Washington Township School District

***The mission of the Washington Township Public Schools** is to provide a safe, positive, and progressive educational environment that provides opportunity for all students to attain the knowledge and skills specified in the NJ Learning Standards at all grade levels, so as to ensure their full participation in an ever-changing world as responsible, self-directed and civic-minded citizens.*

Course Title:	**Advanced Placement Physics 1**
Grade Level(s):	**11-12**

Duration:	*Full Year:*	**x**	*Semester:*		*Marking Period:*	

Course Description:	Advanced Placement (AP) Physics 1 is intended to provide a strong introductory physics experience equivalent to a first course in algebra-based physics at the college level. It also provides students with instruction that will prepare them for the College Board's AP Physics 1 Exam in May. To meet the AP Audit requirements of College Board, in addition to presentation of the required topics, 25 percent of the instructional time [will] be spent in hands-on laboratory work, with an emphasis on inquiry-based investigations that provide students with opportunities to demonstrate the foundational physics principles and apply all seven science practices defined in the course framework. (College Board, 2017) Additionally, the course can be used as part of the High School Plus Program, through which students may earn a semester of credit for Algebra-based Physics 1 at Camden County College. The topics that will be presented and investigated are: 1- and 2- dimensional kinematics, Newton's Laws and forces (dynamics), circular motion and gravitation, momentum, energy, rotational mechanics, electrical charge, electrical forces, electrical fields, basic circuits, concepts in electromagnetism*, mechanical waves and sound, and optics*. Additionally, topics in thermodynamics and fluid dynamics will be investigated. These topics exceed those required by College Board and include those required by the High School Plus program. *These topics are required neither by College Board or High School Plus, and their inclusion will be dictated by time constraints. It is important to recognize that all the material to be assessed by the AP Physics 1 Exam must be completed by mid-April and reviewed prior to the exam. Because seniors typically comprise about half of the enrollment for the course, the timeline before May is impacted by the Senior trip. During the 2 weeks of AP Exams, many of the students (both juniors and seniors) miss multiple days to take multiple exams, which further limits our post-exam timeline.
Grading Procedures:	Tests: 50% Quizzes: 15% Lab Work & Projects: 25% Independent Work & Problem Solving: 10%

Primary Resources:	**College Board AP Physics 1 Course & Exam Description** **(https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-physics-1-course-and-exam-description.pdf)** **NGSS & New Jersey Student Learning Standards (NJSLS)** **College Physics, Etkina, et. al.** **TIPERs: Sense-making Tasks for Introductory Physics, Hieggelke, et. al.**

Washington Township Principles for Effective Teaching and Learning

- Implementing a standards-based curriculum
- Facilitating a learner-centered environment
- Using academic target language and providing comprehensible instruction
- Adapting and using age-appropriate authentic materials
- Providing performance-based assessment experiences
- Infusing 21st century skills for College and Career Readiness in a global society

Designed by:	Shannon Hornibrook
Under the Direction of:	Dr. Patricia Hughes

Written: ___________________________________

Revised: ___________________________________

BOE Approval: ______________________________

Unit Title: Kinematics (1 and 2 Dimensional)

Unit Description: In this unit, students will explore one and two-dimensional motion, and the forces that cause changes in motion. They will use a variety of inquiry methods that include, but are not limited to, student designed laboratory investigations and video analysis of different types of motion, leading to the development of multiple representations of the systems that they are studying. These representations include motion diagrams, graphs, mathematical models, and oral descriptions. *Note: Students begin the first unit over the summer, via the summer assignment.*

Unit Duration: 3 weeks

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 3: The interaction of an object with other objects can be described by forces.
    - All forces share certain common characteristics when considered by observers in inertial reference frames. (3.A)
- Big Idea 4: Interactions between systems can result in changes in those systems.
    - The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma\vec{F}}{m}$. (4.A)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS

- Motion and Stability: Forces and Interactions (HS-PS2)
- Engineering Design (HS-ETS1)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed and acceleration. (3.A.1)
- The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. (4.A.1)
- The acceleration of a system is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time. (4.A.2)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2.A)
- Engineering Design: Optimizing the Design Solution (HS-ETS1.C)
- Engineering Design: Developing Possible Solutions (HS-ETS1.B)

Understandings:	**Essential Questions:**
Students will understand that… • Motion requires that an object's position has changed. • A vector quantity has both a magnitude and a direction, while a scalar has only a magnitude. • Depending on the reference frame, a vector may be broken down into components.	• What is a scientific model? • What is motion? • What is a reference frame, and how does the choice of reference frame influence the observer's? description of motion? • What is an inertial reference frame?

• Vectors may be added and subtracted using vector math operations. • Motion is changed by the action of net external force, and the result is acceleration. * • When the net external force on an object is zero, it will experience no acceleration. * • An object does not require the action of a force to maintain its state of motion. * • When an object experiences an acceleration in the same direction of its velocity, it will speed up. • When an object experiences an acceleration in the opposite direction of its velocity, it will slow down. • Using the equations of kinematics, one can predict the behavior of an object. • An object in free fall is under the influence of only the force of gravity, its acceleration is vertical, and has the magnitude ***g***. • Graphs of position vs time and velocity vs time contain information about the behavior of an object and can be used to generate mathematical models of its motion. • Every experimental measurement includes uncertainty; correct reporting of results must include the uncertainty in order to convey the meaning of the results. • The vertical and horizontal components of projectile motion are independent of one another. • The range of a projectile depends on the launch angle, launch speed, and total vertical displacement, as well as the gravitational field strength in the location being assessed. *The concepts underlying these understandings are introduced briefly in earlier grades and relevant here; they will be investigated thoroughly in the next unit.	• How can motion be described with vector and scalar quantities? • How can motion be represented pictorially? • What *is* acceleration? • What experimental methods can be used to analyze accelerated motion? • What mathematical models can be developed from the analysis of motion? • How can graphical analysis of motion be used to glean information about the motion? • How can the equations of motion be used to predict the behavior of a particle or body? • What role does uncertainty in measurement play in analysis of experimentally derived data? • What factors affect the motion of an object moving vertically in Earth's gravitational field? • What kind of mathematical relationship exists between the displacement of a freefalling body and the time it spends in freefall? • How does projectile motion look in displacement-time graphs and velocity-time graphs?

Assessment Evidence

Performance Tasks: **APP1 Learning Objectives: (The student is able to…)** (Johnson, 2017) • express the motion of an object using narrative, mathematical, and graphical representations (3.A.1.1) • design an experimental investigation of the emotion of an object (3.A.1.2) • analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations (3.A.1.3) • use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi quantitatively (4.A.1.1) • make predictions about the motion of a system based on the fact that acceleration is equal to the	**Other Evidence:** Summer Assignment: • Students are introduced to the basic concepts of kinematics (position, distance, displacement, speed and velocity) as well as the use of Vernier Video Analysis (Logger Pro™) in the summer assignment, which is due the first day of school. • The summer assignment also includes a brief assessment of algebraic manipulation skills, sine, cosine and tangent, and inverse trigonometric functions. Graphical skills are also assessed. Daily informal and formal formative assessments of student activities, such as: • Warm up problems/questions • Whiteboarding/problem solving sessions • Peer tutoring

change in velocity per unit time, and velocity is equal to the change in position per unit time (4.A.2.1) • create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system (4.A.2.3) **Other:** • Recognize and/or define the following terminology related to the analysis of motion: reference frame, system, center of mass, scalar, vector, position, distance, displacement, speed, velocity, acceleration, force, slope, derivative (in reference to slope), integral (in reference to area under a curve), freefall, terminal speed, projectile, range • Use video analysis to investigate and mathematically model the motion of a system. • Determine an unknown quantity within a system in the lab by analyzing the system, using relevant measurements and calculations. • Calculate the components of a vector. • Describe the conditions of projectile motion. • Develop and apply an algorithm for the position of a projectile. (*Note: At the AP 1 level, students should be able to solve for initial launch angles.)* • Design and conduct an experiment or set of experiments that can be used to predict the vertical and horizontal position of a projectile for a specified target. • Select the appropriate trigonometric function to solve for an unknown side of a triangle, given the hypotenuse and an angle. • Utilize experience in labs and other activities in order to solve assorted kinematics problems of varying levels of difficulty.	• Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): • 1-Dimensional Kinematics, concepts and problems • Motion Graphs • 2-D Kinematics, concepts and problems Independent work such as: • Completion of online and written problem sets • Completion of ranking tasks, etc. ("TIPERs" tasks) • Partial and/or full formal laboratory reports • Participation in online discussion groups • Problem-Based Learning Project (based on a complex projectile motion situation) Test • Kinematics Project • Trebuchet (or other projectile launching device)

Benchmarks:

Lab:

Projectile Motion Analysis and Predictions

Project:

Each student team will design and test a projectile launcher, built to teacher-provided specifications.

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 1 and 3.

Kinematics (Motion):

1. One dimensional kinematics (straight-line motion without acceleration and with intervals of constant acceleration)

   Topics:
   distance vs. displacement, speed vs. velocity, concept of vectors
   motion (dot) diagrams
   motion/kinematics graphs (distance-time, position-time, speed-time, velocity-time)
   Motion/kinematics graphs (speed-time, velocity-time)- slope=acceleration
   Equations of kinematics for motion with constant acceleration

Free fall acceleration

Suggested Activities:
Buggy Motion Lab (constant speed OR changing speed using digital OR ticker tape timing OR video analysis), Accelerated Motion Lab (Student Designed, Cart on Ramp or Free Fall, using analog or digital/Vernier measuring methods), Spark Timer Tape Activity/Lab, Changing Velocity (Vernier Physics with Video Analysis©), Demon Drop (Vernier Physics with Video Analysis©),), Distance & Displacement Challenge (Physics Aviary), Spark Timer Tape Activity/Lab, Graph Matching Challenge (Physics Aviary), Changing Velocity (Vernier Physics with Video Analysis©), Moving Man (PhET), Acceleration Challenge (Physics Aviary), Analyzing Free Fall Lab (using Vernier LoggerPro™, and LabQuest2™with photogate), High School Toss (Physics Aviary), Fireworks Vertical Motion (Physics Aviary), Demon Drop (Vernier Video Analysis), Motion on an Incline (Student Inquiry Lab using available materials and probes), Equations of Motion (Physics Aviary), Problem sets & video tutorials from Mastering Physics™ Chapter 1, TIPERs tasks- Kinematics

2. Two-dimensional kinematics (focus on projectile motion)
   a. Digging deeper into vectors and vector math
      Topics:
      Resolving vectors into components
      Adding vectors
      Multiplying & Dividing Vectors
      Suggested Activities: Vector Addition (PhET), River Crossing (Physics Aviary), Problem sets & video tutorials from Mastering Physics™, Chapter 3

   b. Analyzing Projectile Motion
      Topics:
      Analysis of objects undergoing projectile motion (graphical and mathematical)
      -include non-zero angle launches, but limit finding angles to challenge problems, rather than general practice type problems.
      Objects under the influence of drag/air resistance in addition to gravity (conceptual)

      Suggested Activities:
      Creation and analysis of graphs of displacement, velocity and acceleration for the x and y components of PM vectors; Calculate range, time in flight, maximum height, etc. for horizontally launched projectiles and projectiles launched a non-zero angle; Predict landing location for an actual projectile; Projectile Motion (PhET), Drone Delivery Challenge (Physics Aviary), Ground to Wall Soccer Kick (Physics Aviary), Difference in Landing Speeds (Physics Aviary), Difference in Landing Locations (Physics Aviary) Projectile Motion Lab (student inquiry lab using available materials and probes), PBL Projectile Motion Challenge, Problem sets & video tutorials from Mastering Physics™ Chapter 3, TIPERs tasks- Kinematics

Further Information regarding suggested activities:

❖ PBL Group Challenges: Students can be presented with a problem-based-learning challenge for kinematics material, (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.

❖ Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

❖ Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of motion, including constant velocity, constant acceleration, and free fall acceleration.

❖ Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm ups, computer labs, independent work, or assessments.

❖ Completion of TIPERs Tasks refers to ranking tasks for physics (see resources).

❖ Use of Mastering Physics Activities/Assignments
- Online resources for Chapters 1 and 3 (including practice questions, practice problems, and video tutor demonstrations)

- Teacher-selected questions and problems for independent work (chapters 1 and 3)
- Students will read textbook content via e-book (chapters 1 and 3)

❖ Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete.
  - Example: trebuchet/catapult for launching a projectile

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

McCulley, Frank. The Physics Aviary. The Physics Aviary. N.p., 2017. Web. 28 June 2017. <http://www.thephysicsaviary.com/>.

PhET Interactive Simulations. PhET. University of Colorado, 2017. Web. 28 June 2017. <https://phet.colorado.edu/>.

Physics, Institute of. Problem Based Learning Modules. Problem Based Learning Modules, Institute of Physics, www.iop.org/education/higher_education/stem/problem-based/page_55225.html.

Problem Based Learning for College Physics-A Website of Lifelike Activities. Problem Based Learning for College Physics-A Website of Lifelike Activities, pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720.

Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s):
AP Essential Knowledge Statements
- An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed and acceleration (3.A.1)
- The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. (4.A.1)
- The acceleration of a system is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time. (4.A.2)

4.0	**Students will be able to:** • Examine a parametric function to determine the physical quantities represented by that function and then: invent a story for that motion, sketch a position-time graph for that motion, sketch a velocity-time graph for that motion, and use the function equation and the graphs to determine a value of interest (i.e.- time when the object stops, turns around, etc.)
3.0	**Students will be able to:** • Examine a parametric function to determine the physical quantities represented by that function.
2.0	**Students will be able to:** • Recognize the parameters of a function and state what they physically represent. • Use given kinematics graphs to derive various quantities (such as total displacement, instantaneous velocity, average acceleration, etc.)
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**

0.0	**Even with help, no success**

Standard(s): NGSS/NJLS • Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2.A)	
4.0	**Students will be able to:** • Predict the landing location of a projectile, given an initial launch velocity with a non-zero angle.
3.0	**Students will be able to:** • Determine an unknown quantity within a system in the lab by analyzing the system, using relevant measurements and calculations. • Design and conduct an experiment by which the muzzle velocity of a projectile can be determined. • Develop and apply an algorithm for the position of a projectile. • Draw and explain a graph of horizontal position vs time for a projectile. • Draw and explain a graph of vertical position vs time for a projectile. • Draw and explain a graph of horizontal velocity vs time for a projectile. • Draw and explain a graph of vertical velocity vs time for a projectile. • Draw and explain a graph of horizontal acceleration vs time for a projectile. • Draw and explain a graph of vertical acceleration vs time for a projectile.
2.0	**Students will be able to:** • Recognize and/or define the following terminology related to the analysis of an object under the influence of one or more forces: gravity, acceleration, vector, vector component, coordinate system. • Select the appropriate trigonometric function to solve for an unknown side of a triangle, given the hypotenuse and an angle. • Calculate the components of a vector. • Visualize relevant forces acting on an object. • Describe the conditions of projectile motion. • Interpret kinematics graphs (position-time and velocity-time) for a variety of motions. • Use the equations of kinematics to solve for an unknown variable, given the other quantities.
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics ™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/*	• Coordinate with ELL advisors to modify activities where appropriate.

modelcurriculum/ela/ELLSupport.pdf)	• Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.

- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
- HSA.SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems.
- HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- HSF-IF.C.7: Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases.
- HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Unit Title: Newtonian Mechanics and Applications of Newton's Laws

Unit Description: Newton's laws of motion (along with his law of universal gravitation) form the bases of all classical mechanics. In this unit, students will experimentally develop the concept behind Newton's second law and work to dispel misconceptions about inertia and force pairs. Students will apply mathematical modeling to their experimental data to show that $\vec{a} = \frac{\Sigma\vec{F}}{m}$. They will analyze various scenarios using Newton's laws to predict the behavior of these systems. Applications of Newton's laws will include scenarios involving normal forces, tension, friction, drag/air resistance, buoyant force, and gravity. The problem-solving skills developed and stressed in this unit will be used throughout the remainder of the course.

Unit Duration: 4 weeks

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
    - The internal structure of a system determines many properties of the system. (1.A)

- Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. (1.C)

- Big Idea 2: Fields existing in space can be used to explain interactions.
  - A gravitational field is caused by an object with mass. (2.B)
- Big Idea 3: The interaction of an object with other objects can be described by forces.
  - All forces share certain common characteristics when considered by observers in inertial reference frames. (3.A)
  - Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma \vec{F}}{m}$. (3.B)
  - At the macroscopic level, forces can be categorized as either long-range (action-at-adistance) forces or contact forces. (3.C)
- Big Idea 4: Interactions between systems can result in changes in those systems.
  - The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma \vec{F}}{m}$. (4.A)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS-NJLS

- Motion and Stability: Forces and Interactions (HS-PS2-1)
- Engineering Design (HS-ETS1, HS-ETS1-2, HS-ETS1-3)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- Forces are described by vectors. (3.A.2)
- A force on an object is always due to the interaction of that object with another object. (3.A.3)
- If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. (3.A.4)
- If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. (3.B.1)
- The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. (4.A.1)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2.A)
- Engineering Design: Optimizing the Design Solution (HS-ETS1.C)
- Engineering Design: Developing Possible Solutions (HS-ETS1.B)

Understandings:

Students will understand that…

- Mass is a measure of inertia.
- A body will maintain its state of motion unless and until it is acted upon by external, unbalanced force.
- All forces share certain common characteristics when considered by observers in inertial reference frames. *
- Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma \vec{F}}{m}$.*
- The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma \vec{F}}{m}$*

Essential Questions:

- What is a force?
- What is the main difference between inertial and non-inertial reference frames?
- What is inertia?
- What is a force pair?
- How can one (mathematically) describe a force that acts a nonzero angle in a reference frame?
- How would the motion graphs of an object change for an object that undergoes a constant force? A variable force?
- Why do objects accelerate at ***g*** in the absence of air resistance and other forces, regardless of their masses?
- How do forces affect the motion of a body?
- What is a free body diagram (or force diagram), and how is one drawn?

- A free body diagram can be drawn to represent a system and the forces acting on it. This can be used in conjunction with Newton's laws to determine the net force acting on the system. - The weight of an object in a gravitational field is the product of its mass and ***g***. - All objects, regardless of mass, accelerate at ***g***, in the absence of other forces, as $\vec{a} = \frac{\Sigma \vec{F}}{m}$ *(and* $\vec{\mathbf{a}} = \vec{\boldsymbol{g}}$. - Frictional forces arise from the electrostatic forces that arise between the atoms and molecules of surfaces in contact with one another. - Static frictional coefficients are generally larger than kinetic frictional coefficients. - Rolling is accomplished only when static friction exists between surfaces. - Tension forces are a result of intermolecular forces within ropes, chains, etc. and the ability of a material to withstand tension force depends on its microscopic structure. - Air friction and drag forces are variable, and depend increase with increasing speed, until terminal velocity is reached. - Normal forces are forces perpendicular to a surface. - Buoyant forces are normal to the surface of an object and are equal to the weight of displaced fluid, which depends on the density of the fluid. - Force vectors can be broken down into components parallel to the axes established in the reference frame. *Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.	- How can one test the hypothesis that acceleration is directly related to net force and inversely proportional to mass? - What is friction? - How are static and kinetic friction similar, and how do they differ? What is rolling friction? - How can the coefficient of friction be determined experimentally? - How can Newton's laws be used in conjunction with one another to analyze a system and predict its behavior?

Assessment Evidence

Performance Tasks: **APP1 Learning Objectives (Johnson, 2017)** *The student is able to…* - Model verbally or visually the properties of a system based on its substructure and to relate this to changes in the system properties over time as external variables are changed. (1.A.5.1) - design an experiment for collecting data to determine the relationship between the net force exerted on an object to its inertial mass and its acceleration. (1.C.1.1) - design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish the difference between the two experiments. (1.C.3.1) - apply $\vec{F} = m\vec{g}$ to calculate the gravitational force on an object with mass *m* in a gravitational field of strength *g* in the context of the effects of a net force on objects and systems. (2.B.1.1)	**Other Evidence:** Daily informal and formal formative assessments of student activities, such as: - Warm up problems/questions - Whiteboarding/problem solving sessions - Peer tutoring - Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): - Free body diagrams and Newton's Laws - Applications of Newton's Laws - Buoyant force and Density Independent work such as: - Completion of online and written problem sets - Completion of TIPERs tasks - Partial and/or full formal laboratory reports - Participation in online discussion groups

• represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. (3.A.2.1) • challenge a claim that an object can exert a force on itself. (3.A.3.2) • describe a force as an interaction between two objects and identify both objects for any force (3.A.3.3) • construct explanations of physical situations involving the interaction of bodies using Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. (3.A.4.2) • analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. (3.A.4.3) • predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. (3.B.1.1) • design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. (3.B.1.2) • re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. (3.B.1.3) • create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. (3.B.2.1) • make claims about various contact forces between objects based on the microscopic cause of those forces. (3.C.4.1) • explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. (3.C.4.2) **Other** Students will… • Recognize and/or define the following terminology related to forces and Newton's laws of motion: system, environment, external interactions, internal interactions, inertia, force, mass, vector component (or scalar component of a force vector), free-body diagram (or force diagram), dynamics processes, normal, gravity, air resistance, weight, tension, static friction, kinetic friction, rolling friction, coefficient of friction, apparent weight, buoyant force • Use video analysis to investigate and mathematically model the motion of a system under the action of one or more forces. • Calculate the components of a force vector.	Test • Forces and Newton's Laws Project • Problem-Based Learning Project (mid-length project- ex: accident reconstruction) • Trebuchet (or other projectile launching device)- this project is a marking-period length project • Long term project (ex- student groups identify community issue and offer potential engineering solutions)

- Describe the reliance of air resistance and drag on velocity.
- Design and conduct an experiment or set of experiments that can be used to measure ***g*** using an object on a ramp.
- Design and conduct an experiment or set of experiments that can be used to measure coefficients of friction (static, kinetic) for pairs of surfaces.
- Utilize experience in labs and other activities in order to solve assorted dynamics problems of varying levels of difficulty.

Benchmarks:

Lab:

Newton' 2nd Law

Project:

Each student team will design and test a projectile launcher, built to teacher-provided specifications. (Launch will be video recorded and the videos will be analyzed using Logger Pro™ video analysis.)

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 2 & 3.

Forces & Newton's Laws:

1. Newtonian mechanics (Chapter 2)
   Topics
   Describing and representing interactions (free body diagrams)
   Adding and measuring forces
   Relationship between force and motion
   Inertial reference frames and Newton's 1st law
   Newton's 2nd law
   Gravitational force
   One dimensional applications of Newton's 2nd law (incl. problem solving strategies for apparent weight problems)
   Force pairs and Newton's 3rd law
   Stopping distance and force (everyday applications- seat belts and air bags)

   Suggested Activities: Open-ended discussion/Brainstorming- What it a force? What are some forces we encounter every day? Apparent Weight in and Elevator Lab/Activity (Vernier Force Plates, LoggerPro™), Coffee Filter Demo/Lab (Vernier Video Analysis OR LoggerPro™ and LabQuest2™ with Motion Detector), Linear Net Force Game (Physics Aviary), Car Stopping Distance (Physics Aviary), PBL Challenge: First Day on the Job, TIPERs tasks (forces and Newton's laws), Problem sets & video tutorials from Mastering Physics™, Chapter 2

2. Applications of Newton's Laws (Chapter 3)
   Topics:
   Force Components
   Problem solving strategies: inclines, connected objects, friction, air resistance, drag, buoyant force

   Suggested Activities: Force Table Lab (Resolution and addition of force vectors), Friction Lab (drag test, stopping distance or friction on incline), Newton's Law on an Incline (Physics Aviary), Newton's 2nd Law Lab simulation (Physics Aviary), Half-Atwood Machine Lab, PBL First Day on the Job PBL Challenge (Stopping distance), Buoyancy Lab (PhET), Cargo Challenge (Physics Aviary), Problem sets & video tutorials from

Mastering Physics™, Chapters 3 and 10 (hydrostatics & buoyancy), TIPERs tasks (forces and Newton's laws, hydrostatics/fluids)

<u>Further Information regarding suggested activities:</u>

- PBL Group Challenges: Students can be presented with a problem-based-learning challenge for dynamics material, (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.

- Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

- Use of Vernier LoggerPro™ and sensors for experimental development of Newton's 2nd law (i.e.-acceleration of cart down a ramp or on a half-Atwood apparatus can be derived from velocity measurements using either photogates or motion detectors)

- Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm ups, computer labs, independent work, or assessments).

- Use of TIPERs tasks (see Resources).

- Use of Mastering Physics™ Activities/Assignments
  - Online resources for Chapters 2 and 3(including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (chapters 2, 3 and 10)
  - Students will read textbook content via e-book (chapters 2, 3 and 10)

- Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete.
  - Example: trebuchet/catapult for launching a projectile

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Laws, Priscilla W. <u>Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools</u>. Beaverton, OR: Vernier, 2009. Print.

McCulley, Frank. The Physics Aviary. The Physics Aviary. N.p., 2017. Web. 28 June 2017. <http://www.thephysicsaviary.com/>.

PhET Interactive Simulations. PhET. University of Colorado, 2017. Web. 28 June 2017. <https://phet.colorado.edu/>.

Physics, Institute of. Problem Based Learning Modules. Problem Based Learning Modules, Institute of Physics, www.iop.org/education/higher_education/stem/problem-based/page_55225.html.

MyLyProblem Based Learning for College Physics-A Website of Lifelike Activities, pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720.

Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): AP Enduring Understanding • The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma\vec{F}}{m}$. (4.A) AP Essential Knowledge Statements • If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. (3.B.1) • The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. (4.A.1) NGSS-NJLS • Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2.A)	
4.0	**Students will be able to:** • Design an experiment to determine the relationship between net force, mass and acceleration using available lab equipment, and with very little guidance from the instructor. • Decide how to analyze the data from the above experiment in order to uncover the relationship $\vec{a} = \frac{\Sigma\vec{F}}{m}$. • Prepare a formal lab report and/or present their findings to the class.
3.0	**Students will be able to:** • Analyze a system on which one or more external forces act on the object(s) in the system using Newton's laws, such that the behavior of the system can be predicted. • Calculate the net force acting on a system (systems include those involving normal force, tension, gravity, friction, etc.) • Correctly draw and label a free body diagram to represent a system under the action of one or more forces • Differentiate between internal forces and external forces for a given system
2.0	**Students will be able to:** • Define/explain the following terminology: force, vector, vector component, acceleration, mass, inertia, net force, reference frame, friction, normal force, tension, gravity • Identify correct free body diagrams to represent various scenarios
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™).

	• Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• Coordinate with ELL advisors to modify activities where appropriate. • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.

- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
- HSA.SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems.
- HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- HSF-IF.C.7: Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases.
- HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Unit Title: Circular Motion and Universal Gravitation

Unit Description:

Students encounter examples of circular motion every day, both in the natural realm and in manmade systems. In this unit, students will examine various examples systems for which there is a net force (and therefore an acceleration) inward. Newton's 2nd law will be used to analyze such cases. Some examples will include a car traveling a curved path with friction and/or normal force providing centripetal acceleration, an object swinging in a horizontal circle at the end of a cord or string with tension providing centripetal acceleration, a vehicle cresting a hill, a roller coaster in a vertical loop, and a vertical swing. Additionally, Newton's law of universal gravitation will be used to analyze systems involving satellites of central objects. Kepler's laws will also be included in order to provide a theoretical basis for planetary motions.

