`Rumson-Fair Haven Regional High School

Course: *AP Physics C*
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Section I: Course Description

AP Physics C (Mechanics and Electricity & Magnetism–both calculus based) is the equivalent of two semesters of college level calculus based Physics courses. Topics covered in mechanics include Kinematics, Newton's laws, Work & Energy, Momentum & Collisions, Circular Motion, Rotational Dynamics, Simple Harmonic Motion, and Gravitation. Topics covered in Electricity & Magnetism are Electric Fields and Forces, Gauss' Law, Electric potential, DC Circuits, Magnetic Fields, and Induction. As most of these topics will have been covered in previous Physics courses by the time students take this course, they become enhanced by applying calculus knowledge and skills to similar concepts. Out of class preparation and application of critical thinking skills are vital components of this course. Data collection techniques and analysis are emphasized. Students who demonstrate proficiency will be prepared to take both the *AP Physics C Mechanics Exam* and *AP Physics C Electricity & Magnetism Exam* offered in May.

Section II: NJSLS: New Jersey Student Learning Standards/Learning Objectives

1. ***2020 New Jersey Student Learning Standards – Science*:**
   - "Scientific and technological advances have proliferated and now permeate most aspects of life in the 21st century. It is increasingly important that all members of our society develop an understanding of scientific and engineering concepts and processes. Learning how to construct scientific explanations and how to design evidence-based solutions provides students with tools to think critically about personal and societal issues and needs. Students can then contribute meaningfully to decision-making processes, such as discussions about climate change, new approaches to health care, and innovative solutions to local and global problems."
2. ***2016 English Language Arts Companions for Grades 11-12 (History, Social Studies, Science and Technical Subjects):***
   - The ELA Standards were revised in 2016, with the recommendations of teams of teachers, parents, administrators, supervisors and other stakeholders and reflect the strong beliefs that, "...Literacy must be recognized and guided in content areas so that students recognize the academic vocabulary, media representations, and power of language inherent in the work of scholars and experts..."
3. ***Standard 8.1 (Computer Science) and 8.2 (Design Thinking)* of the *2020 NJSLS*:**
   - "The 'Intent and Spirit of the Computer Science and Design Thinking Standards' is to focus on deep understanding of concepts that enable students to think critically and systematically about leveraging technology to solve local and global issues. Authentic learning experiences that enable students to apply content knowledge, integrate concepts across disciplines, develop computational thinking skills, acquire and incorporate varied perspectives, and communicate with diverse audiences about the use and effects of computing prepares New Jersey students for college and careers."
4. ***Standard 9.4 (Life Literacies and Key Skills)* of the *2020 NJSLS*:**
   - "This standard outlines key literacies and technical skills such as critical thinking, global and cultural awareness, and technology literacy* that are critical for students to develop to live and work in an interconnected global economy."
   - **Climate Change:** The state of New Jersey has mandated instruction in, "Climate Change across all content areas, leveraging the passion students have shown for this critical issue and providing them opportunities to develop a deep understanding of the science behind the changes and to explore the solutions our world desperately needs."
5. ****Amistad Law: N.J.S.A. 18A 52:16A-88:***
   - The inclusion of lessons and resources/texts dealing with the African slave trade, slavery in America, the vestiges of slavery in this country and the contributions of African-Americans to our society will be implemented in English and Social Studies courses in accordance with state law: "Every board of education shall incorporate the information regarding the contributions of African-Americans to our country in an appropriate place in the curriculum of elementary and secondary school students."
6. ****Holocaust Law: N.J.S.A. 18A 35-28:***
   - The inclusion of lessons and resources/texts that enable pupils to identify and analyze applicable theories concerning human nature and behavior; to understand that genocide is a consequence of prejudice and discrimination; and to understand that issues of moral dilemma and conscience have a profound impact on life will be implemented in English and Social Studies courses in accordance with state law: "Every board

of education shall include instruction on the Holocaust and genocides in an appropriate place in the curriculum of all elementary and secondary school pupils. The instruction shall further emphasize the personal responsibility that each citizen bears to fight racism and hatred whenever and wherever it happens."

7. ***LGBT and Disabilities Law: N.J.S.A. 18A:35-4.35*:**
    - A transformative approach to the inclusion of lessons and resources/texts on the contributions and issues concerning the LGBTQ+ population and people with disabilities will be implemented across all core subjects in accordance with state law: "A board of education shall include instruction on the political, economic, and social contributions of persons with disabilities and lesbian, gay, bisexual, and transgender people, in an appropriate place in the curriculum of middle school and high school students as part of the district's implementation of the New Jersey Student Learning Standards (N.J.S.A.18A:35-4.36). A board of education shall have policies and procedures in place pertaining to the selection of instructional materials to implement the requirements of N.J.S.A. 18A:35-4.35."
8. ***Asian American and Pacific Legislation: N.J.S.A 4021/A6100:***
    - The inclusion of lessons and resources/texts on the history and contributions of Asian Americans and Pacific Islanders, will enable New Jersey's schools to provide a curriculum that reflects the diversity of our state. In accordance with state law: "A board of education shall include instruction on the history and contributions of Asian Americans and Pacific Islanders in an appropriate place in the curriculum of students in grades kindergarten through as part of the school district's implementation of the New Jersey Student Learning Standards in Social Studies."
9. Acquisition/development/refinement of the higher-order critical thinking skills aligned with the *Revised Bloom's Taxonomy of Cognitive Objectives*

Section III: Curriculum Modifications

The *AP Physics C Curriculum* is subject to case-by-case modifications to support/advance the needs of all students, including special education students, English language learners, gifted students and those at risk of school failure. These modifications are based on Individualized Learning Programs (IEPs), recommendations made by the district's English Language Learners (ELL) coordinator, feedback from members of the Intervention & Referral Services Team (*I&RS*) for at-risk students, and 504 Plans.

Coursework and assessments will be modified on an individual basis for students when necessary. Modifications may include but are not limited to:

- Small group instruction
- One on one instruction
- Independent work stations
- Use of graphic organizers
- Interest inventories and questionnaires
- Audio resources to complement written texts and concepts
- Visual resources to complement written texts and concepts
- Extra time on assessments and large scale projects
- Reduced length of written assignments
- Large projects broken into smaller tasks and timelines
- Tiered Instruction
- Individual help during practice
- Diagrams and color coding for visual learners
- Verbal and written directions for visual and auditory learners
- Provided class notes
- Preferential seating
- Spelling not penalized
- Varied supplemental activities
- Assessments delivered orally

Section IV: Preparation for Standardized Testing

Instruction in *AP Physics C* is aligned with the requirements of state and national standardized assessments, including the *NJSLA*, the *ACT*, the *PSAT* and the *SAT*.

