ROBBINSVILLE PUBLIC SCHOOLS

OFFICE OF CURRICULUM AND INSTRUCTION

SCIENCE

AP PHYSICS I: ALGEBRA BASED

Board of Education

Curriculum Writing Committee
Anupama Benegal

Supervisors
Tiffany Brennan

BOARD OF EDUCATION INITIAL ADOPTION DATE:

Course Philosophy

The goal of the course is to help students develop a deep understanding of the foundational principles that shape classical mechanics. By confronting complex physical situations or scenarios, the course is designed to enable students to develop the ability to reason about physical phenomena using important scientific practices, such as explaining relationships, applying and justifying the use of mathematical routines, designing experiments, analyzing data, and making connections across multiple topics within the course.

Course Description

AP Physics I is an algebra-based, introductory college-level physics course. It is the first course in our AP Physics program, and is a prerequisite for AP Physics II. The prerequisite for this course is Algebra II and the corequisite is Geometry. The course is founded on the six big ideas, and these allow students to create meaningful connections among concepts. They are often abstract concepts or themes that become threads that run throughout the course. Revisiting the big ideas and applying them in a variety of contexts allows students to develop deeper conceptual understanding. The big ideas are:

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

Core and Supplemental Instructional Materials

Core Materials	Supplemental Materials
• AP Physics I: Algebra-Based Course and Exam Description • AP Classroom (College Board) • PSI Curriculum (NJCTL) • College Physics (online text) by OpenStax	• nTIPERS (Newtonian Tasks Inspired by Physics Education Research) • Phet.Colorado.edu Simulation Labs • The Physics Classroom • Flipping Physics

Social Emotional Learning Connections
Below are the five core SEL Competencies as outlined by CASEL, and examples of how each may be addressed within this curriculum
Self-awareness: The ability to accurately recognize one's emotions and thoughts and their influence on behavior. This includes accurately assessing one's strengths and limitations and possessing a well-grounded sense of confidence and optimism. **Example 1:** Students assess their own strengths and abilities to determine how best to prepare for exams. **Example 2:** Students recognize that there is a learning curve, and that success requires hard work and perseverance.
Self-management: The ability to regulate one's emotions, thoughts, and behaviors effectively in different situations. This includes managing stress, controlling impulses, motivating oneself, and setting and working toward achieving personal and academic goals. **Example 1:** Students will learn to manage their stress during high stakes assessments such as unit tests. **Example 2:** By implementation of skills learned during PEI, students will learn to motivate themselves and control their impulses.
Social awareness: The ability to take the perspective of and empathize with others from diverse backgrounds and cultures, to understand social and ethical norms for behavior, and to recognize family, school, and community resources and supports. **Example 1:** Students from different backgrounds and cultures learn to work collaboratively on labs and projects to benefit the whole group. **Example 2:** Students recognize the problems faced by people from third world countries, and recognize the power of scientific thinking in solving many of these problems.
Relationship skills: The ability to establish and maintain healthy and rewarding relationships with diverse individuals and groups. This includes communicating clearly, listening actively, cooperating, resisting inappropriate social pressure, negotiating conflict constructively, and seeking and offering help when needed. **Example 1:** Students work in collaboration with other students, offering and accepting constructive criticism, and providing support when needed. **Example 2:** Students from different backgrounds and cultures work together on projects that could someday benefit mankind.
Responsible decision-making: The ability to make constructive and respectful choices about personal behavior and social interactions based on consideration of ethical standards, safety concerns, social norms, the realistic evaluation of consequences of various actions, and the well-being of self and others.

Example 1: Students are careful never to submit another person's work as their own.
Example 2: While collaborating on a group project, each student contributes equally to the work.