Unit Duration: 3 weeks

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
  - The internal structure of a system determines many properties of the system. (1.A)
  - Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. (1.C)
- Big Idea 2: Fields existing in space can be used to explain interactions.
  - A gravitational field is caused by an object with mass. (2.B)
- Big Idea 3: The interaction of an object with other objects can be described by forces.
  - All forces share certain common characteristics when considered by observers in inertial reference frames. (3.A)
  - Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma \vec{F}}{m}$. (3.B)
  - At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces. (3.C)
- Big Idea 4: Interactions between systems can result in changes in those systems.
  - The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma \vec{F}}{m}$. (4.A)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS-NJLS

- Motion and Stability: Forces and Interactions (HS-PS2-1, HS-PS2-4)
- Engineering Design (HS-ETS1, HS-ETS1-2, HS-ETS1-3)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields. (1.C.2)
- Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principals. (1.C.3)
- A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector. (2.A.1)
- A gravitational field ***g*** at the location of an object with mass *m**g*** causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field. (2.B.1)
- The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object. (2.B.2)
- An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. (3.A.1)
- Forces are described by vectors. (3.A.2)
- A force on an object is always due to the interaction of that object with another object. (3.A.3)
- If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. (3.A.4)
- If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. (3.B.1)
- Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. (3.B.2)
- Gravitational force describes the interaction of one object with mass with another object with mass. (3.C.1)
- Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales. (3.G.1)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2.A)

- Types of Interactions: Newtons law of universal gravitation…provides the mathematical model to describe and predict the effect of gravitational force between distant objects. Forces at a distance are explained by fields permeating space that can transfer energy through space. (HS-PS2.B)
- Engineering Design: Optimizing the Design Solution (HS-ETS1.C)
- Engineering Design: Developing Possible Solutions (HS-ETS1.B)

Understandings:
Students will understand that…

- A body will maintain its state of motion unless and until it is acted upon by external, unbalanced force.
- All forces share certain common characteristics when considered by observers in inertial reference frames. *
- Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma \vec{F}}{m}$.*
- A free body diagram can be drawn to represent a system and the forces acting on it. This can be used in conjunction with Newton's laws to determine the net force acting on the system.
- An object moving in a curved path must experience an acceleration toward the center of that path. This acceleration is known as *centripetal* or center-seeking.
- Centripetal acceleration results from a net force inward.
- Centripetal force is the net inward force that results in a curved path; this is not to be confused with *centrifugal force*, which is only experienced by an observer in a non-inertial reference frame.
- The weight of an object in a gravitational field is the product of its mass and ***g***.
- Force vectors can be broken down into components parallel to the axes established in the reference frame.
- Mass is a measure of inertia.
- Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. *
- Certain types of forces are considered fundamental. *
- The gravitational force varies as the square of the center-to-center distance between two masses.
- A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long range forces) as well as a variety of other physical phenomena. *
- A gravitational field is caused by an object with mass. *
- At the macroscopic level, forces can be characterized as either long range (action-at-a-distance) forces or contact forces. *

Essential Questions:

- What are the properties used to describe an object in circular motion?
- What are the conditions for uniform circular motion?
- What are some scenarios for which curved motion is non-constant (speed is changing)?
- How can Newton's laws be used in conjunction with one another to analyze a system when the object in the system follows a curved path?
- What is a *field*?
- What are the fundamental forces?
- How does the strength of the gravitational force compare to that of each of the other fundamental forces?
- What was the thought experiment used by Newton that led to his law of universal gravitation? Did he suggest an actual mechanism for this?
- In what ways could one determine the gravitational mass of an object? How might one measure the inertial mass of the same object? What should one discover about the two results?
- How does the strength of the gravitational field around a mass depend on the magnitude of that mass?
- What is the relationship between the gravitational field strength and distance from the center of the field-producing mass?
- How do the motions of Earth and other planets (and satellites) support Newton's law of universal gravitation? How are Kepler's laws related to Newton's and how can they be used to predict planetary motion?
- Are astronauts in the ISS weightless?

*Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.	

Assessment Evidence

Performance Tasks:

APP1 Learning Objectives (Johnson, 2017)

The student is able to…

- apply $\vec{F} = m\vec{g}$ to calculate the gravitational force on an object with mass *m* in a gravitational field of strength *g* in the context of the effects of a net force on objects and systems. (2.B.1.1)
- apply $\vec{g} = \frac{GM}{\vec{r}^2}$ to calculate the gravitational field due to an object with mass *M*, where the field is a vector directed toward the center of the object of mass *M*. (2.B.2.1)
- approximate a numeric value of the gravitational field (*g*) near the surface of an object from its radius and mass relative to those of the Earth of other reference objects. (2.B.2.2)
- express the motion of an object using narrative, mathematical, and graphical representations. (3.A.1.1)
- design an experimental investigation of the motion of an object. (3.A.1.2)
- analyze experimental data describing the motion of an object an is able to express the results of the analysis using narrative, mathematical and graphical representatives. (3.A.1.3)
- design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. (1.C.3.1)
- represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. (3.A.2.1)
- analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. (3.A.3.1)
- challenge a claim that an object can exert a force on itself. (3.A.3.2)
- describe a force as an interaction between two objects and identify both objects for any force. (3.A.3.3)
- construct explanations of physical situations involving the interaction of bodies using Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. (3.A.4.2)
- analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. (3.A.4.3)

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

In class and independent quizzes (appropriate topics include):

- Uniform circular motion (w/o universal gravitation) concepts and problem
- Non-uniform circular motion (i.e.- vertical loops, hills) concept and problems
- Planetary motions and mechanics concepts and problem

Independent work such as:

- Completion of online and written problem sets
- Partial and/or full formal laboratory reports
- Participation in online discussion groups

Test

- Circular Motion and Universal Gravitation

Project

- Problem-Based Learning Project (mid-length project- ex: building an exit ramp)
- Trebuchet (or other projectile launching device)- this project is a marking-period length project
- Long term project (ex- student groups identify community issue and offer potential engineering solutions)

• predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. (3.B.1.1) • design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. (3.B.1.2) • re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. (3.B.1.3) • create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. (3.B.2.1) • use Newton's law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in contexts other than orbital motion. (3.C.1.1) • use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only). (3.C.1.2) • evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified. (4.A.2.2) Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017. **Other** • Recognize and/or define the following terminology related to circular motion and gravitation: tangential velocity, tangential speed, tangential acceleration, centripetal (or radial) acceleration, centripetal force, inertial reference frame, non-inertial reference frame, field, satellite, geostationary, apparent weightlessness • Utilize experience in labs and other activities in order to solve assorted circular motion and universal gravitation problems of varying levels of difficulty. • Without the input of the instructor, design and conduct an experiment, using available laboratory equipment, to test predictions about the motion of an object moving in a circular path. • Analyze the gravitational force acting on an object in circular orbit around a planet or star, in order to calculate orbital speed, orbital radius, or other variables associated with the system. • Draw a diagram of an elliptical orbit and identify locations where the orbiting body moves at minimum and maximum speeds, based upon Kepler's laws and the law of Universal Gravitation. • Sketch an appropriate graph of gravitational force vs. distance between objects, indicating an understanding of the inverse square proportionality of the relationship.	

Benchmarks:

Lab:

Circular motion

Project:

Each student team will design and test a projectile launcher, built to teacher-provided specifications. (Launch will be video recorded and the videos will be analyzed using Logger Pro video analysis.)

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapter 4.

Circular Motion and Universal Gravitation:

1. Circular Motion
   Topics
   Velocity change in circular motion
   Direction of acceleration in circular motion
   FBD's for circular motion
   Period of circular motion
   Analyzing processes involving circular motion (banked and unbanked turns, tethered objects, rotor rides, swings, vertical loops)

   Suggested Activities:
   Use of textbook examples (Ch 4), Broom & Bowling Ball (activity or video clip), Motion in 2-D (PhET), Flying Pig (Circular Motion) Lab (no sensors, student-design lab), Classic Circular Motion Lab (swinging a stopper on a string, student-design lab), Circular Motion Lab (Physics Aviary), Car on a Turn (Physics Aviary), Force Normal on a Spinning Space Station (Physics Aviary), Ice Bucket Challenge (Physics Aviary), Oh, Snap (Physics Aviary), TIPERs tasks (circular motion), Problem sets & video tutorials from Mastering Physics™, Chapter 4

2. Universal Gravitation & Planetary Mechanics
   Topics:
   Newton's law of universal gravitation
   Proportional reasoning for UG problems
   Kepler's Laws
   Satellites and Weightlessness

   Suggested Activities: Gravity Force Lab (PhET), Gravitational Field Strength (Physics Aviary), Gravity and Orbits (PhET), Inertial Mass Balance Lab (Student design lab), TIPERs tasks (gravitation), Student independent viewing of Mechanical Universe: The Apple and the Moon (available online)
   Problem sets & video tutorials from Mastering Physics, Chapter 4

Further Information regarding suggested activities:

- PBL Group Challenges: Students can be presented with a problem-based-learning challenge for circular motion material, (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.

- Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

- Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm ups, computer labs, independent work, or assessments).

- Use of TIPERs tasks (see Resources).

❖ Use of Mastering Physics™ Activities/Assignments
   - Online resources for Chapter 4 (including practice questions, practice problems, and video tutor demonstrations)
   - Teacher-selected questions and problems for independent work (chapter 4)
   - Students will read textbook content via e-book (chapter 4)

❖ Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete.
   - Example: trebuchet/catapult for launching a projectile

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

McCulley, Frank. The Physics Aviary. The Physics Aviary. N.p., 2017. Web. 28 June 2017. <http://www.thephysicsaviary.com/>.

PhET Interactive Simulations. PhET. University of Colorado, 2017. Web. 28 June 2017. <https://phet.colorado.edu/>.

Physics, Institute of. Problem Based Learning Modules. Problem Based Learning Modules, Institute of Physics, www.iop.org/education/higher_education/stem/problem-based/page_55225.html.

Problem Based Learning for College Physics-A Website of Lifelike Activities. Problem Based Learning for College Physics-A Website of Lifelike Activities, pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720.

Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s):
AP Essential Knowledge Statements
- If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. (3.B.1)

NGSS/NJLS
- (Focus on circular and orbital motion) Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic object. (HS-PS2.A)

- (Gravitational force only) Types of Interactions: Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2.B)

4.0	**Students will be able to:** • Evaluate statements made about forces acting on an object that moves in a circular or semi-circular path, and identify errors in reasoning regarding forces acting on that object.

	• Determine an unknown quantity within a lab system that features an object in moving in a circular path, by analyzing the system, using relevant measurements and calculations, without help from the instructor. * Potential lab systems could include conical pendulums or objects on rotating turntables.
3.0	**Students will be able to:** • Draw and utilize a free body diagram and Newton's second law to predict the motion of an object that is being acted on by one or more forces, resulting in a centripetal acceleration. • Discuss the reason for perceived forces in a non-inertial frame of reference and describe how those disappear when viewed from an inertial frame of reference. • Identify an appropriate coordinate system by which to analyze the motion of and forces on an object moving in a circular path. • Use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion. • Draw a diagram of an elliptical orbit and identify locations where the orbiting body moves at minimum and maximum speeds, based upon Kepler's laws and the law of Universal Gravitation. • Apply g=G M/r2 to calculate the gravitational field due to an object with mass M, where the field is a vector directed toward the center of the object of mass M. • Approximate a numerical value of the gravitational field (g) near the surface of an object from its radius and mass relative to those of the Earth or other reference objects. Note: Systems will include those involving non-uniform circular motion (changing speed) in addition to those involving uniform circular motion (constant speed). This will include vertical loops, pendulums, and planetary mechanics.
2.0	**Students will be able to:** • Recognize and/or define the following terminology related to the analysis of an object that is moving in a circular or semi-circular path under the influence of one or more forces: centripetal acceleration, force, acceleration, mass, weight, normal force, tension, friction, inertia, gravity (universal gravitation), apparent weight, action-reaction pair, equilibrium, vector, vector component, coordinate system. • Select the appropriate trigonometric function to solve for an unknown side of a triangle, given the hypotenuse and an angle. • Identify the direction of the net force on a body in circular motion as inward, toward the center of the circular path. • Draw an appropriate free body diagram to represent the forces acting on an object. • Calculate the vector sum of a forces acting on an object and its resulting acceleration. • Visualize relevant forces acting on an object.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena.

	• Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• Coordinate with ELL advisors to modify activities where appropriate. • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1)
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)
- WHST.11-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3), (HS-PS2-5)
- WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1), (HS-PS2-5)

Common Core State Standards: Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)
- MP.4: Model with mathematics. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5)
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5)
- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5)
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1), (HS-PS2-4)
- HSA.SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1), (HS-PS2-4)
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1), (HS-PS2-2)
- HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1), (HS-PS2-2)
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1), (HS-PS2-2)
- HSF-IF.C.7: Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1)
- HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Unit Title: Momentum & Energy, Conservation Laws

Unit Description:

Momentum and energy are two of the fundamental concepts in all of science; they provide a powerful modeling tool by which complex physical systems can be analyzed. Students will be introduced to and investigate the following topics: impulse and momentum, collisions and conservation of momentum, work-energy theorem, types of mechanical energy, conservation of energy, and power. The conservation laws will be the primary focus of this unit.

