motion Centripetal force Force problems involving uniform circular motion Apparent weight in circular motion Center of mass Rotational objects viewed as systems Rotational kinematics Angular Displacement Angular velocity Angular acceleration Related tangential quantities Moment of inertia Parallel axis theorem Torque Torque vectors Cross product of vectors Right hand rule Rotational statics Rotational dynamics Conservation of energy in rotation Angular momentum Angular momentum vectors Right hand rule Change in angular momentum Conservation of angular momentum	period, speed, and acceleration will be determined. (EU 3.A, 3.B) (SP 1, 2, 7) Groups given real world scenarios involving uniform circular motion will draw vectors representing tangential velocity, centripetal acceleration and centripetal force, complete free-body diagrams, determine equations solving for the centripetal force, acceleration, and tangential velocity for the object. Share and critique the results with another group. (EU 1.A, 3.A, 3.B) (SP 1, 2, 7) **[CR7]** *Lab 10: Determine the speed of a mass moving as a conical pendulum (battery-powered airplane) using two methods: kinematics of uniform circular motion and by summing forces. Compare the results obtained by both methods.* (EU 1.A, 3.A, 3.B) (SP 1, 2, 4, 5, 7) Students will analyze various real world scenarios that create apparent weight. (EU 3.A, 3.B) (SP 1, 2, 3, 7) Given various symmetrical objects and systems, students will locate the center of mass and state its relationship to the linear and rotational motion of a freely moving object. (EU 4.A) (SP 5) After seeing several demonstrations, students will compare the effect on the center of mass due to forces acting within a system to forces acting on the system. In addition, students must recognize that if no external forces act, the system will move at constant velocity. (EU 4.A, 5.D) (SP 1, 2, 6) Describe how a rotating system can be visualized as a collection of objects in circular motion. (EU 1.A) (SP 1) Students will compare rotational and linear quantities and solve rotational kinematic problems using previously learned techniques. (EU 4.D) (SP 2, 7) Groups will be given a scenario where a compound body is experiencing rotation. Students will identify the components of force creating torque, characterize each torque as positive or negative, determine the net torque, and determine the resulting motion of the system. Groups will share their scenarios and findings and critique each other. They will record their own and the other group's findings in the lab book. (EU 3.F) (SP 1) **[CR7]** *Lab 11: [Guided-Inquiry] Students will design a lab to demonstrate rotational statics.* (EU 3.F) (SP 4, 5) [CR6b] *Lab 12: Given an apparatus that rotates horizontally due to the vertical motion of a mass draped over a pulley, students will collect a variety of data to determine the moment of inertia of the rotating system, the net torque acting on the system, the angular and linear acceleration, the final velocity of the system, the work done during the motion. Students will also use conservation of energy to determine the final velocity and compare this to the value obtained using torque and kinematics.*

	(EU 3.F, 4.D, 5.B) (SP 4, 5) Given a rotating system, students will determine angular momentum using both linear and rotational variables. Students will make predictions and compare how interactions with external objects or changes within the system can influence angular momentum. (EU 4.D, 5.E) (SP 1, 2, 3, 7) *Lab 13: [Guided-Inquiry] Using a pulley and a rotating platform, students will design a lab involving a rotating system where a net torque results in angular acceleration. Students will also make changes to the system's configuration to explore the effect on angular momentum. Students will compare the change in angular momentum to the change in average torque multiplied by time.* (EU 3.F, 4.D, 5.E) (SP 1, 2, 4, 5) **[CR6b]**

UNIT 5. SIMPLE HARMONIC MOTION [CR2d]

- Linear restoring forces and simple harmonicmotion
- Simple harmonic motiongraphs
- Simplependulum
- Mass-springsystems
- Universal Law ofGravitation

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
Big Idea 2: Fields existing in space can be used to explain interactions
Big Ideas 3: The interactions of an object with other objects can be described by forces.
Big Ideas 4: Interactions between systems can result in changes in those systems.
Big Ideas 5: Changes that occur as a result of interactions are constrained by conservation laws.
Learning Objectives: 1.C.3.1, 2.B.1.1, 2.B.2.1, 2.B.2.2, 3.B.3.1, 3.B.3.2, 3.B.3.3, 3.B.3.4, 3.C.1.1, 3.C.1.2, 3.C.2.1, 3.C.2.2, 3.G.1.1, 5.B.2.1, 5.B.3.1, 5.B.3.2, 5.B.3.3, 5.B.4.1, 5.B.4.2