Integration of 21st Century Themes and Skills

NJSLS-CLKS 9.4: Life Literacies and Key Skills	
Creativity and Innovation	*See specific standards and their connections/examples for this disciplinary concept listed within each individual unit* Can be found in unit: 4, 5
Critical Thinking and Problem Solving	*See specific standards and their connections/examples for this disciplinary concept listed within each individual unit* Can be found in unit: 1 - 7
Digital Citizenship	*See specific standards and their connections/examples for this disciplinary concept listed within each individual unit* Can be found in unit: n/a
Global and Cultural Awareness	*See specific standards and their connections/examples for this disciplinary concept listed within each individual unit* Can be found in unit: 4
Information and Media Literacy	*See specific standards and their connections/examples for this disciplinary concept listed within each individual unit* Can be found in unit: 5
Technology Literacy	*See specific standards and their connections/examples for this disciplinary concept listed within each individual unit* Can be found in unit: 1-7

Robbinsville Ready 21st Century Skill Integration

The following skills will be embedded throughout the curriculum and instruction of this course.

Collaborative Team Member: Robbinsville students will learn more by working together than in isolation. As educational theorist Lev Vygotsky advocated, learning is a social process. Many workplaces today encourage employees to work in teams to solicit diverse perspectives, brainstorm new ideas and/or products, and solve problems. Further, collaboration fosters interpersonal relationships, self-management skills, cooperation, and a sense of collective responsibility. Collaborative team members are able to work with diverse groups of people who hold a variety of perspectives.

Effective Communicator: Robbinsville students must be able to clearly articulate their ideas orally, in writing, and across various media in order to successfully connect to the world around them. As the world becomes increasingly globalized, communication is more than just sharing one's ideas. Effective communicators are able to communicate their convictions, actively listen and analyze others' work to identify perspective and/or potential bias.

Emotionally Intelligent Learner: Robbinsville students who are emotionally intelligent learn to be empathetic, demonstrate integrity and ethical behavior, are kind, are self-aware, willing to change, and practice self-care. They are better able to cope with the demands of the 21st century digital society and workplace because they are reliable, responsible, form stable and healthy relationships, and seek to grow personally and professionally. Emotionally intelligent people are able to manage their emotions, work effectively on teams and are leaders who can grow and help to develop others.

Informed and Involved Citizen: Robbinsville students need to be digital citizens who are civically and globally aware. The concept of what it means to be "literate" has evolved along with 21st century technological and cultural shifts. Our progressive vision of literacy entails having our students explore real world problems in the classroom. Informed and involved citizens are able to safely and accurately communicate with people all around the world and are financially, environmentally and informationally literate.

Innovative Thinker: Robbinsville students must encompass innovative thinking skills in order to be successful lifelong learners in the 21st century world. As stated by Karl Fisch and Scott McLeod in the short film Shift Happens, "We are currently preparing students for jobs that don't yet exist . . . using technologies that haven't been invented . . . in order to solve problems we don't even know are problems yet." Innovative thinkers are able to think analytically, solve problems critically, creatively engage in curiosity and tinkering, and demonstrate originality.

Resilient and Self-Directed Learner: Robbinsville students need to take risks and ultimately make independent and informed decisions in an ever-changing world. Author of Life, the Truth, and Being Free, Steve Maraboli stated, "Life doesn't get easier or more forgiving, we get stronger and more resilient." Self-directed scholars of the 21st century are able to set goals, initiate resolutions by seeking creative approaches, and adjust their thinking in light of difficult situations. Resilient students are able to take risks without fear of failure and overcome setbacks by utilizing experiences to confront new challenges. Resilient and self directed scholars will consistently embrace opportunities to initiate solutions and overcome obstacles.

Career Awareness and Planning Standards 9.2	
• 9.2.12.CAP.5: Assess and modify a personal plan to support current interests and postsecondary plans.	Example: Students decide to take the AP Physics I Exam based on their performance in this course, and on whether they will earn college credit.
• 9.2.12.CAP.2: Develop college and career readiness skills by participating in opportunities such as structured learning experiences, apprenticeships, and dual enrollment programs.	Example: A student who is successful in AP Physics I returns as a Teaching Assistant, working alongside the teacher in running laboratory activities and providing support to students.