Section V: Curriculum Pacing Guide

Curriculum Pacing Guide	
Course Title: *AP Physics C*	**Grade Level:** 12th Grade
Unit I: Kinematics	Weeks 1-2
Unit II: Newton's Laws of Motion	Weeks 3-4
Unit III: Work, Energy and Power	Weeks 5-6
Unit IV: Systems of Particles and Linear Momentum	Weeks 7-8
Unit V: Rotation	Weeks 9-11
Unit VI: Oscillations	Week 12
Unit VII: Gravitation	Weeks 13-14
Unit VIII: Electrostatics	Weeks 15-16
Unit IX: Gauss's Law	Weeks 17-18
Unit X: Electric Potential	Weeks 19-20
Unit XI: Capacitance	Weeks 21-22
Unit XII: Direct Current	Weeks 23-25

Unit XIII: Magnetism	Weeks 26-28
Unit XIV: Induction	Weeks 29-30
Unit XV: AP Review	Weeks 31-33
Unit XVI: End of Year Project	Weeks 34-40

Section VI: Technology Skills

Students in *AP Physics C* are required to complete the technology skills components of the curriculum:

- Collect raw data using technology
- Evaluate raw data
- Evaluate a graphical representation of raw data through the use of technology
- Analyze a graphical representation of raw data to determine relevance
- Evaluate multiple representations of data.
- Use data to make predictions.
- Operate a Vernier Interface
- Use probes and sensors correctly with the Vernier Interface

Section VII: Primary Texts and Year Long Instructional Resources

The following texts and instructional resources are employed in *AP Physics C*:

- *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition
- AP Classroom
- *Common Sense Education* (www.commonsense.org)

Section VIII: Grading Formula and Assessment Modes

Marking period grades in *AP Physics C* are determined via a percentage weighting model. The specific grading categories and weightings of each will be determined prior to the start of each academic year and will be published in the posted/distributed course syllabi.

Section IX: Unit Templates

The following unit templates have been established for the *AP Physics C* curriculum by the *AP Physics C* instructional team:

Unit I: Kinematics
Unit Summary
Unit I introduces students to kinematics—particularly one-dimensional, two-dimensional, and projectile motion. Students will not only learn how to define each kinematic quantity (position, velocity, acceleration, and time), but also learn how to distinguish between them, and how to graphically and mathematically represent the relationships among them. Kinematics serves as a foundation for various Physics principles and concepts, and in the units that follow, students are expected to call upon their knowledge of kinematic quantities to describe components of motion in a variety of scenarios.
Standards/Core Ideas/Performance Expectations
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C*: ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4

- HSN-QA.1 & 2
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
    - NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4,8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
    - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
    - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
• What are the appropriate expressions for velocity and acceleration in terms of position as a function of time for an object moving in one dimension? • How can you calculate the position as a function of time and velocity as a function of time for an object moving with a constant or a variable acceleration? • What are the appropriate expressions for velocity and acceleration in terms of position as a function of time for an object moving in two dimensions? • What are the appropriate expressions for the maximum height, time of flight, horizontal range of a projectile?	• The first derivative of position is velocity and the second derivative is acceleration. • Differential equations can be used to determine position and velocity equations. • Derivatives and vector algebra can be used to relate velocity and acceleration vectors to the position vector. • The equations of kinematics in two dimensions can be used to obtain maximum height, time of flight, and horizontal range of a projectile.

Evidence of Learning

Formative Assessment:	Summative Assessment:	Resources Needed:
• Classwork • Homework • Performance activities • Labs	• Quizzes on individual sections • Chapter test	• *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition • AP Classroom • Vernier probes and Software

Unit II: Newton's Law of Motion

Unit Summary

Unit II investigates Newton's Laws of Motion, which describe the relationship among moving objects and the forces acting on them. Students will learn how forces can change the motion of an object; about the relationship between force, mass, and motion; and why balanced forces become unbalanced. These laws form the foundation for classical mechanics, and in subsequent units, students will evolve their understanding by applying Newton's Laws of Motion to a variety of Physics principles, including the conservation of energy, rotation, simple harmonic motion, and the orbital motion of satellites.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
    - MP.2 & 4
    - HSN-QA.1-2
    - HS-PS2-1
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
    - NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4,8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
    - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
    - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
• When is an object in a state of equilibrium? • What are Newton's Laws of motion? • How can we calculate the acceleration of an object moving in one dimension when a single constant force (or a net constant	• An object is in a state of equilibrium when the net force on it is zero. • Newton's first law introduces the concept of a force, the second law relates acceleration to force and mass, and the third law states that forces always exist in action-reaction pairs. • The acceleration of an object is calculated using Newton's second law.

force) acts on the object during a known interval of time? ● How is the motion of a physical system consisting of one or more connected objects (such as the Atwood's Machine) described? ● What is the relationship between frictional force and the normal force for static and kinetic friction? ● How can we describe the direction of frictional forces (static or kinetic) acting on an object under various physical situations? ● How can we describe the acceleration, velocity, or position in relation to time for an object subject to a resistive force that is proportional to the velocity (directly or quadratically) (with different initial conditions, i.e., falling from rest or projected vertically)? ● How can we calculate the terminal velocity of an object moving vertically under the influence of a resistive force of a given relationship?	● The acceleration of a system consisting of multiple connected objects is obtained by first drawing free body diagrams for each of the objects, then relating the forces on each object to its acceleration, and then solving the system of equations. ● The force of friction (both static and kinetic) is directly proportional to the normal force. It also depends on the materials in the contact (coefficient of friction). ● The direction of friction can be determined by the relative motion between surfaces in kinetic frictional cases. In cases where the direction of friction is not obvious or is not directly evident from relative motion, then the net motion of the object and the other forces acting on the object are required to determine the direction of the frictional force. ● Newton's second law gives us a differential equation that relates the acceleration (rate of change of velocity) to the velocity. Upon solving this equation we can obtain the velocity as a function of time. This allows us to solve for the acceleration or the position as functions of time. ● The terminal velocity is defined as the maximum speed achieved by an object falling under the influence of a given drag force. The terminal condition is reached when the magnitude of the drag force is equal to the magnitude of the weight of the object.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Quizzes on individual sections ● Chapter test	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit III: Work, Energy, and Power
Unit Summary
In Unit III, students will explore the relationship between work, energy, and power and will be introduced to the principle of conservation as a foundational model of Physics, as well as the concept of work as an agent of change for energy. Students are not only expected to functionally define and calculate work, energy, and power, but must also be comfortable graphically and mathematically representing them. Understanding these relationships will help students make connections to other content presented in the course including the topic of climate change.
Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*
● *2020 New Jersey Student Learning Standards: Science*
    ○ MP.2 & 4
    ○ HSN-QA.1-2
    ○ HS-PS3-2
● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
    ○ NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,304,8-9
● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
    ○ 8.1.12.DA.5-6
● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
    ○ 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	**Unit Enduring Understandings**
● What is the work done by a given force on an object that undergoes a specified displacement? What kind of a quantity is it? Can it be negative or zero?	● The work done by a force on an object is the line integral of the component of the force in the direction of the displacement. Work is a scalar quantity and can be negative and also zero.