Unit Duration: 4-5 weeks

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 3: The interactions of an object with other objects can be described by forces.
  - A force exerted on an object can change the momentum of an object (3.D)
- Big Idea 4: Interactions between systems can result in changes in those systems.
  - Interactions with other objects or systems can change the total linear momentum of a system. (4.B)
  - Interactions with other objects or systems can change the total linear momentum of a system. (4.C)
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
  - Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. (5.A)
  - The energy of a system is conserved. (5.B)
  - The linear momentum of a system is conserved. (5.D)

NGSS-NJLS

- Motion and Stability: Forces and interactions (HS-PS2.2, HS-PS2.3)
- Energy (HS-PS3.1, HS-PS3.2, HS-PS3.3)
- Engineering Design (HS-ETS1.2, HS-ETS1.3)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- The change in momentum of an object is a vector in the direction of the net force exerted on the object. (3.D.1)
- The change in momentum of an object occurs over a time interval. (3.D.2)
- The change in kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the same timer interval that the force is exerted. (3.E.1)
- For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. (5.A.2)
- Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects. (5.B.1)
- A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy (includes mass-spring oscillators and simple pendulums). (5.B.2)
- A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces. (5.B.3)
- The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of configuration of the objects that make up the system. (5.B.4)
- Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. (5.B.5)
- In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after. (5.D.1)
- In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after. (5.D.2)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Definitions of Energy (HS-PS3.A)
- Conservation of Energy (HS-PS3.B)
- Relationship Between Energy and Forces (HS-PS3.C)
- Energy in Chemical Processes (HS-PS3.D)
- Forces and Motion (HS-PS2.A)
- Engineering Design: Optimizing the Design Solution (HS-ETS1.C)
- Engineering Design: Developing Possible Solutions (HS-ETS1.B)

Understandings:
Students will understand that…

- mass is a conserved quantity.
- momentum is the product of an object's mass and velocity, and is a vector quantity.
- impulse is a change in momentum, brought about by the action of a force on a system through a time interval.
- single objects can have momentum, but single objects cannot have impulse.
- the center of mass velocity (and momentum) of a system cannot change in the absence of unbalanced external force on the system.
- the total momentum of a system is conserved in the absence of external impulse.
- collisions can be used to examine conservation of momentum.
- devices such as airbags, seatbelts and helmets are designed in such a way as to minimize force during a collision by maximizing impulse time.
- single objects can have kinetic energy, but only systems of objects can possess potential energy.
- energy is a scalar quantity
- kinetic energy and momentum are quantities associated with moving objects.
- certain forces (gravity, spring force, electrostatic, magnetic) are conservative.
- friction and air resistance or drag are non-conservative forces.
- work done on an object or system is a scalar quantity and is calculated as the dot product of force and displacement.
- the total energy of a system is conserved.
- the mechanical energy of a system is conserved in the absence of non-conservative forces.

*Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Essential Questions:

- What is momentum?
- What is the relationship between impulse and momentum?
- What can one derive from analyzing a graph of force vs time?
- What is the relationship between Newton's laws and conservation principles?
- Is momentum *always* conserved?
- How can conservation of momentum be applied to the analysis of physical systems?
- What happens to momentum during different types of collisions and interactions?
- What is the relationship between work and energy?
- What can one derive from a graph of force vs. distance?
- Is energy *always* conserved?
- How can conservation of energy be applied to the analysis of physical systems?
- How does one determine when best to rely on Newton's laws versus conservation principles when analyzing physical systems?
- How do engineers design safety devices and systems that protect objects from excessive forces?
- How are the principles of conservation of momentum and energy used in (for example) rocket propulsion?

Assessment Evidence

Performance Tasks:

APP1 Learning Objectives: (Johnson, 2017)
The student is able to…

- predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. (3.D.2.2)

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

• analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. (3.D.2.3) • design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time. (3.D.2.4) • calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.). (4.B.1.1) • analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass. (4.B.1.2) • apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system. (4.B.2.1) • perform analysis on data presented as a force-time graph and predict the change in momentum of a system. (4.B.2.2) • define open and closed systems for everyday situations and apply conservation concepts for energy, (charge), and linear momentum to those situations. (5.A.2.1) • make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. (5.D.1.1) • make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations. (5.D.1.2) • apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy. (5.D.1.3) • design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between prediction and outcome. (5.D.1.4) • classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an	In class and independent quizzes (appropriate topics include): • Impulse and momentum concepts and problem • Work and energy concepts and problems Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports • Participation in online discussion groups Test • Conservation Laws (Impulse & Momentum, Work & Energy) Project • Problem-Based Learning Project • Long term project (ex- student groups identify community issue and offer potential engineering solutions)

elastic collision, solve for missing variables, and calculate their values. (5.D.1.5) • qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic. (5.D.2.1) • plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically. (5.D.2.2) • apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. (5.D.2.3) • analyze data that verify conservation of momentum in collisions with and without an external friction force. (5.D.2.4) • classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate principle for analyzing an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. (5.D.2.5) • predict the velocity of the center of mass of a system when there is not interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force). (5.D.3.1) • make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves. (3.E.1.1) • use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged. (3.E.1.2) • use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged. (3.E.1.3) • apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object. (3.E.1.4) • calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy. (4.C.1.1) • predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. (4.C.1.2) • make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or	

antiparallel to the direction of the displacement vector of the center of mass. (4.C.2.1) • apply the concepts of Conservation of Energy and the Work-Energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the system, and/or the internal energy of the system. (4.C.2.2) • set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy. (5.B.1.1) • translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies. (5.B.1.2) • calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system. (5.B.2.1) • describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. (5.B.3.1) • make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. (5.B.3.2) • apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of that system. (5.B.3.3) • describe and make predictions about the internal energy of systems. (5.B.4.1) • calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. (5.B.4.2) • design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance. (5.B.5.1) • design an experiment and analyze graphical data in which interpretation is of the area under a force-distance curve are needed to determine the work done on or by the object or system. (5.B.5.2) • predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance. (5.B.5.3) • make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). (5.B.5.4) • predict and calculate the energy transfer to (i.e., the work done on) an object or system from	

information about a force exerted on the object or system through a distance. (5.B.5.5) Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.	

Benchmarks:

Lab: Collisions and Conservation of Momentum (OR) Bungee Jump Challenge
Test: Conservation Laws

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapter 5.

Impulse, Linear Momentum and Conservation of Momentum (Chapter 5):

Topics
Mass Accounting
Linear Momentum
Impulse
Connection of Newton's laws with impulse and momentum
Impulse-momentum principle
Applications of impulse-momentum principle
Conservation of Momentum
Collisions and separations
2-dimensional collisions

Suggested Activities:
PBL Activity/Project such as: Potato chip shipping contest, Finding Speed from Impulse Graph (Physics Aviary), Collisions (Physics Aviary), "Center of Mass Motions", (Vernier Physics with Video Analysis©), Impulse-Momentum Lab (using Vernier or analog equipment), Momentum Conservation (Physics Aviary), 2-D Momentum Conservation (Physics Aviary), PBL Car Crash Lab/Activity (accident "reconstruction" and/or safety device engineering), TIPERs tasks (momentum), Problem sets & video tutorials from Mastering Physics™- Chapter 5

Work, Energy and Conservation of Energy (Chapter 6):

Topics
Work & Energy
Work-energy theorem
Types of energy
Conservative and non-conservative forces
Conservation of Energy
Energy changes in collisions

Suggested Activities
Energy Skate Park (PhET), Speed from Work Graphs (Physics Aviary), Work from Elastic (Physics Aviary), Power Pulling Billy up a Hill, (Physics Aviary), Work-Energy Lab (using Vernier or analog equipment), "Net Work-KE", (Vernier Physics with Video Analysis), Energy Conservation Lab (spring energy→kinetic energy→gravitational potential energy), TIPERs tasks (energy), Bungee Jumper Lab (Energy Conservation Challenge Lab activity), Problem sets & video tutorials from Mastering Physics™- Chapter 6

Further Information regarding suggested activities:

- PBL Group Challenges: Students can be presented with a problem-based-learning challenge for impulse-momentum material, (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.

- ❖ Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

- ❖ Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm-ups, computer labs, independent work, or assessments).

- ❖ Use of TIPERs tasks (see Resources)

- ❖ Use of Mastering Physics™ Activities/Assignments
  - Online resources for Chapter 5 & 6 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (chapter 5 & 6)
  - Students will read textbook content via e-book (chapter 5 & 6)

- ❖ Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete.
  - Example: Potato chip shipping project

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.
Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

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Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s):
AP Enduring Understanding
- Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. (5.A)

NGSS/NJLS
- Conservation of Energy and Energy Transfer: Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring)

	and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3.B)
4.0	**Students will be able to:** • Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy, without assistance from the instructor AND can accurately explain the physical performance of that device as compared to the other devices presented. (OR) • Design, build, and refine a device that works within given constraints in, without assistance from the instructor AND can accurately explain the physical performance of that device as compared to the other devices presented. • Examine a sample explanation of the energy changes in a system to find inaccuracies, and then correct the inaccuracies, providing justification for corrections.
3.0	**Students will be able to:** • Make predictions about the changes in kinetic energy of an object based on considerations of direction of the net force on the object as the object moves. • Derive an equation relating the energy content of a system at one point in time to that of the same system at another point in time. • Use energy conservation concepts and work-energy considerations to make predictions about the motion of an object at different points in time. • Identify systems in which mechanical energy is not converted to non-mechanical forms. • Quantify the amount of mechanical energy converted to thermal energy in a system that includes a dissipative force. • Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). • Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy, without assistance from the instructor.
2.0	**Students will be able to:** • Recognize and/or define the following vocabulary: work, energy, gravitational potential energy, elastic potential energy, kinetic energy, work-energy theorem, conservation of energy, power, conservative force, non-conservative force • Calculate work done on an object by the action of a constant force. • Calculate the gravitational potential energy of system. • Calculate the elastic potential energy of a system. • Calculate the kinetic energy of a moving object. • Manipulate the terms in an equation to solve for an unknown variable.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): AP Essential Knowledge Focus Statement • The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted. NGSS/NJLS • Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. (HS-PS2.3)	
4.0	**Students will be able to:** • Design, build, and refine a simulation that enables a user to input initial system conditions for objects within the system such that those values can be predicted and then tracked during and after an interaction between the objects (i.e.- a separation or a collision) • Use a simulation designed by another student/group of students for adherence to impulse-momentum theorem and conservation of momentum

3.0	**Students will be able to:** • Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. • Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. • Justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction • Predict the change in momentum of an object from the average force exerted on it and the interval of time during which the force is exerted • Predict the post-interaction velocities of particles or objects within a system, based on the type of interaction in which they are involved • Design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.
2.0	**Students will be able to:** • Calculate the net external force acting on an object, as the vector sum of all of the individual forces acting on the object. • State, verbally and via momentum equations, the impulse-momentum theorem. • State, verbally and via momentum equations, the law of conservation of momentum. • Calculate the momentum of an individual particle or object. • Calculate the total momentum of a system of objects. • Describe the path of the center of mass of an object • Recognize that the change in momentum of the center of mass of a system is zero if all forces acting are internal to the system. • Calculate the change in momentum of a particle based on a graph of the force acting on the particle versus time • Define the following terms: impulse, momentum, inertia, force, elastic collision, inelastic collision • Draw representative diagrams of a system of objects to show their properties before, during and after an interaction
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• Coordinate with ELL advisors to modify activities where appropriate. • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE,

	experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)
- WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4), (HS-PS3-5)
- WHST.9-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4), (HS-PS3-5)
- SL.11-12.5: Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1), (HS-PS3-2), (HS-PS3-5)

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)

- MP.4: Model with mathematics. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1), (HS-PS3-3)
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1), (HS-PS3-3)
- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1), (HS-PS3-3)

Unit Title: Equilibrium, Torque, and Rotational Motion

Unit Description:

In this unit, students will investigate systems in rotational (and translational) equilibrium and those undergoing rotational motion. The unit will begin with static systems and introduce the concepts of torque and equilibrium. Next, students will apply prior understanding of kinematics from linear motion to rotational motion, learning the rotational analogues to the variables and equations of kinematics. They will experimentally examine Newton's second law for rotation and apply it to a variety of scenarios. Finally, the conservation of energy and conservation of momentum will be presented in rotational (or angular) terms. Examples from natural and engineered systems will be discussed.

Unit Duration: 4 weeks

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 3: The interactions of an object with other objects can be described by forces.
  - All forces share certain common characteristics when considered by observers in inertial reference frames. (3.A)
  - A force exerted on an object can cause a torque on that object. (3.F)

- Big Idea 4: Interactions between systems can result in changes in those systems.
  - A net torque exerted on a system by other objects or systems will change the angular momentum of the system. (4.D)
- Big Idea 5: Changes that occur because of interactions are constrained by conservation laws.
  - Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. (5.A)
  - The energy of a system is conserved. (5.B)
  - The angular momentum of a system is conserved. (5.E)

NGSS-NJLS

- Motion and Stability: Forces and interactions (HS-PS2.2, HS-PS2.3)
- Energy (HS-PS3.1, HS-PS3.2, HS-PS3.3)
- Engineering Design (HS-ETS1.2, HS-ETS1.3)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis. (3.F.1)
- The presence of a net torque along any axis will cause a rigid system to change its rotational motion about that axis. (3.F.2)
- A torque exerted on an object can change the angular momentum of an object. (3.F.3)
- Torque, angular velocity, angular acceleration, and angular momentum are vectors and can be characterized as positive or negative depending upon whether they give rise to or correspond to counterclockwise or clockwise rotation with respect to an axis. (4.D.1)
- The angular momentum of a system may change due to interactions with other objects or systems. (4.D.2)

- The change in angular momentum is given by the product of average torque and the time interval during which the torque is exerted. (4.D.3)
- For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. (5.A.2)
- Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects. (5.B.1)
- If the net external torque exerted on the system is zero, the angular momentum of the system does not change. (5.E.1)
- The angular momentum of a system is determined by the locations and velocities of the objects that make up the system. The rotational inertia of an object or system depends upon the distribution of mass within the object or system.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Definitions of Energy (HS-PS3.A)
- Conservation of Energy (HS-PS3.B)
- Relationship Between Energy and Forces (HS-PS3.C)
- Forces and Motion (HS-PS2.A)

Understandings:

Students will understand that…

- linear quantities that have been applied to systems up to this point have rotational analogues. (i.e. displacement, velocity, acceleration)
- torque is the vector (cross) product of force and lever arm.
- the moment of inertia is the rotational analogue of mass, and depends on the amount of mass and its distribution in an object or system.
- net torque is equal to the product of the moment of inertia of an object (or system) and the angular acceleration of that system; this is Newton's 2nd law for rotation.
- net torque and net force on a static system must both be zero.
- the motion of rolling, spinning, turning, and rotating objects can be described using equations of kinematics.
- the angular acceleration of a round object (such as a ball or cylinder) depends on the net torque it experiences as well as the moment of inertia of that object.
- rotating objects/systems have angular momentum AND rotational kinetic energy.
- some percentage of the mechanical energy of a rolling object is in the form of rotational kinetic energy. If that object is also moving translationally, it will also have translational kinetic energy.
- a system can have angular momentum even when it "appears" that nothing in the system is turning.
- angular momentum must be conserved. If an object or system experiences an external net torque, then its angular momentum can change, but an equal and opposite change will occur for

Essential Questions:

- How do engineers determine how forces on a bridge will affect its stability?
- How can the motion of a rotating object or system be described?
- How do Newton's laws and the laws of conservation of energy and momentum apply to rotating (or rolling, or spinning) objects or systems?
- Why do ice skaters speed up when they pull their arms inward during a spin? Why do stars spin faster as they collapse?
- Why does a solid ball always win a downhill "race" with a hollow ball, if both start from rest at the same location?

the object or system that applies that external net torque.	