Robbinsville Public Schools
Scope, Sequence, Pacing and Assessment

AP Physics I: Algebra Based

Unit Title	Unit Understandings and Goals	Recommended Duration/ Pacing	Assessments
Kinematics	● All forces share certain common characteristics when considered by observers in inertial reference frames. ● The acceleration of the center of mass of a system is related to the net force exerted on the system, where $a = \frac{\Sigma F}{m}$.	9-10 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs Summative · Kinematics Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) Projectile Motion Lab with report in CER format
Dynamics	● The internal structure of a system determines many properties of the system. ● A gravitational field is caused by an object with mass. ● At the macroscopic level, forces can be categorized as either long-range (action-at a-distance) forces or contact forces. ● Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. ● All forces share certain common characteristics when considered by observers in inertial reference frames.	10-11 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs Summative · Dynamics Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) Labs with reports in CER format: Finding an experimental value for g, Fan Cart Lab, Hooke's Law Lab.

	• Classically, the acceleration of an object interacting with other objects can be predicted by using $a = \frac{\Sigma F}{m}$. • The acceleration of the center of mass of a system is related to the net force exerted on the system, where $a = \frac{\Sigma F}{m}$.		
Uniform Circular Motion/Universal Gravitation	• 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. • Certain types of forces are considered fundamental. • At the macroscopic level, forces can be categorized as either long-range (action-at a-distance) forces or contact forces.A gravitational field is caused by an object with mass. • Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.	4-5 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs Summative · Circular Motion/Universal Gravitation Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) · Lab: Determine an experimental value for 'g' using the provided apparatus. Lab report submitted in CER format.
Energy	• 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. • A force exerted on an object can change the kinetic energy of the object. • Interactions with other objects or systems can change the total energy of a system. • The energy of a system is conserved.	10-11 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs Summative · Energy Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) · Energy Escape room · Lab with CER: Determining the coefficient of friction between a block and a ramp
Momentum	• A force exerted on an object can change the momentum of the object. • Interactions with other objects or systems can change the total linear momentum of a system.	7-8 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs

	• 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. • The linear momentum of a system is conserved.		Summative · Momentum Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) · Accident Reconstruction Project · Airbag Effectiveness Analysis
Simple Harmonic Motion	• Classically, the acceleration of an object interacting with other objects can be predicted by using $a = \frac{\Sigma F}{m}$. • The energy of a system is conserved.	2-3 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs Summative · Simple Harmonic Motion Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) · Pendulum Lab with lab report in CER format

Rotational Motion	• All forces share certain common characteristics when considered by observers in inertial reference frames. • A force exerted on an object can cause a torque on that object. • A net torque exerted on a system by other objects or systems will change the angular momentum of the system. • The angular momentum of a system is conserved.	8-9 blocks	Formative · Quizzes, AP Classroom Progress Checks (Multiple Choice and Free-Response Problem Sets), AP Physics I Workbook assignments, Inquiry-Based Labs Summative · Rotational Motion Unit Test Common Benchmark Assessments (mid/end of course) · AP Physics I Exam, Final Exam Alternative Assessments (projects, etc when appropriate) · Angular Races · Mass of the Meterstick · Torque Feeler Activity · Ladybug Rotation Phet Lab

Unit 1: Kinematics

Enduring Understandings:	**Essential Questions:**
• All forces share certain common characteristics when considered by observers in inertial reference frames. • The acceleration of the center of mass of a system is related to the net force exerted on the system, where $a = \frac{\Sigma F}{m}$.	• How and why are vectors used to analyze motion? • What is the difference between speed and velocity? Why is this difference important? • What are the relationships between position, velocity, and acceleration? • How can position, velocity, and acceleration in one and two dimensions be described quantitatively, qualitatively, and graphically?

Interdisciplinary Connections

High School Mathematics (NJSLS Geometry: Similarity, Right Triangles, and Trigonometry G-SRT-C . Define trigonometric ratios and solve problems involving right triangles.
Example: Students use trigonometry to resolve velocity vectors into their vertical and horizontal components in order to solve problems involving projectiles.

ELA 11-12: NJSLSA.R7. Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
Example: Students translate between graphs, equations, and verbal claims when describing the motion of an object.