● How can we calculate a value for work done on an object from a force versus position graph? ● What is kinetic energy? Can it be negative or zero? ● How can we calculate the change in kinetic energy due to the work done on an object or a system by a single force or multiple forces? ● How can we compare conservative and dissipative forces? Or describe the role of a conservative force or a dissipative force in a dynamic system? ● How are potential energy and conservative forces related? ● What is a Hooke's Law or Ideal Spring? ● How can we derive the expression for the potential energy function of an ideal spring? Or derive an expression for the potential energy function of a nonideal spring that has a nonlinear relationship with position? ● How can we calculate the potential energy of a system consisting of an object in a uniform gravitational field? ● How can we derive an expression for the gravitational potential energy of a system consisting of a satellite or large mass (e.g., an asteroid) and the Earth at a great distance from the Earth? ● What is meant by the conservation of energy? ● What is mechanical energy and when is it conserved? ● How can we describe physical situations in which the total mechanical energy of an object in a system changes? ● How can we calculate unknown quantities (e.g., speed or positions of an object) that are in a conservative system of connected objects, such as the masses in an Atwood machine, masses connected with pulley/ string combinations, or the masses in a modified Atwood machine, or of an object under the influence of an ideal spring or of an object that is moving under the influence of some other nonconstant one-dimensional force? ● What is power? ● How can we calculate the amount of power required for an object to be raised vertically at a constant rate?	● The area under the curve of a force versus position graph is equivalent to the work done on the object or system. ● Kinetic energy is the energy of motion. It can be zero but cannot be negative. ● The net work done on an (point-like) object is equal to the object's change in the kinetic energy. (Work-Kinetic Energy Theorem) ● A force can be defined as a conservative force if the work done on an object by the force depends only on the initial and final position of the object. The work done by a conservative force will be zero if the object undergoes a displacement that completes a complete closed path. Common dissipative forces discussed in this course are friction, resistive forces, or externally applied forces from some object external to the system. ● The change in the potential is equal to the opposite of the work done by the work conservative force. The conservative force is the negative of the rate of change of the potential energy with position. ● An ideal spring exerts a linear restoring force when disturbed from its unstretched state. ● The potential energy stored in an ideal spring is proportional to the spring constant and the square of the change in its length from its unstretched state. The relation between potential energy and the force is used to obtain the potential energy stored in nonlinear springs. ● The gravitational potential energy near the surface of the Earth (uniform field) is the product of the mass, the acceleration due to gravity, and the height relative to a chosen reference point where the potential energy is zero. ● Using the relationship between the conservative force and potential energy, it can be shown that the gravitational potential energy of the object-Earth system is inversely proportional to the distance and proportional to the mass of each of the objects. ● The energy of a system can transform from one form to another without changing the total amount of energy in the system. ● Mechanical energy is the sum of the kinetic and potential energies of a system and is conserved in the absence of outside forces. ● When nonconservative forces are acting on the system, the work they do changes the total energy of the system. ● The application of the conservation of total mechanical energy is used to solve for unknown quantities such as speed or position in each of the cases described to the left. ● Power is the rate at which energy is transferred. ● For an object moving at a constant velocity, the power required is equal to the dot product of the force with the velocity.

Evidence of Learning

Formative Assessment:	Summative Assessment:	Resources Needed:
● Classwork ● Homework ● Performance activities	● Quizzes on individual sections ● Chapter test	● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit IV: Systems of Particles and Linear Momentum

Unit Summary
Unit IV introduces students to these factors through the concepts of center of mass, impulse and momentum, and the conservation of linear momentum. Students will learn the relationship between impulse and momentum via application or calculations. The conservation of linear momentum and how it's applied to collisions is also addressed. Unit IV offers a complete picture of the motion of a system, which is explored primarily through impulse and changes in momentum.

Standards/Core Ideas/Performance Expectations
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:* ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4 ○ HSN-QA.1-2 ○ HS-PS2-2 ● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12* ○ NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4,8-9 ● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking* ○ 8.1.12.DA.5-6 ● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills* ○ 9.4.12.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● Where is the center of mass of a system of point masses or a system of regular symmetrical objects located? ● How can we describe the motion of the center of the mass of a system for various situations? ● How do you explain the difference between the terms "center of gravity" and "center of mass," and identify physical situations when these terms have identical positions and when they have different positions? ● What is linear momentum of an object or a system of objects? ● What is the relationship between force and linear momentum? ● When is linear momentum conserved? ● What is impulse and how is it related to linear momentum? ● How can we describe relationships between a system of objects' individual momenta and the velocity of the center of mass of the system of objects? ● How can we calculate the momentum change in a collision using a force versus time graph for a collision? ● How can we calculate the change in momentum of an object given a nonlinear function, F(t), for a net force acting on the object? ● How can we calculate the velocity of one part of a system after an explosion or a collision of the system in one or two dimensions?	● A symmetrical, regular solid of uniform mass density has a center of mass at its geometric center. ● If there is no net force acting on an object or a system, the center of mass does not accelerate; therefore, the velocity of the center of mass remains unchanged. ● If the gravitational field is constant over a mass distribution then the center of gravity and center of mass coincide. Otherwise they do not. ● Linear momentum is the product of mass and velocity of an object. The total momentum of a system of objects is the vector sum of the momenta of the individual objects. ● The rate of change of momentum is equal to the external force. ● In the absence of external forces the linear momentum of a system is conserved. ● Impulse is the product of force and time and is equivalent to the change in the linear momentum of the object. ● A collection of objects with individual momenta can be described as one system with one center of mass velocity. ● Impulse is equivalent to the area under a force versus time graph. ● Momentum changes can be calculated by evaluating the integral of the force with respect to time. ● Linear momentum conservation can be used to calculate the velocity of a part of a system after an inelastic collision or an explosion. For an elastic collision, the conservation of linear momentum and kinetic energy can be used.

Evidence of Learning		
Formative Assessment: ● classwork ● homework ● performance activities	**Summative Assessment:** ● Quizzes on individual sections ● Chapter test	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit V: Rotation	
Unit Summary	
In this unit, students will investigate torque and rotational statics, kinematics, and dynamics, in addition to angular momentum and its conservation, to gain an in-depth and comprehensive understanding of rotation. Students are provided with opportunities to make connections between the content and models explored in the first four units, as well as with opportunities to demonstrate the analogy between translational and rotational kinematics. Unfortunately, when dealing with rotational motion, all the conceptual difficulties found in translational motion also have direct analogs.	
Standards/Core Ideas/Performance Expectations	
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:* ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4 ○ HSN-QA.1-2 ○ HS-PS2-2 ● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12* ○ NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4,8-9 ● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking* ○ 8.1.12.DA.5-6 ● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills* ○ 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3	
Unit Essential Questions	**Unit Enduring Understandings**
● How can we calculate the magnitude and direction of the net torque associated with a given force acting on a rigid body system? ● What are the two conditions of equilibrium for an extended object? ● How do we derive the moment of inertia of a system of point particles, a thin uniform rod about an arbitrary axis perpendicular to the rod, a thin cylindrical shell or disc? ● How do we derive the moments of inertia of an extended rigid body for different rotational axes (parallel to an axis that goes through the object's center of mass) if the moment of inertia is known about an axis through the object's center of mass? ● How can we calculate unknown quantities such as angular positions, displacement, angular speeds, or angular acceleration of a rigid body in uniformly or non-uniformly accelerated motion, given initial conditions? ● How are translational and rotational quantities related? ● What is the relationship between angular acceleration and torque? ● How can we describe the net torque experienced by a rigid extended body in situations such as, but not limited to, rolling down inclines, pulled along horizontal surfaces by external forces, a pulley system (with rotational inertia), simple pendulums, physical pendulums, and rotating bars? ● How can we derive expressions for physical systems such as Atwood machines, pulleys with rotational inertia, or strings connecting discs or strings	● Torque is the vector product of the moment arm with the force. The direction of the torque is obtained by the right-hand rule. ● The net force and the net torque are both zero for an extended object in equilibrium. ● For point particles the moment of inertia is the sum of the mass of the individual particle times the square of the distance of the particle from the axis. To calculate the moment of inertia of extended objects such as rods, rings, discs, etc. the above idea can be extended using calculus. ● The parallel axis theorem is used to calculate the moment of inertia of extended objects for different rotational axes that are parallel to the axis through the center of mass. ● The equations of angular kinematics are used to calculate the angular positions, angular speeds, or angular acceleration of objects that are rotating about a fixed axis. ● Displacement, velocity, and tangential acceleration are the product of the radius times the angular displacement, angular velocity, and the angular acceleration respectively. ● Angular acceleration is directly proportional to the net torque and is inversely proportional to the moment of inertia of the object. ● All real forces acting on an extended rigid body can be represented by a rigid body diagram. The point of application of each force can be indicated in the diagram.The rigid body diagram is used in applying the rotational Newton's second law to the rotating body. ● A complete analysis of a dynamic system that is rolling without slipping can be performed by applying both of Newton's second laws properly to the system. In addition the rotational quantities are related to the linear quantities (i.e. velocity is the radius times the angular velocity, etc).