Restoring forces Hooke's Law Equilibrium Simple harmonic motion Spring Simple pendulum Physical pendulum Period and frequency Force and energy relationships during an oscillation Graphing oscillations Fundamental forces Long range forces Gravity field Mass and weight Newton's Law of Gravity Inverse Square Law Elliptical orbits	Read 7.5 to 7.6 and 13.1 to 13.2 Working in groups, students will predict which properties influence the motion of an oscillating spring and an oscillating pendulum. Students will share their predictions. (EU 3.B) (SP 6, 7) *Lab 14: [Guided-Inquiry] Hooke's Law and oscillations.* *Students will design a two-part lab. In the first part, they will determine the relationship between a spring's restoring force, spring constant, and displacement. In the second part of the lab, students will examine the oscillation of the spring determining the period of the oscillation, the energy of the system, and the force and speed acting on the mass at various locations during the oscillation.* (EU 3.B, 5.B) (SP 4, 5) **[CR6b]** Students will compare and contrast a simple pendulum and a physical pendulum. (EU 3.B, 5.B) (SP 6, 7) Given potential energy graphs of an oscillation, students working in groups will qualitatively and quantitatively analyze the motion. Analysis will include determining frequency and period, identifying equilibrium, identifying the significance of minima and maxima, determining the force constant, determining values of force and acceleration, and determining kinetic energy and total energy. Results will be shared with another group and critiqued, and then both sets of results will be added to the lab book. (EU 3.B, 5.B) (SP 3) **[CR7]**

Kepler's Laws Conservation of angular momentum Conservation of energy Circular orbits Orbital speed Escape speed	*Lab 15: [Guided-Inquiry] Using a pendulum, students will design a lab to determine the strength of the gravity field on Earth.* (EU 3.B, 5.A, 5.B) (SP 2, 3, 4, 5, 7) **[CR6b]** Discuss gravity as a fundamental force, how it is represented as gravity field, and the relationship between the gravitational field and gravitational force. (EU 2.A, 2.B, 3.G) Compare and contrast inertial mass and gravitational mass. (EU 1.C) Diagram and compare the uniform gravitational field near Earth's surface with the radial field surrounding Earth. Determine the magnitude and direction of the gravity field and the gravitational force acting on a smaller mass inserted into the field. Investigate the effect of moving objects in each field. (EU 1.A, 1.C, 2.A, 2.B, 3.A, 3.B, 3.C) (SP 1, 2, 6, 7) Use the inverse square law to predict the magnitude of the gravity field at a specific location in space. (EU 2.B) Students will compare elliptical and circular orbits, listing Kepler's Laws, using conservation of angular momentum and/or energy to determine the orbiting bodies speed in various parts of an elliptical orbit, and determine speed and escape speed in circular orbits. (EU 3.A, 5.A, 5.B, 5.E) *Lab 16: Students will use the PhET simulation "My Solar System" to construct a planetary system consisting of a sun and a single planet. They will vary the radius and determine the speed required for uniform circular motion, and graph the data to calculate "G" for the PhET "universe."* (EU 3.A, 5.A, 5.B, 5.E) (SP 1,2,4,5,6)

UNIT 6. MECHANICAL WAVES [CR2j]

- Travelingwaves
- Wavecharacteristics
- Sound
- Superposition
- Standing waves on astring
- Standing soundwaves

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.

Learning Objectives: 6.A.1.1, 6.A.1.2, 6.A.1.3, 6.A.2.1, 6.A.3.1, 6.A.4.1, 6.B.1.1, 6.B.2.1, 6.B.4.1, 6.B.5.1, 6.D.1.1, 6.D.1.2, 6.D.1.3, 6.D.2.1, 6.D.3.1, 6.D.3.2, 6.D.3.3, 6.D.3.4, 6.D.4.1, 6.D.4.2, 6.D.5.1

Medium Dependence on medium for mechanical waves, but not for electromagnetic waves	Read 13.3 to 13.5 and 14.1 to 14.2 and 14.4 to 14.6 Students will see demonstrations of transverse and longitudinal waves. Working in groups, they will create a wave model explaining how independent oscillators act in characteristic patterns in order to transmit energy. Students will diagram each type of wave and label key elements such as equilibrium, wavelength, and amplitude. Particular attention will be focused on examining the direction of the oscillations as compared to the direction of energy transfer. Students will site real world examples of mechanical