Assessment Evidence	
Performance Tasks: **APP1 Learning Objectives: (**Johnson, 2017) The student is able to… • compare the torques on an object caused by various forces. (3.F.1.2) • design an experiment and analyze data testing a question about torques in a balanced rigid system. (3.F.1.4) • calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction). (3.F.1.5) • make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis. (3.F.2.1) • plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis. (3.F.2.2) • predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum. (3.F.3.1) • plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object. (3.F.3.3) • use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. (4.A.1.1) • describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems. (4.D.2.1) • plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems. (4.D.2.2) • appropriate mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum. (4.D.3.1) • plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted. (4.D.3.2)	**Other Evidence:** Daily informal and formal formative assessments of student activities, such as: • Warm up problems/questions • Whiteboarding/problem solving sessions • Peer tutoring • Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): • Rotational Mechanics (equilibrium) concepts and problems • Rotational Kinematics concepts and problem • Rotational Mechanics (non-equilibrium) concepts and problems Independent work such as: • Completion of online and written problem sets • Completion of TIPERs tasks • Partial and/or full formal laboratory reports • Participation in online discussion groups Test • Equilibrium and Rotational Mechanics Project • Long term project (ex- student groups identify community issue and offer potential engineering solutions)

- make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque. (5.E.1.1)
- make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero. (5.E.1.2)
- describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system. Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses. (5.E.2.1)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Benchmarks:

Lab: Torque and Angular Acceleration
Midterm Exam: All topics from MP 1 and 2 to be assessed

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 7 and 8.

Static Equilibrium -Rotational and Translational Equilibrium (Chapter 7)

Topics
Extended and rigid bodies
Center of mass
Gravity and center of mass, center of gravity
Torque, lever arm, axis of rotation
Variables affecting magnitude of torque
Determining direction and sign of torque vectors
Conditions of equilibrium
Revisiting (calculating) center of mass
Analysis of systems in static equilibrium
Stability and equilibrium

Suggested Activities
Predicting and locating the center of mass (hands-on activity), torque about axis demonstrations (door hinge, broom balance, meterstick balance, etc.), "Bridge Lab" (static equilibrium with parallel forces; forces measured using Vernier ™ force sensors and Vernier LoggerPro™), "Watch Your Back!" (PBL Activity), Scale Lab- Torque and Equilibrium (Physics Aviary), Suspension Bridge (Physics Aviary), Rotational Equilibrium (Physics Aviary), Finding Mass from Torque (Physics Aviary), TIPERs tasks (torque and equilibrium)
selected questions and problems from textbook (and via Mastering Physics ™)- chapter 7

Rotational Motion (Chapter 8)

Rotational kinematics
Torque and angular acceleration
Rotational inertia (moment of inertia)
Newton's 2nd law for rotation
Rotational kinetic energy and applications in energy conservation
Angular momentum and conservation of angular momentum

Suggested Activities

Net Torque (Physics Aviary), Walk the Plank (Physics Aviary), Student-designed experiment- Torque and Angular Acceleration (Vernier LoggerPro™ and sensors), Demo w/class pre-debate: downhill race, Demo/group activity- Conservation of Angular Momentum (Vernier LoggerPro™ and sensors), Conservation of Linear and Angular Momentum During a Collision (Direct Measurement Video Activity), selected questions and problems from textbook (and via Mastering Physics™)- chapter 8, TIPERs (torque, angular acceleration)

Further Information regarding suggested activities:

❖ PBL Group Challenges: Students can be presented with a problem-based-learning challenge for impulse-momentum material, (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.

❖ Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

❖ Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm-ups, computer labs, independent work, or assessments).

- Physics Aviary (Frank McCulley)
- Direct Measurement Videos (Peter Bohacek)

❖ Use of TIPERs tasks (see Resources)

❖ Use of Mastering Physics™ Activities/Assignments
- Online resources for Chapter 7 & 8 (including practice questions, practice problems, and video tutor demonstrations)
- Teacher-selected questions and problems for independent work (chapter 7 & 8)
- Students will read textbook content via e-book (chapter 7 & 8)

❖ Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete. Alternately, projects that include applications of the concepts in this unit may be assigned later in the year, as culminating projects.
- Example: Mousetrap powered boat, Rube Goldberg device

Resources:

Bohacek, Peter. "Conservation of Linear and Angular Momentum During a Collision." •*Direct Measurement Videos*. Science Education Resource Center, 06 July 2017. Web. 16 Aug. 2017.

Etkina, Eugenia, et al. College Physics. Pearson, 2014.
Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

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Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): **AP Essential Knowledge Focus Statement** • The presence of a net torque along any axis will cause a rigid system to change its rotational motion about that axis. (3.F.2)	
4.0	**Students will be able to:** • Design and conduct an experiment (with very little instructor assistance) by which the mathematical relationship between net torque, moment of inertia, and angular acceleration can be determined. • Analyze the data from their experiment using graphical analysis and mathematical modeling.
3.0	**Students will be able to:** • Determine the direction (and sign) of individual torques and net torque. • Calculate net torque from description and/or diagram of a scenario in which multiple forces are applied to an extended body. • Calculate the angular acceleration of an extended body from a description and/or diagram of a scenario in which multiple forces are applied to that extended body. • Suggest an experimental design and data collection strategy to show the mathematical relationship between net torque, moment of inertia, and angular acceleration.
2.0	**Students will be able to:** • Define/describe the following terms/concepts: force, lever arm, torque, angular acceleration, angular velocity, angular displacement • Perform a torque calculation given force, distance from axis of rotation, and angle of application • Determine force or distance from axis given torque and one of the other variables in the equation $\tau = rFsin\varphi$. • Calculate the net torque on an object given its angular acceleration and moment of inertia. • Calculate the moment of inertia for an extended body by choosing the appropriate equation from a list of moment of inertia equations. • Calculate the angular acceleration or the moment of inertia for a body given the net torque on that body and one of the other variables in the equation $\tau = I\alpha$ • Sketch a basic extended body diagram that shows the location and relative sizes (and angles of application) of the forces exerted on the extended body, as well as the indication of an appropriated axis of rotation.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).

	• Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/ modelcurriculum/ela/ELLSupport.pdf)*	• Coordinate with ELL advisors to modify activities where appropriate. • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
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- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)
- WHST.11-12.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)

- WHST.11-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3), (HS-PS2-5)
- WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1), (HS-PS2-5)

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)
- MP.4: Model with mathematics. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)
- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1), (HS-PS2-4)
- HSA.SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1), (HS-PS2-4)
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1), (HS-PS2-2)
- HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1), (HS-PS2-2)
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1), (HS-PS2-2)
- HSF-IF.C.7: Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1)
- HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

Unit Title: Oscillatory Motion, Waves, and Sound

Unit Description:

Oscillatory motions and waves are ubiquitous in our universe. These include waves along strings, water waves, seismic waves, sound, light, and other EM waves, as well as those in mechanical systems and in technology. Research has even recently confirmed the propagation of gravitational waves, predicted over a century ago by Einstein. This unit will provide students with opportunities to investigate basic properties of oscillatory motion and waves, and to explore some of the ramifications of these properties and behaviors on our abilities to study the universe, diagnose medical conditions, compose and create music, and create new technologies.

Unit Duration: 3-4 weeks

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 3: The interactions of an object with other objects can be described by forces.
  - Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma\vec{F}}{m}$. (3.B)
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
  - The energy of a system is conserved. (5.B)

- 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.
    - A wave is a traveling disturbance that transfers energy and momentum. (6.A)
    - A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy. (6.B)
    - The direction of propagation of a wave such as light may be changed when the wave encounters an interface between two media. (6.E)
    - Electromagnetic radiation can be modeled as waves or as fundamental particles. (6.F)

NGSS-NJLS

- Motion and Stability: Forces and interactions (HS-PS2.4)
- Energy (HS-PS3.5)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects. (5.B.1)
- A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. (5.B.2)
- A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces. (5.B.3)
- The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of configuration of the objects that make up the system. (5.B.4)
- For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum. (6.A.2)
- The amplitude is the maximum displacement of a wave from its equilibrium value. (6.A.3)
- Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves. (6.A.4)
- For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time. (6.B.1)
- For a periodic wave, the wavelength is the repeat distance of the wave. (6.B.2)
- A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave. (6.B.3)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Definitions of Energy (HS-PS3.A)
- Conservation of Energy (HS-PS3.B)
- Relationship Between Energy and Forces (HS-PS3.C)
- Forces and Motion (HS-PS2.A)
- Wave Properties (HS-PS4.A)
- Information Technologies and Instrumentation (HS-PS4.C)

Understandings:

Students will understand that…

- Oscillatory motions repeat at regular intervals, and can be described in terms of period and frequency.
- Some oscillations are categorized as simple harmonic motion.
- Simple harmonic motion requires that a restoring force act opposite the displacement of the system in order to bring it back to equilibrium. No dissipative or driving forces act on the system.
- Mechanical energy is conserved in a simple harmonic oscillator. If motion is damped or driven,

Essential Questions:

- What are oscillations?
- What are characteristics of oscillatory motion?
- How is simple harmonic motion different from other kinds of oscillatory motion?
- What is meant by “restoring force”? What are examples of restoring forces?
- How can Newton’s laws of motion and the conservation of energy be applied to an oscillating system?
- What is the relationship between period and frequency for an oscillator?

then mechanical energy is either lost (as heat) or gained (due to external work) by the system. • Acceleration is at maximum when the system is at maximum displacement, since the restoring force will be greatest there. • Frequency and period are reciprocals of one another. • A wave is a disturbance in a medium (or in a field) that transfers energy, rather than matter, from place to place. • Mechanical waves require a medium while electromagnetic waves do not. • More than one wave can occupy a location at a time (superposition). When waves coincide, they interfere momentarily, then continue on in their prior state. • Waves can interfere such that, at certain frequencies, “standing wave patterns” (or harmonics) can form (for example, along a string or in a column of air). • Wave amplitude is the maximum displacement of medium particles from equilibrium as the wave travels through. • Wavelength is the distance between successive crests or troughs. • Wave speed is equal to frequency times wavelength. • Wave speed is dictated by properties of the medium through which waves travel. • The energy of a wave is proportional to the square of its amplitude. • Mechanical waves are classified as transverse and longitudinal. • Sound is a longitudinal wave, propagated by compressions and rarefactions in the medium through which it travels. • The speed of sound depends on the medium, including its temperature. • The speed of sound can be measured using echoes or standing wave patterns. • Human hearing is approximately logarithmic, and that is why we use the decibel system to describe loudness, rather than absolute intensity measurements. • The Doppler effect is an apparent frequency change due to the relative motion of the observer and source. • Doppler effect applications include weather radar, astronomical observations, and everyday sound pitch “changes”.	• What factors affect the period/frequency of a harmonic oscillator? Are these the same factors for all oscillators? • What happens to oscillatory in the presence of other forces than just the restoring force of the system? • What is a wave? • How do mechanical waves differ from EM waves, and how are they similar? • What are the “parts” of a generalized wave? • What are examples of mechanical waves? • What happens when two or more waves occupy the same space? • How do waves interact with the media through which they travel? • What happens when a wave enters a different medium from the one in which it is traveling? • What is wave interference, and what are some everyday examples of wave interference? • What is a *standing wave*? • What kind of mechanical wave is a sound wave? • How does the intensity of sound waves change with distance from a source? What factors affect sound intensity? • Why do we use sound intensity level (in dB) to “rank” sounds, rather than sound intensity (in W/m^2)? • How can the speed of sound be measured using interference patterns? • What is the Doppler Effect? What kinds of waves illustrate it, and what are some examples of the Doppler Effect in nature and in engineered systems?
Assessment Evidence	
Performance Tasks: **APP1 Learning Objectives: (**Johnson, 2017) The student is able to… • predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. (3.B.3.1)	**Other Evidence:** Daily informal and formal formative assessments of student activities, such as: • Warm up problems/questions • Whiteboarding/problem solving sessions • Peer tutoring • Lab work (including mathematical modeling)

• design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force. (3.B.3.2) • analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown. (3.B.3.3) • construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. (3.B.3.4) • use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave. (6.A.1.1) • describe representations of transverse and longitudinal waves. (6.A.1.2) • describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples. (6.A.2.1) • use graphical representation of a periodic mechanical wave to determine the amplitude of the wave. (6.A.3.1) • and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example. (6.A.4.1) • a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation. (6.B.1.1) • use a visual representation of a periodic mechanical wave to determine wavelength of the wave. (6.B.2.1) • design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. (6.B.4.1) • create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer. (6.B.5.1) • use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses. (6.D.1.1) • design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves). (6.D.1.2) • design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium. (6.D.1.3) • analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in	In class and independent quizzes (appropriate topics include): • Simple Harmonic Motion concepts and problems • Waves concepts and problems • Sound concepts and problems Independent work such as: • Completion of online and written problem sets • Completion of TIPERs tasks • Partial and/or full formal laboratory reports • Participation in online discussion groups Test • Simple Harmonic Motion, Waves and Sound

one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes. (6.D.2.1)

- refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively. (6.D.3.1)
- predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes (6.D.3.2)
- plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air. (6.D.3.3)
- describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region. (6.D.3.4)
- challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region. (6.D.4.1)
- calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments. (6.D.4.2)
- use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats. (6.D.5.1)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Benchmarks:

Lab: Measuring the Speed of Sound
Test: Simple Harmonic Motion, Waves and Sound

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 19 & 20.