connecting multiple pulleys that relate linear or translational motion characteristics to the angular motion characteristics of rigid bodies in the system that are rolling without slipping or rotating and sliding simultaneously? ● How can we calculate the rotational kinetic energy of an object that is purely rotating or is rolling? ● How can we calculate the work done on a rotating rigid body by a specified force over a specified angular displacement? ● How can we derive expressions using energy conservation principles for physical systems such as rolling bodies on inclines, Atwood machines, pendulums, physical pendulums, and systems with massive pulleys that relate linear or angular motion characteristics to initial conditions (such as height or position) or properties of rolling body (such as moment of inertia or mass)? ● How can we calculate the angular momentum of a rotating rigid body? ● How can we calculate the angular momentum vector of a linearly translating particle about a defined stationary point of reference? ● How are angular momentum and torque related? ● Under what conditions will the angular momentum be conserved? ● CHow can we calculate changes in angular velocity of a rotating rigid body when the moment of inertia of the body changes during the motion (such as a satellite in orbit, or a point mass particle has a collision with a rigid body, etc.)?	For the case of an object rotating and sliding simultaneously the rolling condition that relates translational and rotational quantities cannot be used. ● Rotational kinetic energy is one half times the product of the moment of inertia and the square of the angular velocity. For an object that is rolling the total kinetic energy is the sum of the rotational and translational kinetic energies. ● Work done on a rotating body is the product of the torque times the angular displacement. ● If a rigid body is defined as "rolling," this implies (in the ideal case) that the frictional force does not work on the rolling object. The consequence of this property is that in some special cases (such as a sphere rolling down an inclined surface), the conservation of mechanical energy can be applied to the system. ● Angular momentum of a rotating rigid body is the product of the moment of inertia and the angular velocity. ● The angular momentum of a linearly translating particle about a stationary point of reference is calculated using the cross product of the moment arm and the linear momentum of the particle. ● The rate of change of angular momentum is equal to the external torque. ● In the absence of external torques acting on a rotating body or system, the total angular momentum of the system is constant. ● The conservation of angular momentum can be applied to many types of physical situations. In all cases, it must be determined that there is no net external torque on the system.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Quizzes on individual sections ● Chapter test	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit VI: Oscillations

Unit Summary

Unit VI pays close attention to the type of motion we experience when we talk or listen to music. Through the concept of oscillations, students are introduced to the model of simple harmonic motion (SHM), springs, and pendulums. Students will discover why some objects repeat their motions with a regular pattern. They will also apply the model of SHM, define the three kinematic characteristics (displacement, velocity, and acceleration), and practice representing them graphically and mathematically. During their study of oscillations, students will gain a more in-depth understanding of motion, making them better equipped to apply their knowledge of forces and motion to waves.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4,8-9

- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
  - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● How can we describe the general behavior of a spring-mass system in SHM in qualitative terms? ● How are frequency and time period of the oscillations related? ● How can we describe each of the three kinematic characteristics of a spring-mass system in SHM in relation to time (displacement, velocity, and acceleration). Describe the general features of the motion. Identify the places where these values are zero or have maximum positive or negative values? ● How can we derive a differential equation to describe a spring-mass system in SHM or for the simple pendulum? ● How can we derive the expression for the period of oscillation for various physical systems oscillating in SHM? ● How can we describe the effects of changing the amplitude of a spring-mass system? ● How can we describe a relationship between the period of a system oscillating in SHM and physical constants of the system?	● The mass attached to a spring moves in a sinusoidal manner with respect to time. ● Frequency and time period are reciprocals of each other. ● Using calculus and the position in relation to time relationship for an object in SHM, all three kinematic characteristics can be explored. Recognizing the positions or times where the trigonometric functions have extrema or zeroes can provide more detail in qualitatively describing the behavior of the motion. ● Newton's law is used to show that the second derivative of the position is proportional to the opposite of the position. ● The period can be derived from the characteristic differential equation. The following types of SHM systems can be explored: a. Mass oscillating on spring in vertical orientation b. Mass oscillating on spring in horizontal orientation c. Mass-spring system with springs in series or parallel d. Simple pendulum e. Physical pendulum f. Torsional pendulum ● Total energy of a spring-mass system is proportional to the square of the amplitude and is therefore affected by the change in the amplitude. ● The square of the period of a mass-spring system is directly proportional to the mass and inversely proportional to the spring constant. ● The square of the period of a simple pendulum is directly proportional to the length and inversely proportional to the acceleration due to gravity.

Evidence of Learning

Formative Assessment:	Summative Assessment:	Resources Needed:
● Classwork ● Homework ● Performance activities	● Quizzes on individual sections ● Chapter test	● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit VII: Gravitation

Unit Summary

Unit VII investigates Newton's Laws of Gravity and the relationships shared between planets, satellites, and their orbits. Students will become familiar with the law of universal gravitation and how it can be applied to any pair of masses and will consider the motion of an object in orbit under the influence of gravitational forces. Additionally, students will be given opportunities to relate connected knowledge across units by applying and deriving Kepler's Laws of Planetary motion to circular or general orbits.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2
  - HS-PS2-4
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4, 8-9

- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
  - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● How can we calculate the magnitude of the gravitational force between two large spherically symmetrical masses? ● How can we calculate the value for g or gravitational acceleration on the surface of the Earth (or some other large planetary object) and at other points outside of the Earth? ● How can we describe the motion in a qualitative way of an object under the influence of a variable gravitational force, such as in the case where an object falls toward the Earth's surface when dropped from distances much larger than the Earth's radius? ● How can we calculate quantitative properties (such as period, speed, radius of orbit) of a satellite in circular orbit around a planetary object? ● What is Kepler's third law? ● How can we calculate the gravitational potential energy and the kinetic energy of a satellite/ Earth system in which the satellite is in circular orbit around the earth? ● What is the escape speed? ● How can we calculate positions, speeds, or energies of a satellite launched straight up from the planet's surface, or a satellite that is projected straight toward the planet's surface? ● How can we describe elliptical satellite orbits qualitatively? ● How can we calculate the orbital distances and velocities of a satellite in elliptical orbit?	● The magnitude of the gravitational force between two masses can be determined by using Newton's universal law of gravitation. ● The gravitational force between a planet and a particle divided by the mass of the particle is the gravitational acceleration due to the planet at the location of the particle. ● The gravitational force is proportional to the inverse of distance squared; therefore, the acceleration of an object under the influence of this type of force will be nonuniform. ● The centripetal force acting on a satellite is provided by the gravitational force between the two. The velocity of a satellite in circular orbit is inversely proportional to the square root of the radius and is independent of the satellite's mass. ● Kepler's third law states that the square of the period of a planet is proportional to the cube of its orbital radius. ● The gravitational potential energy of a satellite-Earth system is proportional to the masses of the two objects and inversely proportional to the distance between the two. ● Escape speed is the minimum speed required for an object to escape the gravitational field of a planet. It is proportional to the square root of the mass of the planet and the inverse square root of the initial distance from the planet. ● In ideal non orbiting cases, a satellite's physical characteristics of motion can be determined using the conservation of energy. ● Kepler's three laws are used to describe the orbits of satellites in general. ● The conservation of mechanical energy and the conservation of angular momentum can both be used to determine speeds at different positions in the elliptical orbit.

Evidence of Learning

Formative Assessment:	Summative Assessment:	Resources Needed:
● Classwork ● Homework ● Performance activities	● Quizzes on individual sections ● Chapter test	● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit VIII: Electrostatics (Forces and Fields)

Unit Summary

Students will begin the study of electric force, which acts on all objects with a property called charge. The electric force, in contrast to gravitational force, is one of attraction or repulsion and therefore leads to different effects on objects. This knowledge will help students understand the role electrostatics has in common devices such as photocopiers, defibrillators, and printers, as well as television, radio, and radar industries.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2

- HS-PS3-5
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4, 8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
  - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● How can we calculate the net electrostatic force on a single point charge due to other point charges? ● How can we determine the motion of a charged object of specified charge and mass under the influence of an electrostatic force? ● How can we describe and calculate the electric field due to a single point charge? ● How can we describe and calculate the electric field due to a dipole or a configuration of two or more static-point charges? ● How can we explain or interpret an electric field diagram of a system of charges? ● How do we sketch an electric-field diagram of a single point charge, a dipole, or a collection of static-point charges? ● What is the electric field due to a uniformly charged ring along the axis of the ring, a semicircular ring or part of a semicircular arc, a finite wire or line charge at a distance that is collinear with the line charge?	● The magnitude of electrostatic force between two point charges is given by Coulomb's Law. The net force is determined by superposition of all forces acting on a point charge due to the vector sum of other point charges. ● The motion of the object (characteristics such as the acceleration, velocity, trajectory of the object) is determined from the force acting on the charged particle and the initial conditions of the charged particle (such as its velocity). ● The electric field of a single point charge is the electrostatic force due to the point charge on a test charge divided by the test charge. ● The electric field, due to a configuration of static-point charges, is determined by applying the definition of electric field and the principle of superposition using the vector nature of the fields. ● Electric field lines have properties that show the relative magnitude of the electric field strength and the direction of the electric field vector at any position in the diagram ● Using the properties of electric field diagrams, a general field line diagram will be drawn for static-charged situations. ● The electric field of any charge distribution is determined using the principle of superposition, symmetry, and the definition of electric field due to a differential charge dq, evaluated via integration over appropriate limits.

Evidence of Learning

Formative Assessment:	Summative Assessment:	Resources Needed:
● Classwork ● Homework ● Performance activities	● Quizzes on individual sections ● Chapter test	● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit IX: Electrostatics (Gauss's Law)

Unit Summary

Students will describe Gauss's law and an alternative procedure for calculating electric fields. Gauss's law is based on the inverse square behavior of the electric force between point charges. Although Gauss's law is a direct consequence of Coulomb's law, it is more convenient for calculating the electric fields of highly symmetric charge distributions and makes it possible to deal with complicated problems using qualitative reasoning. Gauss's law is important in understanding and verifying the properties of conductors in electrostatic equilibrium.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2
  - HS-PS2-4
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1&W4, RST.11-12.1,3-4,8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*

- 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
• How can we calculate the electric flux through an arbitrary area or through a geometric shape? (e.g., cylinder, sphere). • How can we qualitatively apply Gauss's Law to a system of charges or charged region to determine characteristics of the electric field, flux, or charge contained in the system? • How can we use Gauss's Law in integral form to derive unknown electric fields for planar, spherical, or cylindrically symmetrical charge distributions? • How can we describe the general features of an unknown charge distribution, given other features of the system? • How can we calculate the electric field in the vicinity of a conductor?	• The flux through a geometric closed surface is defined by the surface integral of the normal component of the electric field to the surface. • The total flux through a closed Gaussian surface is proportional to the charge enclosed by the Gaussian surface and is independent of the size of the Gaussian shape. • The electric field is calculated by drawing an appropriate Gaussian surface, calculating the flux through the surface, calculating the total charge contained within the surface, and using Gauss's Law. • The amount of charge contained within a symmetrical region is proportional to the flux through that region. • The electric field inside a conductor in electrostatic equilibrium is zero, and just outside the conductor the electric field is proportional to the surface charge density and is perpendicular to the surface.

Evidence of Learning

Formative Assessment:	**Summative Assessment:**	**Resources Needed:**
• Classwork • Homework • Performance activities	• Quizzes on individual sections • Chapter test	• *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition • AP Classroom • Vernier Probes and Software

Unit X: Electrostatics - Electric Potential

Unit Summary

Students will use the concept of potential energy to study electrical phenomena. Because the electrostatic force is conservative, electrostatic phenomena can be conveniently described in terms of an electric potential energy. This idea enables us to define a quantity known as electric potential. Because the electric potential at any point in an electric field is a scalar quantity, we can use it to describe electrostatic phenomena more simply than if we were to rely only on the electric field and electric forces. The concept of electric potential is of great practical value in the operation of electric circuits and devices

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2
  - HS-PS2-4
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
  - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
• Is the electrostatic force conservative? • What is the electric potential difference between two points in an electric field?	• The conservative nature of the electric force is proved by showing that the work done by the electrostatic force is independent of the path between two points.