Mechanical waves Transverse waves Waves on a string Longitudinal waves Sound Period and frequency Wavelength Amplitude Interference Constructive Destructive Superposition Reflection Standing waves Sound specific Resonance Loudness Doppler effect Beats	waves, such as strings and sound. (EU 1.A, 6.A, 6.B) (SP 1, 6, 7) Given a variety of interfering wave functions, students will add the waves pictorially to visualize wave superposition, noting areas of constructive and destructive interference. (EU 6.D) (SP 1) Given several real world objects and a set of measured data describing each object, students will make density determinations. Students will also articulate the significance of density of each object in real world situations. (EU 1.E) (SP 4, 6) Students will see demonstrations of mechanical waves reflecting at a boundary between two mediums with differing densities. Students will diagram the types of reflections seen compared to the medium densities. Students will be given other scenarios involving mediums with differing densities and then will predict how each reflection will behave. (SP 1) *Lab 17: Using an adjustable wave driver, students will generate standing waves in a string. In the first part of the lab, the medium will remain constant (constant string tension and length) while frequency is varied to identify the fundamental frequency and several harmonics. In the second phase of the lab, the tension will be varied to access the effect on frequency, wavelength, and wave speed of altering the medium. In the third phase, the effect of changing wave amplitude will be explored. Students will quantitatively determine period, frequency, wavelength and wave speed. Students will assess the effect on wave energy due to changes in frequency, wavelength, andamplitude.* (EU 6.A, 6.B, 6.D) (SP 4, 5) Students will describe how sound moves in a medium and how it transfers energy. Real world examples involving the relationship of energy to frequency, wavelength, and amplitude will be discussed. (EU 6.A, 6.B) (SP 1, 6) Students will diagram the waves associated with the fundamental frequency, 1^{st} harmonic, 2nd harmonic, and 3rd harmonic for a string, an open tube, and a closed tube. The dependence of wavelength on the size of the region, as opposed to the frequency, will be discussed. Students will calculate wavelengths and frequencies associated with each wave form. (EU 6.D) (SP 1, 2, 6) *Lab 18: [Guided-Inquiry] Using a tube submerged in water, a set of tuning forks, and a meter stick, design an experiment to determine the speed of sound in air.* (EU 6.B, 6.D) (SP 4, 5, 6, 7) **[CR6b]** Given a series of wave front diagrams, showing sound waves emitted from a moving source, students will determine the direction of motion and qualitatively access the speed of the source compared to the speed of sound in air. (EU 6.B) (SP 1) Students will superimpose diagrams of two waves having different frequencies. The waves will be added graphically to demonstrate beats.

	(EU 6.D) (SP 1)

UNIT 7. ELECTROSTATICS AND DC CIRCUITS [CR2h] [CR2i]

- Electric charge and conservation ofcharge
- Electric force: Coulomb'sLaw
- Electricresistance
- Ohm'sLaw
- DCcircuits
- Series and parallelconnections
- Kirchhoff'sLaws

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
Big Ideas 3: The interactions of an object with other objects can be described by forces.
Big Ideas 5: Changes that occur as a result of interactions are constrained by conservation laws.

Learning Objectives: 1.B.1.1, 1.B.1.2, 1.E.2.1, 1.B.3.1, 3.C.2.1, 3.C.2.2, 5.A.2.1, 5.B.9.1, 5.B.9.2, 5.B.9.3, 5.C.3.1, 5.C.3.2, 5.C.3.3

Charge Electric field Electric force Conductors and insulators Conservation of charge Charging Conduction Induction Current Batteries and EMF Resistance Ohm's Law Power Kirchhoff's Laws DC resistor circuits	Read 15.1 to 15.4 and 16.1 and 17.1 to 17.4 and 18.1 Students will identify the atomic particles having the property of charge and list their characteristics, including the charge on an electron, proton, and neutron. (EU 1.B) (SP 6) The statement that charge is conserved and quantized will be analyzed, with students predicting its significance. Given a variety of charged objects/systems, students will characterize each as an object/system depending on given parameters. Students will discuss the meaning of net charge and determine the net charge for each object/system. (EU 1.A, 1.B) (SP 1, 7) Students will diagram and compare the uniform electric field between plates with the field surrounding spherical point charges. The direction of force on a point charge placed in each field will be diagrammed. Compare and contrast the electric field and force to the gravity field and gravitational force. Using Coulomb's Law, students will determine the magnitude of force between two point charges. (EU 3.C) (SP 1, 2, 7) Various objects will be charged and students will use the principle of conservation of charge to predict the resulting charge and the sign of the charge on each object. (EU 1.B, 5.A) (SP 6, 7) A model of electric current in a simple circuit will be proposed and diagrammed. How EMF and resistivity affect current will be modeled. Students will be asked to make analogies to real world systems that have similarities to electric circuits. (EU 1.A) (SP 1) Given a variety of data, students will select data relevant in determining the resistivity of a substance, and will determine and test the resistance in a length wire. (EU 1.E) (SP 2, 4) *Lab 19: Ohm's Law. Using a multi-meter, students will explore the relationships between EMF, current, and resistance in a simple circuit. The rate that electric energy is consumed by the circuit will also be determined.* (EU 5.B) (SP 5, 6)

	Lab 20: Students construct one series and one parallel circuit involving the same three resistors. Measurements of potential, current, and resistance will be used to deduce Kirchhoff's Laws. The connections to conservation of charge and energy will be stressed. (EU 5.B) (SP 1, 6, 7) *Lab 21: Students will design their own circuit mixing series and parallel pathways. They will prepare a schematic of the circuit, and use Kirchhoff's laws to predict the current and potential drops across each resistor. Using a multi-meter, students will then confirm their predictions.* (EU 5.C) (SP 2, 4, 5, 6) Given a variety of circuit schematics, students will be able to determine the current, voltage drops, and power consumption in all components comprising the circuit. (EU 5.C) (SP 1, 2, 5)