Oscillatory Motion (Chapter 19)

Topics
Observations of vibrational motion
Hooke's Law
Kinematics and dynamics of vibrational motion
Energy in simple harmonic motion
Damped and driven motion, resonance

Analysis of systems with spring-mass oscillators and systems with pendulums

Suggested Activities
Oscillations Lab (Vernier Physics with Video Analysis©), Hooke's Law & Energy of SHM Lab (Mass-spring oscillator- using Vernier LoggerPro™, LabQuest2™, and motion detectors), Pendulum Lab (Student-design lab, using Vernier LoggerPro™, LabQuest2™, and photogates), Finding ***g*** From a Pendulum (Physics Aviary), Collision to Oscillation (Physics Aviary), Energy of a Displaced Pendulum (Physics Aviary), Problem sets & video tutorials from Mastering Physics™- Chapter 19

Waves (Chapter 20)

Topics
Pulses and wave motion
Mathematical descriptions of waves
Dynamics of wave motion, wave speed
Energy, power, and intensity of waves
Reflection and impedance
Superposition and interference

Suggested Activities
Wave demonstrator kit (Slinky™, tight spring set, students generate different wave types and interference patterns), Wave Speeds (Vernier Physics with Video Analysis©), Wave Superposition (Vernier Physics with Video Analysis©), wave generator demo (motor on string), Wave Properties from Graph (Physics Aviary), Interfering Waves (Physics Aviary), Wave Equations (Physics Aviary), Gravitational Wave Astronomy (use current gravitational wave information-see resources), Problem sets & video tutorials from Mastering Physics™- Chapter 20

Sound (Chapter 20)

Topics
Sound waves
Huygens' principle
Pitch, frequency, standing waves
Standing waves on a string
Standing waves in an air column
Doppler effect and applications

Suggested Activities
Sound Wave Problem (Physics Aviary), Sound Intensity Problem (Physics Aviary), Standing Wave on a String (Physics Aviary), Speed of Sound Lab (using echoes- Vernier LoggerPro™, LabQuest2™ and sensors), Speed of Sound Lab (using resonance tubes and tuning forks), Doppler Effect (Physics Aviary), Waves and Sound (PhET), Doppler Effect demonstration (apparatus), Doppler Sound Lab (Vernier Physics with Video Analysis©), Problem sets & video tutorials from Mastering Physics™- Chapter 20

Further Information regarding suggested activities:

- PBL Group Challenges: Students can be presented with a problem-based-learning challenge for waves and sound material, (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.

- Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

- Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm-ups, computer labs, independent work, or assessments).

  - Physics Aviary (Frank McCulley)
  - Direct Measurement Videos (Matt Vonk)
  - PhET (phet.colorado.edu)

- Use of TIPERs tasks (see Resources)

- ❖ Use of Mastering Physics™ Activities/Assignments
  - Online resources for chapters 19 & 20 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (chapters 19 & 20)
  - Students will read textbook content via e-book (chapters 19 & 20)

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.
Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

“Hands-on Gravitational Wave Astronomy: Extraction of Astrophysical Information from Simulated Signals.” Center for Gravitational Wave Physics - Education and Outreach, Pennsylvania State University, 2007, cgwp.gravity.psu.edu/outreach/activities/handson_activity/.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

Vonk, Matt. “Keep in Time - Student Activity.” *Activities*, University of Wisconsin River Falls, 20 Dec. 2014, serc.carleton.edu/dmvideos/activities/keep_in_time.html.

McCulley, Frank. The Physics Aviary. The Physics Aviary. N.p., 2017. Web. 28 June 2017. <http://www.thephysicsaviary.com/>.

PhET Interactive Simulations. PhET. University of Colorado, 2017. Web. 28 June 2017. <https://phet.colorado.edu/>.

Physics, Institute of. Problem Based Learning Modules. Problem Based Learning Modules, Institute of Physics, www.iop.org/education/higher_education/stem/problem-based/page_55225.html.

Problem Based Learning for College Physics-A Website of Lifelike Activities. Problem Based Learning for College Physics-A Website of Lifelike Activities, pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720.

Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): AP Essential Knowledge Statements • A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave. (6.B.3) NGSS/NJLS • The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4.A)	
4.0	**Students will be able to:** • Analyze a waveform (graph) to develop the mathematical formula representing the behavior of the wave.
3.0	**Students will be able to:** • Locate amplitude and equilibrium positions on a graph of a wave. • Determine the period, frequency, and wavelength of a wave from its graph.

	• Describe similarities between wave motion graphs and graphs of pendulum or spring mass oscillator motion.
2.0	**Students will be able to:** • Define transverse wave, longitudinal wave, amplitude, equilibrium, wavelength, period and frequency, as they relate to waves. • Calculate period from frequency, and vice versa. • Differentiate between a sin curve and a cosine curve. • Differentiate graphs of oscillatory motion from those of linear motion. • Give examples of mechanical waves.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See **http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf**)*	• Coordinate with ELL advisors to modify activities where appropriate. • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered

	• Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1)

Common Core State Standards Connections Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS4-1)
- MP.4: Model with mathematics. (HS-PS4-1)
- HSA-SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1)
- HSA-SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1)
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1)

Unit Title: Electricity and Magnetism

Unit Description:

Electrical charges, the forces that arise between them, and the manipulation of their behavior to design useful circuits will be the main topics of this unit. Students will begin with investigation into the nature of charge as well as how objects become charged. They will describe, qualitatively, the electric field around a stationary charge or set of charges, and learn that the interactions among such fields give rise to the electrostatic forces that are so important in natural and engineered systems. The concept of current and moving charge will then be studied, but limited to basic battery-resistor (or bulb) DC circuits for mathematical analysis and only a qualitative description of capacitance and basic AC circuits. Students will also experience a brief introduction to electromagnetism to the extent that they will be able to describe how a current can generate a magnetic field and how changing magnetic fields can generate current. Deeper analysis will be available for further independent study by students interested in the material (specifically, juniors planning to take AP Physics C in their senior year or seniors planning to enroll in a college course in electricity and magnetism in their freshman year).

Unit Duration: 6 weeks *(This time frame will likely straddle the AP Review and AP Exam.)*

Desired Results

Standard(s):

AP Physics 1Framework (Johnson, 2017)

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
  - Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge. (1.B)
- Big Idea 2: Fields existing in space can be used to explain interactions.
  - A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena. (2.A)
  - An electric field is caused by an object with electric charge. (2.C)
  - A magnetic field is caused by a magnet or a moving electrically charged object. Magnetic fields observed in nature always seem to be produced either by moving charged objects or by magnetic dipoles or combinations of dipoles and never by single poles. (2.D)
- Big Idea 3: The interactions of an object with other objects can be described by forces.
  - At the macroscopic level, all forces can be categorized as either long range (action-at-a-distance) forces or contact forces. (3.C)
  - Certain types forces are considered fundamental. (3.G)
- Big Idea 4: Interactions between systems can result in changes in those systems.
  - The electric and magnetic properties of a system can change in response to the presence of, or changes in, other objects or systems. (4.E)
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
  - Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. (5.A)

NGSS-NJLS

- Motion and Stability: Forces and interactions (HS-PS2.4)
- Energy (HS-PS3.5)

Indicators:

APP1 Essential Knowledge statements: (Johnson, 2017)

- The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom. Coulomb's law is qualitatively useful for understanding the structure of the atom. (1.B.1)
- There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge. The presence of a net torque along any axis will cause a rigid system to change its rotational motion about that axis. (1.B.2)
- The magnitude of the electric force $\vec{F}$ exerted on an object with electric charge q by an electric field $\vec{E}$ is $\vec{F} = q\vec{E}$ (2.C.1)
- The magnitude of the electric field vector is proportional to the net electric charge of the object(s) creating that field. (2.C.2)
- The magnetic field exerts a force on a moving electrically charged object. That magnetic force is perpendicular to the direction of velocity of the object and to the magnetic field and is proportional to the magnitude of the charge, the magnitude of the velocity, and the magnitude of the magnetic field. It also depends on the angle between the velocity and the magnetic field vectors. Treatment is quantitative for angles of 0°, 90°, or 180° and qualitative for other angles. (2.D.1)
- The magnetic field vectors around a straight wire that carries electric current are tangent to concentric circles centered on the wire. The field has no component toward the current-carrying wire. (2.D.2)
- Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge. (3.C.2)
- A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet. (3.C.3)
- Electromagnetic forces are exerted at all scales and can dominate at the human scale (3.G.2)
- Changing magnet flux induces an electric field that can establish an induced emf in a system. (4.E.2)
- For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. (5.A.2)

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Definitions of Energy (HS-PS3.A)
- Conservation of Energy (HS-PS3.B)
- Relationship Between Energy and Forces (HS-PS3.C)
- Forces and Motion (HS-PS2.A)

Understandings:

Students will understand that…

- Charge is a fundamental property of a system or object.
- There are two types of charge, positive and negative.
- Charge is quantized.
- Charge is a conserved quantity.
- Opposite charges attract; like charges repel.
- Charging involves moving electrons from one place to another, not creating new ones.
- Typically, electrons (not protons) are transferred during charging of objects. Movement of ions in biochemical systems can be responsible for buildup of charge in one location relative to another.
- Two ways to charge an object are conduction and induction. These can be performed with simple objects and systems.
- Every charge is associated with an electric field, which extends infinitely out from the charge.
- Electric field strength is directly proportional to the charge magnitude, and inversely proportional to the square of the distance from the charge.
- The electrostatic force is mathematically described by Coulomb's law: $\overrightarrow{F_E} = \frac{kqq}{r^2}$.
- The net electric field at a location can be associated with a scalar quantity known as electric potential.
- A difference in electric potential from one point to another is required for charges to be moved by the electric field between those points. This difference in potential is generally called voltage.
- Materials can be classified generally as conductors and insulators. Conductors (usually metals) allow electrons to move easily from place to place, which is necessary for current.
- A conductor has a resistivity, which depends on the material.
- Resistance is determined by the resistivity, temperature, and geometry of a wire.
- Current is the rate at which a quantity of charge moves through a cross sectional area of a conductor.
- In Ohmic systems, current is directly proportional to voltage and inversely proportional to resistance.
- Kirchhoff's Loop Rule is a manifestation of the law of conservation of energy.
- Kirchhoff's Junction Rule is a manifestation of the law of conservation of charge.

Essential Questions:

- What is electric charge?
- How do objects become charged?
- What are some examples of charge separation in nature?
- How do batteries and capacitors become sources of electrical energy?
- Do charged objects or systems exert forces on other charged objects or systems? What is the mathematical model for such interactions?
- How can the force between charged bodies be predicted?
- What is an electric field? What is the relationship between the electric field and electric force?
- What is current? How does it arise? What conditions are necessary for current to flow?
- How are electric field, electric potential, and current related?
- How can electrical circuits be modeled by "water circuits"? What are their similarities and differences?
- How do the laws of conservation of charge and conservation of energy apply to electrical circuits?
- What are Kirchhoff's rules, and how are they used to analyze circuits?
- What are some properties of magnetic materials?
- How is Earth like a magnet?
- What are the functions of Earth's magnetic field?
- How does the presence of a magnetic field influence the behavior of a moving charge?
- How do magnetic fields and currents explain a dynamo feedback system?
- How are currents and magnetic fields related, and what happens to one when the other changes?
- How are principles in electromagnetism use to create motors and generators?

• Magnetic materials are those in which electron spin domains are uniformly aligned in a particular direction, giving the material polarity. • To date, no mono-polar magnets have been discovered. • Opposite poles attract; like poles repel. • A charge traveling in a magnetic field will experience a magnetic force perpendicular to its motion, as long as some component of its velocity is perpendicular to the field. • Earth's magnetic field is believed to be maintained by a dynamo effect within the molten core. It changes over time, resulting in periodic reversals, which are recorded in geologic formations. • A current produces a magnetic field concentric to the wire, and decreasing with distance from the center of the wire. The direction of the current dictates whether the field will run clockwise or counterclockwise around the wire. • A changing magnetic flux results in electric current. • The previous statements form the basis of electromagnets, motors, and generators.	

Assessment Evidence

Performance Tasks: **APP1 Learning Objectives: (**Johnson, 2017) The student is able to… • make claims about natural phenomena based on conservation of electric charge. (1.B.1.1) • make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. (1.B.1.2) • construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices. (1.B.2.1) • challenge the claim that an electric charge smaller than the elementary charge has been isolated (1.B.2.1) • use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges. (3.C.2.1) • connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. (3.C.2.2) • define open and closed systems for everyday situations and apply conservation concepts for energy, charge and linear momentum to those situations. (5.A.2.1) • choose and justify the selection of data needed to determine resistivity for a given material. (1.E.2.1) • construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff's loop rule). (5.B.9.1) • apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of	**Other Evidence:** Daily informal and formal formative assessments of student activities, such as: • Warm up problems/questions • Whiteboarding/problem solving sessions • Peer tutoring • Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): • Charge and Coulomb's Law concepts and problems • DC Circuits concepts and problems • Magnetism basic concepts Independent work such as: • Completion of online and written problem sets • Completion of TIPERs tasks • Partial and/or full formal laboratory reports • Participation in online discussion groups Test • Electricity (and Magnetism- time permitting)

Kirchhoff's loop rule ($\Sigma \Delta V=0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. (5.B.9.2) • conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. (5.B.9.3) • conservation of electric charge (Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed. (5.C.3.1) • design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed. (5.C.3.2) • a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. (5.C.3.3) Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.	

Benchmarks:

Lab: Circuit Analysis
Test: Electricity (and Magnetism- time permitting)

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 14-18.