• What is the electric potential in the vicinity of a point charge? • What is the electrostatic potential energy of a collection of two or more point charges held in a static configuration? • What is the work done when a charged particle moves through some known potential difference? • How can we describe the relative magnitude and direction of an electrostatic field given a diagram of equipotential lines? • What is the electric potential due to a uniformly charged wire, a thin ring (along the axis), a semicircular arc or part of a semicircular arc, a uniformly charged disk? • What is the electric potential due to a symmetrical object such as a sphere, an infinite line charge, or an infinite plane of charge? • What is the potential inside a conductor?	• The electric potential difference between two points is the change in the electric potential energy between the two points per unit charge. • Near a point charge the electric potential is proportional to the charge and is inversely proportional to the distance from the charge. • Between two charges the electrostatic potential energy is proportional to the product of the two charges and inversely proportional to the distance between the charges. To calculate the electrostatic potential energy for more than two charges, sum up the potential energies for every pair of charges within the system. • The work done on a charged particle is the product of the charge and the potential difference. • The relative magnitude of an electric field is determined by the gradient of the potential lines. The direction of the electric field is defined to be perpendicular to an equipotential line and pointing in the direction of the decreasing potential. • The electric potential due a charge distribution is calculated by first finding the potential due to a differential charge and then integrating over the entire charge distribution. • The electric potential due to symmetric objects is found by first applying Gauss's Law to determine the electric field near the distribution and then calculate the electric potential, since the electric potential difference is equal to the negative of the line integral of the electric field. • The potential inside a conductor is constant and equal to the value of the potential at the surface.

Evidence of Learning		
Formative Assessment: • Classwork • Homework • Performance activities	**Summative Assessment:** • Quizzes on individual sections • Chapter test	**Resources Needed:** • *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition • AP Classroom • Vernier Probes and Software

Unit XI: Capacitance

Unit Summary

Students will examine how an electric charge can move through an object. Conductors, capacitors, and dielectrics are presented to demonstrate that a charge's movement is dependent on an object's material. In electronics, each of these are important based on the type of movement or desired object behavior. Additionally, this unit examines how the behavior of these elements is impacted by electric fields. Knowledge of conductors, capacitors, and dielectrics will prepare students for understanding how electric circuits work and how they behave when one or more electrical elements are altered or modified.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
  - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings

● What is the capacitance of a capacitor? ● How much energy is stored in a capacitor? ● What is the capacitance of a parallel-plate capacitor? ● How is the electric field oriented between the plates of a parallel plate capacitor and what does it depend on? ● What changes occur in a capacitor when a conduction slab is inserted between the plates or when the conducting plates are moved closer or farther apart? ● What is the capacitance of a cylindrical or spherical capacitor? ● How does the capacitance of a capacitor change when a dielectric is inserted between the plates?	● The capacitance is directly proportional to the charge stored and is inversely proportional to the potential difference between the two plates of a capacitor. ● The amount of energy stored in a capacitor is proportional to the capacitance and the square of the potential difference. ● The capacitance of a parallel plate capacitance is directly proportional to the area of the plates and is inversely proportional to the distance between the plates. ● The electric field between the plates of a parallel plate capacitor is uniform and points from the positive plate to the negative plate. The electric field is proportional to the surface charge density of the charge on one plate. ● The charged-capacitor system will have different conserved quantities depending on the initial conditions or conditions of the capacitor. If the capacitor remains attached to a source of a potential difference, then the charge in the system can change in accordance with the changes to the system. If the capacitor is isolated and unattached to a potential source, then the charge in the capacitor system remains constant and other physical quantities can change in response to changes in the physical system. ● The capacitance in general depends on the geometry of the capacitor. ● The capacitance of a capacitor is directly proportional to the dielectric constant of the material inserted between the plates.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Quizzes on individual sections ● Chapter test	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit XII: Direct Current

Unit Summary

This unit serves to illuminate how, and why, our various appliances function by exploring the nature and importance of electric currents, circuits, and resistance. Through activities and lab investigations, students will have opportunities to relate knowledge across the course by using the electrical components they learned about in prior units and will come to discover how to create, modify, and analyze circuits. Students will also analyze the relationships that exist between current, resistance, and power, in addition to exploring and applying Ohm's Law and Kirchhoff's Rules.

Standards/Core Ideas/Performance Expectations

The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:*

- *2020 New Jersey Student Learning Standards: Science*
  - MP.2 & 4
  - HSN-QA.1-2
  - HS-PS3-5
- *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12*
  - NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9
- *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking*
  - 8.1.12.DA.5-6
- *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills*
  - 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● What is an electric currency and in which direction does it flow? ● What is Ohm's Law? ● What quantities affect the resistance of a conductor?	● The electric current is the rate of flow of charge and the conventional current is defined as the direction of positive charge flow. ● Ohm's Law states that the current is directly proportional to the potential difference and inversely proportional to the resistance.

● What does the electric field inside a conductor with an electric current depend on? ● What microscopic quantities does the electric current within a conductor depend on? ● At what rate is heat produced in a resistor? ● What is the difference between series and parallel arrangement of resistors? ● What is the equivalent resistance for a network of resistors that can be considered a combination of series and parallel arrangements? ● What are Kirchoff's Rules? ● How can we describe the proper use of an ammeter and a voltmeter in an experimental circuit and correctly demonstrate or identify these methods in a circuit diagram? ● What is the equivalent capacitance for capacitors arranged in series or parallel? ● How can we calculate the potential difference across a capacitor in a circuit arrangement containing capacitors, resistors, and an energy source under steady-state conditions? ● In transient circuit conditions (i.e., RC circuits), how can we calculate the time constant of a circuit containing resistors and capacitors arranged in series? ● How can we derive expressions to describe the time dependence of the stored charge or potential difference across the capacitor, or the current or potential difference across the resistor in an RC circuit when charging or discharging a capacitor? ● How can we describe stored charge or potential difference across a capacitor or current, or potential difference of a resistor in a transient RC circuit? ● How can we describe the energy transfer in charging or discharging a capacitor in an RC circuit?	● The resistance is directly proportional to the length of the conductor and the resistivity of the material, and inversely proportional to the area of cross section of the conductor. ● The electric field inside a conductor is proportional to the current density within the conductor and the resistivity of the conductor. ● The current in a conductor depends on the number of charge carriers per volume, the charge of the electron, the cross-sectional area, and the drift velocity of the electrons. ● Heat produced in a resistor depends on the potential difference across the resistor and the current through it. ● In a series arrangement the resistors are arranged one after the other, creating one possible branch of charge flow. In a parallel arrangement, the resistors are attached to the same two points creating multiple pathways for the current. ● For a series arrangement the effective resistance is the sum of the individual resistances. For a parallel arrangement the reciprocal of the effective resistance is the sum of the reciprocals of the individual resistances. ● At any junction, the sum of the currents must equal zero, the sum of the potential differences across all elements around any closed circuit loop must be zero. ● An ammeter is connected in series within the branch, a voltmeter is connected in parallel with the circuit element. ● The equivalent capacitance of capacitors arranged in parallel is the sum of the individual capacitances. For a series arrangement, the reciprocal of the equivalent capacitance is the sum of the reciprocal of the individual capacitances. ● When a circuit containing resistors and capacitors reaches a steady-state condition, the potential difference across the capacitor is determined using Kirchhoff's Rules. ● Under transient conditions for t = 0 to t = steady-state conditions, the time constant in an RC circuit is equal to the product of equivalent resistance and the equivalent capacitance. ● Using Kirchoff's Laws and calculus the stored charge or the potential difference across a capacitor is calculated. ● The capacitor in a circuit behaves as a bare wire with zero resistance at a time immediately after t=0 seconds, and behaves as an open circuit or having an infinite resistance when the circuit reaches its steady state. ● The total energy provided by the energy source (battery) that is transferred into an RC circuit during the charging process is split between the capacitor and the resistor.