Guiding / Topical Questions with Specific Standards		**Content, Themes, Concepts, and Skills**	**Teaching Strategies**	**Instructional Resources and Materials**	**Assessment Strategies**
Topic 1.1: Position, Velocity and Acceleration Science Practice: 1.5, 2.1, 2.2, 4.2, 5.1 NJSLS: This unit provides the background and skills required for	How and why are vectors used to analyze motion? What is the difference between speed, velocity, and why is this difference important? What are the components of projectile motion?	Express the motion of an object using narrative, mathematical, and graphical representations. Design an experimental investigation of the motion of an object. Analyze experimental data describing the motion of an object and be able to express the results of the analysis using narrative, mathematical, and graphical representations.	Solve problems specifically by first writing out all variables present, determining the appropriate equation to use, solving the equation for the variable needed, inserting numbers into the equation, and finally performing calculations with a scientific calculator. Apply the qualitative definition of acceleration (speeding up, or slowing down, and/or changing direction) to determine if an object is accelerating. Determine velocity by taking the slope of a position-time graph, and	AP Physics I Workbook (College Board) Presentation Slides Flipping Physics nTIPERS	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments Lab Reports Self-scored Free-Response Questions on AP Classroom

the following units 9.4.12.CT.2.	How do we mathematically predict a projectile's path? How do we use the kinematic equations to predict a projectile's path?		determine acceleration from the slope of a velocity-time graph, as well as the displacement by calculating the area under the curve. Correlate negative and positive slopes with positive and negative velocities and accelerations.		
Topic 1.2: Represent-ations of Motion Science Practice: 1.2, 1.4, 2.2, 2.3, 6.4 NJSLS: This unit provides the background and skills required for the following units. 9.4.12.CT.2 9.4.12.TL.2	What are the relationships between position, velocity and acceleration? How can position, velocity and acceleration in one and two dimensions be described qualitatively, quantitatively and graphically?	Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. Make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time. 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.	Design an experiment and analyze data describing the motion of an object. Graph the motion of a projectile along the horizontal axis and the vertical axis. Generate a position time graph of an object in motion, and then convert it to velocity-time and acceleration-time graphs. Describe the motion of an object from its position-time graph	AP Physics I Workbook (College Board) Presentation Slides Flipping Physics nTIPERS AP Classroom	Kinematics Unit Test Progress Check MCQs and FRQs on AP Classroom Ranking Tasks from nTIPERS

Unit 2: Dynamics

Enduring Understandings:	Essential Questions:
• The internal structure of a system determines many properties of the system. • A gravitational field is caused by an object with mass. • At the macroscopic level, forces can be categorized as either long-range (action-at a-distance) forces or contact forces. • Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles. • 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 $a = \frac{\Sigma F}{m}$. • The acceleration of the center of mass of a system is related to the net force exerted on the system, where $a = \frac{\Sigma F}{m}$.	• How can the properties of internal and gravitational mass be experimentally verified to be the same? • How do you decide what to believe about scientific claims? • How does something we cannot see determine how an object behaves? • How do objects with mass respond when placed in a gravitational field? • Why is the acceleration due to gravity constant on Earth's surface? • Are different kinds of forces really different? • How can Newton's laws of motion be used to predict the behavior of objects? • Why does the same push change the motion of a shopping cart more than the motion of a car?

Interdisciplinary Connections

High School Mathematics NJSLS Standards for Mathematical Practice: Make sense of problems and persevere in solving them.
Example: Students will analyze givens, constraints, relationships, and goals while solving complex problems using Newton's Second Law.

ELA 11-12: NJSLSA.W1. Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
Example: Students will use valid reasoning and evidence while conducting laboratory investigations and writing lab reports.