Charges, Electric Force, and Fields (Chapter 14 & 15) (included on AP Exam)

Topics
What is charge?
Conductors and non-conductors
Conduction, induction and polarization
Interactions between charged objects
Coulomb's law and the electrostatic force
Electric potential energy
Electric field vs gravitational field
Electric potential

Suggested Activities
Sticky tape charge investigation (hands on, no sensors or probes), online Charge Activity Set (PhET): Balloons and Static Electricity, Charges and Fields, Electric Field Hockey, and John Travoltage, Millikan Oil Drop Lab (Physics Aviary), Electroscope charging demos, Coulomb's Law Video Analysis Lab (Vernier Physics with Video Analysis©), Van de Graff generator (if available), Space Around a Charge Activity (Physics Aviary), Problem sets & video tutorials from Mastering Physics™- Chapters 14 and 15

Electrical Circuits (Ch 16) (included on AP Exam)

Topics
Electric current

Batteries and EMF
Making and representing simple circuits
Ohm's law
Joule's law and electric power
Kirchhoff's rules
Series and parallel resistors
Circuit analysis
Properties of Resistors
Applications (circuit breakers, fuses, superconductors, analogy to human circulation)

Suggested Activities
Internal Resistance of a Battery Lab (Physics Aviary), Resistance of a Wire (Physics Aviary), Electrical Equivalent of Heat (Physics Aviary), Ohm's Law Video Analysis Lab (Vernier Physics with Video Analysis©), Series Circuit (Physics Aviary), Parallel Circuit (Physics Aviary), Parallel in Series Circuit (Physics Aviary), Circuit Analysis- Ohm's Law Lab (Vernier Circuit Board™ and digital multimeters), Resistance of Play-doh™ Lab (multimeters, etc.), Problem sets & video tutorials from Mastering Physics™- Chapter 16

Magnetism and Electromagnetism (Ch 17 & 18) (not included on AP Exam)

Topics (These topics may be delayed until after the AP exam, depending on time limitations.)
Magnetic force/interactions
Magnetic field
Magnetic force on a charge
Magnetic force on a current-carrying wire
Magnetic field produced by electric currents
Inducing a current
Magnetic flux
Making a motor
Making a generator
Applications (mass spectrometry, motors, generators, etc.)

Suggested Activities
Visualizing a magnetic field (hands-on activity),Force on a Charge in a Magnetic Field (Physics Aviary),Mass and KE of a Particle Trapped in a Magnetic Field (Physics Aviary) Force on a wire demonstration, Build a motor activity (hands-on, student inquiry), Magnetic Field of a Slinky™ (Vernier LoggerPro© with sensors and probes), Build an electromagnet activity (hands-on, student inquiry), Generating electricity from motion (demonstrations of current induction via changing B-flux, use bar magnet demo and "Faraday flashlight, as well as hand generator, if available), Faraday's Electromagnetic Lab (PhET), Problem sets & video tutorials from Mastering Physics™- Chapters 17 and 18

Further Information regarding suggested activities:

❖ Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm-ups, computer labs, independent work, or assessments).

- Physics Aviary (Frank McCulley)
- PhET (phet.colorado.edu)

❖ Use of TIPERs tasks (see Resources)

❖ Use of Mastering Physics™ Activities/Assignments
- Online resources for chapters 14-18 (including practice questions, practice problems, and video tutor demonstrations)
- Teacher-selected questions and problems for independent work (chapters 14-18)
- Students will read textbook content via e-book (chapters 14-18)

❖ Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete. Alternately, projects that include applications of the concepts in this unit may be assigned later in the year, as culminating projects.
- Example: Mousetrap powered boat, Rube Goldberg device

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.
Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

McCulley, Frank. The Physics Aviary. The Physics Aviary. N.p., 2017. Web. 28 June 2017. <http://www.thephysicsaviary.com/>.

PhET Interactive Simulations. PhET. University of Colorado, 2017. Web. 28 June 2017. <https://phet.colorado.edu/>.

Physics, Institute of. Problem Based Learning Modules. Problem Based Learning Modules, Institute of Physics, www.iop.org/education/higher_education/stem/problem-based/page_55225.html.

Problem Based Learning for College Physics-A Website of Lifelike Activities . Problem Based Learning for College Physics-A Website of Lifelike Activities , pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720.

Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s):
AP Essential Knowledge Statements
- Electric charge is conserved. (1.B.1)
- Kirchhoff's Loop rule describes conservation of energy in electrical circuits. (5.B.9)

NGSS/NJLS
- Definitions of Energy: "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (HS-PS3.A)

4.0	**Students will be able to:** • Use Kirchhoff's rules and Ohm's law to perform a complex circuit analysis. • Use understandings about circuits to predict the brightness of bulbs in various configurations within DC circuits.
3.0	**Students will be able to:** • Write Kirchhoff's Loop rule equations for various circuits or parts of circuits. • Write Kirchhoff's Junction rule equations for various circuits or parts of circuits. • Calculate the total resistance for a circuit that involve both series and parallel components. • Perform a hands-on circuit lab, in which a multimeter is used to measure currents and voltage values at various locations in the circuit. • Use Ohm's law to determine the potential difference across a circuit element or group of elements. • Calculate the equivalent resistance for a group of resistors or bulbs in series. • Calculate the equivalent resistance for a group of resistors or bulbs in parallel.
2.0	**Students will be able to:** • Identify Kirchhoff's Loop rule as a manifestation of the law of conservation of energy. • Identify Kirchhoff's Junction rule as a manifestation of the law of conservation of charge. • Define and/or describe the following: charge, current, resistance, electric potential, voltage, resistivity, conservation of energy, circuit, parallel wiring, series wiring
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**

0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• Coordinate with ELL advisors to modify activities where appropriate. • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here.

	Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)
- WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4), (HS-PS3-5)
- WHST.9-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4), (HS-PS3-5)
- SL.11-12.5: Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1), (HS-PS3-2), (HS-PS3-5)

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- MP.4: Model with mathematics. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1), (HS-PS3-3)
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1), (HS-PS3-3)
- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1), (HS-PS3-3)

Unit Title: Topics in Fluid Mechanics and Thermodynamics

Unit Description:

Students will apply Newtonian mechanics and energy conservation to fluid systems. Specifically, the buoyant force will be revisited and further developed. Hydrostatic pressure, continuity of flow, and Bernoulli's principle will also be examined. Concepts in thermodynamics will include heat transfer, thermal expansion, and work done by/on a gas. Heat engines (cyclic processes) will be emphasized.

Note: This unit is included to meet the requirements of the HS Plus Program for dual credit. If that program becomes unavailable or otherwise is not continued in our district, this unit could be shortened or left out to provide more time for other topics (such as optics, or a fuller treatment of electromagnetism.)

Unit Duration: 4 weeks

Desired Results

Standard(s):

AP Physics 2 Framework (Johnson, 2017)

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
  - Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material. (1.E)
- Big Idea 3: The interactions of an object with other objects can be described by forces.
  - At the macroscopic level, all forces can be categorized as either long range (action-at-a-distance) forces or contact forces. (3.C)
- Big Idea 4: Interactions between systems can result in changes in those systems.
  - Interactions with other objects or systems can change the total energy of a system. (4.C)
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
  - Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. (5.A)
  - The energy of a system is conserved. (5.B)
  - Classically, the mass of a system is conserved. (5.F)
- Big Idea 7: The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.
  - The properties of an ideal gas can be explained in terms of a small number of macroscopic variables including temperature and pressure. (7.A)
  - The tendency of isolated systems to move toward states with higher disorder is describe by probability. (7.B)

NGSS-NJLS

- Motion and Stability: Forces and interactions (HS-PS2.4)
- Energy (HS-PS3.5)

Indicators:

APP2 Essential Knowledge statements: (Johnson, 2017)

- Matter has a property called density. (1.E.1)
- Matter has a property called thermal conductivity. (1.E.3)
- Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. (3.B.2)
- Gravitational force describes the interaction of one object that has mass with another object that has mass. (3.C.1)
- The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy. (4.C.1)
- Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work. (4.C.2)
- Energy is transferred spontaneously from a higher temperature system to a lower temperature system. This process of transferring energy is called heating. The amount of energy transferred is called heat. (4.C.3)
- For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings. (5.A.2)
- The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of configuration of the objects that make up the system. (5.B.4)
- Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. (5.B.5)
- Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer called heat. (5.B.6)
- Bernoulli's equation describes the conservation of energy in fluid flow. (5.B.10)
- The continuity equation describes conservation of mass flow rate in fluids. (5.F.1)
- The first law of thermodynamics is a special case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. (5.B.7)
- The pressure of a system determines the force that the system exerts on the walls of its container and is a measure of the average change in the momentum or impulse of the molecules colliding with the walls of the container. (7.A.1)
- The temperature of a system characterizes the average kinetic energy of its molecules. (7.A.2)

- In an ideal gas, the macroscopic (average) pressure (*P*), temperature (*T*) and volume (*V*), are related by the ideal gas law $PV=nRT$.
- The approach to thermal equilibrium is a probability process. (7.B.1)
- The second law of thermodynamics describes the change in entropy for reversible and irreversible processes. (7.B.2)

Johnson, Trinna, et al. AP Physics 2 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Definitions of Energy (HS-PS3.A)
- Conservation of Energy (HS-PS3.B)
- Relationship Between Energy and Forces (HS-PS3.C)
- Forces and Motion (HS-PS2.A)

Understandings:

Students will understand that…

- fundamental laws of physics apply to fluid systems.
- fluids include liquids, gases and plasmas.
- although the bulk behavior of a fluid system can be examined and predicted, it is really based on the behavior of individual molecular/atomic motions at the microscopic level. A full treatment of such systems required the application of statistical analysis.
- temperature is an indication of the average kinetic energy of the molecules in a sample.
- the total internal energy of a system is changed by the addition or loss of heat and/or by work being done on or by the system.
- the total internal energy of a system is proportional to the temperature of that system.
- as material becomes hotter, it expands at a predictable rate.
- pressure is the ratio of force to area.
- without an input of work on a system, heat will move spontaneously from a warmer to a cooler place.
- an enclosed gas can be heated and caused to expand, then used to do net work on its surroundings; net work done on a gas can be used to move heat to move heat from a cooler location to a warmer one.
- heat engine and refrigerator cycles can be plotted using a *P-V diagram.*
- isothermal processes occur at constant temperature.
- isovolumetric (or isochoric) processes occur at constant volume.
- isobaric processes occur at constant pressure.
- adiabatic processes occur without heat exchange between a system and its surroundings.
- density is the ratio of mass to volume.
- the relative densities of substances dictate the degree to which one will float or sink in the other.
- the buoyant force exerted on an object is equal to the weight of fluid displaced by that object, as per Archimedes' principle.

Essential Questions:

- Why do some clouds become so much tall than others, and why are these clouds associated with storms?
- How do hot air balloons stay airborne for long periods of time?
- Why do our ears "pop" when we travel up or down to different altitudes or depths?
- Why do we only see "the tip of the iceberg"?
- Why do sidewalks and roads have expansion joints?
- What is a heat engine? What is a refrigerator?
- How can the efficiency of a device be determined?
- How does the first law of thermodynamics relate to conservation of energy?
- How is the concentration of carbon dioxide in the atmosphere related to global temperature?
- Why does perspiring cool a human?
- What is entropy, and what is its relevance to the second law of thermodynamics?

- the buoyant force is a result of pressure difference between the top of a body and the bottom of a body in a fluid.
- free body diagrams and force summations can be used to predict the behavior of objects within fluids.
- the pressure from a fluid increase proportionally with depth in that fluid.
- changes in pressure are transmitted evenly throughout a fluid, as per Pascal's principle.
- mass flow rate is constant in laminar flow. The product of cross-sectional area and velocity is constant.
- Bernoulli's principle is a consequence of conservation of energy.
- higher speed flows are associated with lower pressures; slower flows are associated with higher pressures.

Assessment Evidence

Performance Tasks:

APP2 Learning Objectives: (Johnson, 2017)
The student is able to…

- predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction. (1.E.1.1)
- select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. (1.E.1.2)
- design an experiment and analyze data from it to examine thermal conductivity. (1.E.3.1)
- make claims about various contact forces between objects based on the microscopic cause of those forces. (3.C.4.1)
- explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. (3.C.4.2)
- make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level. (4.C.3.1)
- define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. (5.A.2.1)
- describe and make predictions about the internal energy of systems. (5.B.4.1)
- calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. (5.B.4.2)
- make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). (5.B.5.4)
- predict and calculate the energy transfer to (i.e., the work done on) an object or system from

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

In class and independent quizzes (appropriate topics include):

- Thermodynamic processes and heat engines
- Hydrostatics
- Fluid Dynamics

Independent work such as:

- Completion of online and written problem sets
- Completion of TIPERs tasks
- Participation in online discussion groups

Test: Fluid Systems

Project such as (time permitting):

- Design a glove or a greenhouse
- Design and build a boat
- Design and build a mouse trap boat (carried over from previous units)

information about a force exerted on the object or system through a distance. (5.B.5.5) • design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system. (5.B.5.6) • describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation. (5.B.6.1) • qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles. (5.B.7.1) • create a plot of pressure versus volume for a thermodynamic process from given data. (5.B.7.2) • use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics). (5.B.7.3) • use Bernoulli's equation to make calculations related to a moving fluid. (5.B.10.1) • use Bernoulli's equation and/or the relationship between force and pressure to make calculations related to a moving fluid. (5.B.10.2) • Bernoulli's equation and the continuity equation to make calculations related to a moving fluid. (5.B.10.3) • construct an explanation of Bernoulli's equation in terms of the conservation of energy. (5.B.10.4) • make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). (5.F.1.1) • make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. (7.A.1.1) • analyze qualitatively the collisions of a gas molecule with a container wall and determine the cause of pressure, and at thermal equilibrium, to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables. (7.A.1.2) • qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system. (7.A.2.1) • connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes. (7.A.2.2) • from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. (7.A.3.1) • a plan for collecting data to determine the relationships between pressure, volume, and	

temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables. (7.A.3.2) • analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law PV = nRT. (7.A.3.3) • construct an explanation, based on atomic-scale interactions and probability, of how a system approaches (7.B.1.1) • connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes. (7.B.2.1) Johnson, Trinna, et al. AP Physics 2 Course and Exam Description. The College Board, 2017.	

Benchmarks:

Lab: Bernoulli Bottle
Test: Fluid Systems

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 9-13.