Evidence of Learning

Formative Assessment:	**Summative Assessment:**	**Resources Needed:**
● Classwork ● Homework ● Performance activities	● Quizzes on individual sections ● Chapter test	● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit XIII: Magnetism

Unit Summary

This unit introduces students to magnetism and how magnetic fields are generated, behave, and relate to electricity. Students will learn how magnetic fields impact motion and interact with other magnetic fields. The knowledge from

previous units helps students to make connections between electric fields and magnetic fields as well as between Gauss's Law and Ampère's Law.
Standards/Core Ideas/Performance Expectations
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:* ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4 ○ HSN-QA.1-2 ○ HS-PS2-5 ○ HS-PS3-5 ● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12* ○ NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9 ● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking* ○ 8.1.12.DA.5-6 ● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills* ○ 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	**Unit Enduring Understandings**
● How can we calculate the magnitude and direction of the magnetic force of interaction on a moving charged particle in a region of uniform magnetic field? ● Under what conditions will a charged particle experience no force due to a magnetic field? ● How can we describe the path of different moving charged particles (i.e., of different type of charge or mass) in a uniform magnetic field? ● How do we explain why the magnetic force acting on a moving charge particle does not work on the moving charged particle? ● How can we describe the conditions under which a moving charged particle can move through a region of crossed electric and magnetic fields with a constant velocity? ● What is the magnitude and the direction of the magnetic force acting on a straight-line segment of a conductor with current in a uniform magnetic field? ● How can we describe or indicate the direction of magnetic forces acting on a complete conductive loop with current in a region of uniform magnetic field? ● How can we calculate the magnitude and direction of a magnetic field produced at a point near a long, straight, current carrying wire? ● How can we describe the direction of a magnetic-field vector at various points near multiple long, straight, current carrying wires? ● How can we determine the magnitude and the direction of the force of interaction	● The magnitude of the magnetic force is given by the cross product of the velocity and the magnetic field multiplied by the charge of the particle. The direction of the force is given by the right-hand rule. ● If the charged particle is stationary relative to the magnetic field and or if the velocity of the particle is parallel with the magnetic field then the charged particle will not interact with the magnetic field. ● The direction of the magnetic force is always in a direction perpendicular to the velocity of the moving charged particle. This results in a trajectory that is either a curved path or a complete circular path (if it moves in the field for a long enough time). ● The magnetic force is always perpendicular with the velocity of the particle and therefore does zero work. ● In a region containing both a magnetic field and an electric field, a moving charged particle will experience two different forces independent from each other. Depending on the physical parameters, it is possible for each force to be equal in magnitude and opposite in direction, thus producing a net force of zero on the moving charged particle. ● The magnitude of the magnetic force on a current carrying conductor is equal to the current times the cross product of the length of the conductor and the field, and the direction is given by the right-hand rule. ● The magnetic force on a conductive loop is always zero, however a net torque may be exerted depending on the orientation of the loop and the field. ● The magnetic field around a long, straight, current carrying conductor is calculated using Biot-Savart's Law and is directly proportional to the current and inversely proportional to the distance from the conductor. The field lines form circles around the conductor. ● The principle of superposition is used to determine the net magnetic field at a point due to multiple long, straight, current-carrying wires. ● Two long, straight, current carrying conductors attract each other when the currents are pointing in the same direction, and repel each other when the currents are in the opposite direction. The magnitude of the force is directly proportional to the currents and inversely proportional to the distance between them.

between two long, straight, current carrying conductors? ● What is the magnitude of the magnetic field on the axis of a circular loop of current or a segment of a circular loop? ● What is Ampere's Law? ● What is Ampere's law used for?	● The magnetic field on the axis of a circular loop of current is proportional to the current and also depends on the distance from the loop. ● Ampere's law states that the line integral of the magnetic field around a closed loop (Amperian loop) is proportional to the amount of current that passes through that loop. ● Ampere's law is used to calculate the magnetic field around current carrying conductors with symmetry, such as a long, straight conductor, a solenoid, a toroid, long cylindrical conductors, etc.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Quizzes on individual sections ● Chapter test	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit XIV: Induction
Unit Summary
This unit examines electromagnetism through the concept of electromagnetic induction and the application of Maxwell's equations. Through activities and detailed laboratory investigations, students will study, apply, and analyze the concept of induction, as well as investigate the relationship between Faraday's Law and Lenz's Law. Additionally, students are expected to call upon their knowledge obtained in earlier units—particularly that of charges, currents, and electric and magnetic fields—to better understand Maxwell's equations and to be able to mathematically demonstrate, as well as reason with, how these fields are generated.
Standards/Core Ideas/Performance Expectations
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:* ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4 ○ HSN-QA.1-2 ○ HS-PS2-5 ● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12* ○ NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9 ● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking* ○ 8.1.12.DA.5-6 ● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills* ○ 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings

● What is the magnetic flux through a loop of regular shape? ● When will an EMF be induced in a conducting loop? What is the direction of the current? ● What can cause the magnetic flux through a conducting loop to change? ● What is motional EMF? What physical quantities is it dependent on? ● What is self-induction? ● What does the self induced emf depend on? ● What does inductance of a solenoid depend on? ● How can we calculate the initial transient currents and final steady state currents through any part of a series or parallel circuit containing an inductor and one or more resistors? ● What is the maximum current in a circuit that contains only a charged capacitor and an inductor? ● How do you calculate the current through a simple RL circuit as a function of time? ● What are Maxwell's equations?	● Magnetic flux is the scalar product of the magnetic-field vector and the area vector over the entire area contained by the loop. ● An EMF is induced in a conducting loop if the magnetic flux associated with the loop changes. The direction of the current is given by Lenz's Law. ● The magnetic flux is changed by changing the magnetic field, or the area of the loop, or the orientation of the loop relative to the magnetic field. ● Motion EMF is the EMF induced in a conductor when it moves through a magnetic field and it depends on the strength of the field, the length of the conductor, and the speed. ● The emf induced in a loop due to the changing current in the loop is called self induced emf or self induction. ● Self induced emf depends on the rate of change of current and the geometry of the loop, which is contained within the quantity called inductance. ● Inductance of solenoid depends on the number of coils, the area of cross-section of the solenoid, and the length of the solenoid. ● At the initial condition of closing or opening a switch with an inductor in a circuit, the induced voltage will be equal in magnitude and opposite in direction of the applied voltage across the branch containing the inductor. In the steady state condition, the ideal inductor has zero resistance and therefore will behave as a bare wire in a circuit. ● In circuits containing only a charged capacitor and an inductor, the maximum current through the inductor can be determined by applying conservation of energy within the circuit and the two circuit elements that can store energy. ● Kirchoff's rules can be applied to a RL circuit to obtain a differential equation that relates the rate of change of the current to the resistance and the inductance. This equation is then solved to obtain the current as a function of time. ● Maxwell's equations are the most important equations of classical electrodynamics that relate the magnetic and electric fields in steady state conditions as well as in situations in which the fields change in time.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Quizzes on individual sections ● Chapter test	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit XV: AP Review
Unit Summary
AP Review is a short, focused unit that concentrates on the *AP Physics C Examination*. Students will utilize course materials and released AP Physics C Examinations as resources during Unit XV: AP Review.
Standards/Core Ideas/Performance Expectations
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in *AP Physics C:* ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4 ○ HSN-QA.1-2 ○ HS-PS2-1-2, 4-5 ○ HS-PS3-1-2 & 5 ● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12* ○ NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9 ● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking* ○ 8.1.12.DA.5-6 ● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills* ○ 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● What can I expect to encounter on the AP exam? ● What are my personal strengths and weaknesses as we approach the AP exam?	● The exam consists of 35 multiple choice questions in 45 minutes and 3 FRQ in 45 minutes. ● Targeted practice will help students remediate any concepts or skills in need of remediation. Students will evaluate their own personal needs to answer this question.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Released AP Questions	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Unit XVI: Project
Unit Summary
Students will research a topic of their choosing in the field of science or engineering and will prepare a presentation to share with their class.
Standards/Core Ideas/Performance Expectations
The state standards outlined below, and established by New Jersey Department of Education, will guide instruction throughout this unit in AP Physics C: ● *2020 New Jersey Student Learning Standards: Science* ○ MP.2 & 4 ○ HSN-QA.1-2 ○ HS-PS2-1-2, 4-5 ○ HS-PS3-1- 2 & 5 ● *2016 New Jersey Student Learning Standards: English Language Arts Companions for Grades 11-12* ○ NJSLSA.R7, NJSLSA.W1 & W4, RST.11-12.1, 3-4, 8-9 ● *2020 New Jersey Student Learning Standards: Computer Science and Design Thinking* ○ 8.1.12.DA.5-6 ● *2020 New Jersey Student Learning Standards: Career Readiness, Life Literacies and Key Skills* ○ 9.4.2.CI.1-3, 9.4.12.CT.1-2, 9.4.12.TL.3

Unit Essential Questions	Unit Enduring Understandings
● What field of science or engineering does the student find interesting?	● Students will pick a topic that they find interesting and will explore it further.

Evidence of Learning		
Formative Assessment: ● Classwork ● Homework ● Performance activities	**Summative Assessment:** ● Final project	**Resources Needed:** ● *Physics for Scientists and Engineers* by Raymond A. Serway & James W. Jewett, 10th Edition ● AP Classroom ● Vernier Probes and Software

Section X: Unit Reflection

The *AP Physics C* instructional team must confer upon the completion of each instructional unit in the *AP Physics C* curriculum and rate the degrees to which the instructional units meet performance criteria established by the New Jersey Department of Education using the Unit Reflection Form. Completed unit reflection forms must be submitted to the Department Supervisor for approval upon completion of curriculum implementation with a complementing list of suggested modifications to the *AP Physics C* curriculum.

Unit Reflection Form: *AP Physics C*			
Lesson Activities:	**Strongly**	**Moderately**	**Weakly**
Foster student use of technology as a tool to develop critical thinking, creativity and innovation skills;			

Are challenging and require higher order thinking and problem-solving skills;			
Allow for student choice;			
Provide scaffolding for acquiring targeted knowledge/skills;			
Integrate modern, global perspectives, especially those regarding diversity, genocide, global issues, and historical ones regarding racial relations;			
Integrate 21st century skills;			
Provide opportunities for interdisciplinary connection and transfer of knowledge and skills;			
Are varied to address different student learning styles and preferences;			
Are differentiated based on student needs;			
Are student-centered with teacher acting as a facilitator and co-learner during the teaching and learning process;			
Provide means for students to demonstrate knowledge and skills and progress in meeting learning goals and objectives;			
Provide opportunities for student reflection and self-assessment;			
Provide data to inform and adjust instruction to better meet the varying needs of learners.			

Appendix
Writing Instruction and the RFH Community

Writing instruction should happen across the RFH Community. Writing across the curriculum is a philosophy that advances the belief that writing is a method of learning. Since all departments are committed to helping students learn, writing must be used as a methodology to advance student learning.

Each academic discipline has its own unique conventions, formats and structures. It is the responsibility of each department to agree upon domain-specific writing praxes, model them for students, and require them to utilize them on a consistent basis. Students must understand that acceptable writing in one domain may not be acceptable writing in another area. The development of domain-specific writing skills supports the overall development of the student writer because all writing is grounded in the writing situation: audience, context, purpose, subject, and writer. Representatives from the academic disciplines must share their domain-specific writing praxes with each other, identify intersections, and determine how to address perceived gaps that limit student learning.

Students must experience writing situations that help them learn how to think creatively and critically and communicate effectively in the academic disciplines. Writing instruction, regardless of the academic discipline, must always reinforce student understanding of the writing situation. When students experience writing situations, they must study examples of domain-specific writing in order to understand how writers communicate in discipline-related contexts. This does not mean information embedded in textbooks. Domain-specific writing is writing that is used to inform and influence readers as it draws them into an established circle of discourse. Students must use these non-fiction texts to develop the close reading skills that will shape their own writing. Focused engagement with domain-specific writing should not be limited to basic reading comprehension and topical understanding. It must also include the analysis of the writing situation that is represented in the text: audience, context, purpose, subject, and writer. The close reading of well-written texts—regardless of the domain—will show students the importance of writing mechanics, diction, and syntax. The development of close reading skills will also help the students grow in terms of their ability to construct and advance independent and original claims that are well-supported by evidence. Domain-specific writing is grounded in positioning of claims and the effective use of evidence.

The final written product is important; nevertheless, the learning that results in this production must not be devalued. The writing process is not limited to the basic steps of planning, drafting, revising, and editing/proofreading. It is a complex sequence of critical and creative thinking and writing that leads to the production of a text that provides evidence of learning and understanding. Students must ultimately develop the ability to self-assess the effectiveness of their writing as a representation of the writing situation. Without the use of models that evidence learning and understanding, students will not develop the ability to self-assess their own work—the true outcome of the writing process.

What types of writing situations should RFH students engage in?

RFH students should engage in writing situations across the curriculum that require them to:

- write to improve mechanical proficiency, diction usage, and syntactical sophistication
- write to narrate, describe, and reflect
- write to summarize and report
- write to classify and define
- write to explain how process leads to an outcome
- write to compare, contrast and evaluate
- write to speculate on cause and effect
- write to propose solutions and solve problems
- write to analyze

These writing situations should be positioned in a coordinated, developmental sequence that extends across the academic disciplines.

Upon Completion of Grade 12, RFH students must be ready to transition to the following writing situations:

- write to analyze
- write to persuade (argument)

The core focus of first-year college writing courses are analysis and argument. These courses orient the students to the demands and expectations of writing for the academic culture of college. At colleges/universities with carefully coordinated writing programs, students must demonstrate proficiency in analysis and argument before they transition to upper level courses that require them to engage in the following writing situation:

- write to investigate (research)