Gases and Thermodynamics (Topics from Chapter 9, 12, and 13)

Topics
Pressure
Density
Temperature
Thermal energy
Gas processes
Thermodynamic laws
Heating mechanisms
Irreversible processes
Thermodynamic engines and pumps (heat engines and refrigerators)

Suggested Activities
Thermal exploration (bimetallic strips, conductometer, Hero's engine, ball and ring apparatus, ice melting blocks, hand boiler), Vernier Physics with Video Analysis© Heat Engine Lab, PhET Properties of Gases, Heat Added-Isobaric (Physics Aviary), Heat Added-Isovolumetric (Physics Aviary), Heat Added- Isothermal (Physics Aviary), Work Done in a Cyclic Process (Physics Aviary), Efficiency of Engine (Physics Aviary), Heat Transfer Rate (Physics Aviary), Gas in Box Lab (Physics Aviary), Problem sets & video tutorials from Mastering Physics™- Chapters 9, 12 and 13

Static Fluids (Chapter 10)

Topics
Fluid pressure
Pascal's principle
Atmospheric pressure
Pressure at depth
Buoyant force, Archimedes' principle

Suggested Activities

PhET Buoyancy Lab, Hands-on buoyant force lab, Pressure from Fluid Column (Physics Aviary), Cargo Challenge (Physics Aviary), Percent Submerged Challenge (Physics Aviary), Determining Density of Rock (Physics Aviary), Hydraulic Lift Problem (Physics Aviary), Problem sets & video tutorials from Mastering Physics™- Chapters 10

Fluids in Motion (Chapter 11)

Topics

Fluids moving across surfaces
Flow rate and fluid speed
Causes and types of fluid flow
Bernoulli's equation
Viscous flow
Drag force

Suggested Activities

Bernoulli demonstrations (blowing into inverted funnel to keep ping pong ball suspended, blowing across top/bottom of a sheet of paper), Continuity of Flow (Physics Aviary), Flow Rate Problem (Physics Aviary), Fluid Pressure and Flow (PhET), Bernoulli Bottle (Student designed lab to analyze flow rate and exit speed data for 1 L bottle), Landing Location of a Fluid (Physics Aviary), Coffee Filter Lab (modification of Vernier's LoggerPro™ lab on air resistance), Problem sets & video tutorials from Mastering Physics™- Chapter 11

Further Information regarding suggested activities:

- Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm-ups, computer labs, independent work, or assessments).
  - Physics Aviary (Frank McCulley)
  - PhET (phet.colorado.edu)
- Use of TIPERs tasks (see Resources)
- Use of Mastering Physics™ Activities/Assignments
  - Online resources for chapters 9-13 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (chapters 9-13)
  - Students will read textbook content via e-book (chapters 9-13)
- Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete. Alternately, projects that include applications of the concepts in this unit may be assigned later in the year, as culminating projects.
  - Example: Greenhouse design, Mousetrap powered boat, Rube Goldberg device

Resources:

Etkina, Eugenia, et al. College Physics. Pearson, 2014.
Johnson, Trinna, et al. AP Physics 1 Course and Exam Description. The College Board, 2017.

Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

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Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

McCulley, Frank. The Physics Aviary. The Physics Aviary. N.p., 2017. Web. 28 June 2017. <http://www.thephysicsaviary.com/>.

PhET Interactive Simulations. PhET. University of Colorado, 2017. Web. 28 June 2017. <https://phet.colorado.edu/>.

Physics, Institute of. Problem Based Learning Modules. Problem Based Learning Modules, Institute of Physics, www.iop.org/education/higher_education/stem/problem-based/page_55225.html.

Problem Based Learning for College Physics-A Website of Lifelike Activities . Problem Based Learning for College Physics-A Website of Lifelike Activities , pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720.

Why Project Based Learning (PBL)? Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s):
AP Essential Knowledge Statements

- Bernoulli's equation describes the conservation of energy in fluid flow. (5.B.10)
- The continuity equation describes conservation of mass flow rate in fluids. (5.F.1)

NGSS/NJLS

- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3.B)

4.0	**Students will be able to:** • Apply Bernoulli's principle and the continuity equation to analyze a system. • Design an experiment to determine the flow rate and the theoretical speed of water leaving a small hole near the bottom of a large bottle.
3.0	**Students will be able to:** • Solve a problem requiring the use of Bernoulli's principle. • Solve a problem requiring the use of the continuity equation.
2.0	**Students will be able to:** • Identify Bernoulli's principle as an example of energy conservation. • Identify the continuity equation as an example of mass conservation.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students

Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
Struggling Learners	• Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via Mastering Physics™). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• Coordinate with ELL advisors to modify activities where appropriate.

	• Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504	• Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)
- WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4), (HS-PS3-5)
- WHST.9-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4), (HS-PS3-5)
- SL.11-12.5: Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1), (HS-PS3-2), (HS-PS3-5)

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- MP.4: Model with mathematics. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1), (HS-PS3-3)
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1), (HS-PS3-3)
- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1), (HS-PS3-3)

Unit Title: Optics

Unit Description:

Students will explore the nature and behavior of light, mainly through examining ray (geometric) optics. If time permits, activities will also include physical optics.

Note: This unit is included as an "extra" unit, to be used if time permits. Instructors may opt to do a modern physics lesson or lessons in place of this unit. This material is not required by College Board for the AP Exam or by the High School Plus program. As such, if WTHS no longer participates in the High School Plus program, the fluid systems unit could be shortened, leaving more time for this unit.

Unit Duration: ~2 weeks

Desired Results

Standard(s):

AP Physics 2 Framework (Johnson, 2017)

- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as mathematical model for the description of other phenomena.
    - A wave is a traveling disturbance that transfers energy and momentum. (6.A)
    - A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy. (6.B)
    - Only waves exhibit interference and diffraction. (6.C)
    - The direction of propagation of a wave such as light may be changed when the wave encounters an interface between two media. (6.E)
    - Electromagnetic radiation can be modeled as waves or as fundamental particles. (6.F)

NGSS-NJLS

- Waves and Electromagnetic Radiation (HS-PS4)

Indicators:

APP2 Essential Knowledge statements: (Johnson, 2017)

- For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum. (6.A.2)
- When light travels from one medium to another, some of the light is transmitted, some is reflected, and some is absorbed. (6.E.1)
- When light hits a smooth reflecting surface at an angle, it reflects at the same angle on the other side of the line perpendicular to the surface (specular reflection); this law of reflection accounts for the size and location of images seen in mirrors. (6.E.2)
- When light travels across a boundary from one transparent material to another, the speed of propagation changes. At a non-normal incident angle, the path of the light ray bends closer to the perpendicular in the optically slower substance. This is called refraction. (6.E.3)
- Types of electromagnetic radiation are characterized by their wavelengths, and certain ranges of wavelength have been given specific names. These include (in order of increasing wavelength spanning a range from picometers to kilometers) gamma rays, x-rays, ultraviolet, visible light, infrared, microwaves, and radio waves. (6.F.1)

- Electromagnetic waves can transmit energy through a medium and through a vacuum. (6.F.2)
- The nature of light requires that different models of light are most appropriate at different scales. (6.F.4)

Johnson, Trinna, et al. AP Physics 2 Course and Exam Description. The College Board, 2017.

NGSS- NJLS

- Wave Properties (HS-PS4.A)
- Electromagnetic Radiation (HS-PS4.B)
- Information Technologies and Instrumentation (HS-PS4.C)

Understandings:

Students will understand that…

- Visible light is a form of electromagnetic radiation, and displays properties of wave behavior and properties of particle behavior.
- EM radiation can be used to transmit information, as well as energy.
- The intensity of light decreases as the inverse square of the distance from the source.
- The speed of light in vacuum is the universal "speed limit".
- The speed of light varies depending on the medium through which it moves. When light (and all other kinds of waves) encounters a boundary between media, its speed changes, and its path bends.
- Light can be reflected, refracted, diffracted, and polarized.
- Snell's law can be used to analyze the behavior of light as it moves between media.
- Reflected light always leaves a surface at the same angle to the normal that it was incident on the surface (angle of incidence=angle of reflection).
- The refractive properties of lenses can be used for vision correction.
- Total internal reflection is the basis behind fiber-optic technologies.
- There are many technical applications of the diffraction and polarization of light. Many medical and information technologies rely on these behaviors.

Essential Questions:

- What is light?
- Why is it often said that "light has a dual nature"?
- How can light and EM radiation be used to transfer information?
- How does the Doppler Effect pertain to light?
- Why do rainbows form?
- How do glasses correct vision?
- How do images form?

Assessment Evidence

Performance Tasks:

APP2 Learning Objectives: (Johnson, 2017)

The student is able to…

- contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation. (6.A.2.2)
- make claims about the diffraction pattern produced when a wave passes through a small opening, and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave. (6.C.2.1)
- qualitatively apply the wave model to quantities that describe the generation of interference

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

In class and independent quizzes (appropriate topics include):

- Snell's Law
- Mirrors and Lenses
- Physical Optics

patterns to make predictions about interference patterns that form when waves pass through a set of openings whose spacing and widths are small compared to the wavelength of the waves. (6.C.3.1) • predict and explain, using representations and models, the ability or inability of waves to transfer energy around corners and behind obstacles in terms of the diffraction property of waves in situations involving various kinds of wave phenomena, including sound and light. (6.C.4.1) • make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. (6.E.1.1) • make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface. (6.E.2.1) • describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media. (6.E.3.1) • data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law). (6.E.3.2) • make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. (6.E.3.3) • plan data collection strategies, and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors. (6.E.4.1) • use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the reflection of light from surfaces. (6.E.4.2) • quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses. (6.E.5.1) • plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses. (6.E.5.2) • make qualitative comparisons of the wavelengths of types of electromagnetic radiation. (6.F.1.1) • describe representations and models of electromagnetic waves that explain the transmission of energy when no medium is present. (6.F.2.1)	Independent work such as: • Completion of online and written problem sets • Completion of TIPERs tasks • Participation in online discussion groups

Johnson, Trinna, et al. AP Physics 2 Course and Exam Description. The College Board, 2017.	

Benchmarks:

Lab: Thin Lens Equation Lab OR Snell's Law Lab

Learning Plan

Learning Activities:

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section. The concepts in this unit are presented in Etkina's College Physics ,1st ed. in chapters 21-24

Topics
Light sources
Propagation of light
Reflection, refraction, Snell's Law
Total internal reflection
Applications (fiber-optics, prisms, color of the sky, etc.)
Mirrors, law of reflection
Lenses, thin lens equation
Ray diagramming
Young's double slit interference
Thin film interference
Diffraction of light
Polarization
Electromagnetic waves

Suggested Activities
Observations with mirrors and lenses (inquiry activity, no special tools or sensors), Snell's Law Lab (hands-on, pins, cardboard and refraction blocks), Snell's Law (Vernier Physics with Video Analysis©), Refraction of Light Lab (Physics Aviary), The Way a Mirror Works Labs (Physics Aviary), Image from a Converging Lens (Physics Aviary), Light Brightness with Distance Lab (Vernier LoggerPro™ with LabQuest2™, light sensor, and Optical Expansion Kit), Real Images and the Thin Lens Equation (Vernier Optical Expansion Kit), Aperture, Light Intensity, and F-Stops (Vernier LoggerPro™ with LabQuest2™, light sensor, and Optical Expansion Kit), Fiber optics PBL Challenge (http://pblprojects.org/RSL/slide03.html), Designing a Spectroscopy Mission (https://www.teachengineering.org/activities/view/cub_spect_activity8)

Further Information regarding suggested activities:

❖ Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class warm-ups, computer labs, independent work, or assessments).

- Physics Aviary (Frank McCulley)
- PhET (phet.colorado.edu)

❖ Use of TIPERs tasks (see Resources)

- Use of Mastering Physics™ Activities/Assignments
  - Online resources for chapters (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (chapters 21-24)
  - Students will read textbook content via e-book (selected sections from chapters 21-24)

Resources:

"Designing a Spectroscopy Mission - Activity." Www.teachengineering.org. Regents of the University of Colorado, 2008. Web. 20 July 2017. <https://www.teachengineering.org/activities/view/cub_spect_activity8>. Contributed by Laboratory for Atmospheric and Space Physics (LASP), University of Colorado Boulder

Etkina, Eugenia, et al. College Physics. Pearson, 2014.
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Hieggelke, Curtis J., Stephen E. Kanim, Thomas L. O'Kuma, and David P. Maloney. *TIPERs: Sensemaking Tasks for Introductory Physics*. Boston: Pearson, 2015. Print.

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Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s): *This section deals with reflection and refraction of light.*

HS-PS-4A: Wave Properties: The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

4.0	**Students will be able to:** • Plan and carry out an investigation into the relationship between light intensity and distance from a light source, with little or no input from instructor, or… • Plan and carry out an investigation into the mathematical relationship between image distance, object distance, and focal length, with little or no input from instructor.
3.0	**Students will be able to:** • Predict (mathematically calculate) the angle of refraction given the angle of incidence for a ray of light moving through a particular set of materials. • Predict the nature of images (location, type, orientation, and size) produced by various types of lenses or mirrors, using ray diagrams. • Use lab equipment (glass block, acrylic block and/or water tank) to determine the index of refraction for a given object. • Explain the conditions for total internal reflection and how it is used in telecommunications • Investigate multiple lens/mirror combinations in use in various areas of science (microscopes, telescopes, etc.).

2.0	**Students will be able to:** • Define the following terms in relation to physics: *reflection; plane mirror; spherical mirror; law of reflection; refraction; index of refraction; Snell's Law; total internal refection; magnification; real image; virtual image; converging lens/mirror; diverging lens/mirror; radius of curvature; focal length; ray diagram.* • Determine the index of refraction for a material. • Determine the angle of reflection for an incident ray. • State the relationship between density and the speed of light in a material. • Predict the bending of light in general terms (toward/away from the normal) based on Snell's Law • Classify various types of lenses or mirrors. • Classify the focal length of lenses and mirrors as positive or negative based on the type of lens/mirror. • Use the lens equation to locate an image. • Categorize images as real or virtual based on the lens equation. • Describe spherical mirrors. • Describe the use of ray tracing to location and identify images.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system. • Provide challenge problems for advanced learners to solve.
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	• Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
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- WHST.9-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4), (HS-PS3-5)
- SL.11-12.5: Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1), (HS-PS3-2), (HS-PS3-5)

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- MP.4: Model with mathematics. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-4), (HS-PS3-5)
- HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1), (HS-PS3-3)
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- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1), (HS-PS3-3)