Guiding / Topical Questions with Specific Standards		Content, Themes, Concepts, and Skills	Teaching Strategies	Instructional Resources and Materials	Assessment Strategies
Topic 2.1: Systems SP 1.1, 1.7 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2	How do you decide what to believe about scientific claims? How does something we cannot see determine how an object behaves?	Create representations and models of natural or man-made phenomena and systems in the domain. Connect phenomena and models across spatial and temporal scales.	Model verbally or visually the properties of a system based on its substructure and relate this to changes in the system properties over time as external variables are changed.	AP Physics I Workbook (College Board) Presentation Slides Flipping Physics nTIPERS	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments

					Lab Reports Self-scored Free-Response Questions on AP Classroom
Topic 2.2: The Gravitational Field Science Practice: 2.2, 7.2 NJSLS: HS-PS2-1 HS-PS2-4 9.4.12.CT.2 9.4.12.TL.2	How can the properties of internal and gravitational mass be experimentally verified to be the same? How do objects with mass respond when placed in a gravitational field? Why is the acceleration due to gravity constant on Earth's surface?	The student can apply mathematical routines to quantities that describe natural phenomena. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Apply $F=mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems.	AP Physics I Workbook (College Board) Presentation Slides NJCTL Practice Problem Set	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments Lab Reports Self-scored Free-Response Questions on AP Classroom
Topic 2.3: Contact Forces Science Practice: 6.1, 6.2 NJSLS: HS-PS2-1 HS-PS2-6 9.4.12.CT.2 9.4.12.TL.2	Are different kinds of forces really different? How can Newton's laws of motion be used to predict the behavior of objects? Why does the same push change the motion of a shopping cart more than the motion of a car?	The student can justify claims with evidence. The student can construct explanations of phenomena based on evidence produced through scientific practices.	Students can make claims about various contact forces (e.g. friction) between objects based on the microscopic cause of these forces. Students will explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.	AP Physics I Workbook (College Board) Presentation Slides nTIPERS	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments Lab Reports Self-scored Free-Response Questions on AP Classroom
Topic 2.4: Newton's First Law Science Practice: 4.2	How can Newton's laws of motion be used to predict the behavior of objects?	The student can design a plan for collecting data to answer a particular scientific question.	Design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.	PASCO carts and frictionless tracks, hooked masses, frictionless pulley	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS)

NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2			Design a plan for collecting data to measure gravitational mass and inertial mass and to distinguish between the two experiments.	AP Physics I Workbook (College Board) Presentation Slides nTIPERS Flipping Physics	AP Physics I workbook assignments Lab Reports Self-scored Free-Response Questions on AP Classroom
Topic 2.5: Newton's Third Law and Free-Body Diagrams Science Practice: 1.1, 1.4, 6.1, 6.2, 6.4, 7.2 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2	How can Newton's laws of motion be used to predict the behavior of objects?	The student can create representations and models of natural or man-made phenomena and systems in the domain. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can justify claims with evidence. The student can construct explanations of phenomena based on evidence produced through scientific practices. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. 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. Challenge a claim that an object can exert a force on itself. Describe a force as an interaction between two objects, and identify both objects for any force. Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. Analyze situations involving interactions among several objects by using free-body diagrams that include	AP Physics I Workbook (College Board) Presentation Slides Flipping Physics nTIPERS	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments Lab Reports Self-scored Free-Response Questions on AP Classroom

			the application of Newton's third law to identify forces.		
Topic 2.6: Newton's Second Law Science Practice: 1.4, 1.5, 2.2, 4.2, 5.1, 6.4, 7.2 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2	How can Newton's laws of motion be used to predict the behavior of objects? Why does the same push change the motion of a shopping cart more than the motion of a car?	The student can create representations and models of natural or man-made phenomena and systems in the domain. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can re-express key elements of natural phenomena across multiple representations in the domain. The student can apply mathematical routines to quantities that describe natural phenomena. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	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. Design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurement, and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. Re-express a free-body diagram into a mathematical representation, and solve the mathematical representation for the acceleration of the object. Create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.	AP Physics I Workbook (College Board) Presentation Slides Flipping Physics nTIPERS Fan Cart Lab Whiteboard/Markers for constructing free-body diagrams NJCTL Problem Sets	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments Lab Reports Self-scored Free-Response Questions on AP Classroom
Topic 2.7: Applications of Newton's Second Law Science Practice: 1.2, 1.4, 2.2, 2.3, 5.3, 6.4 NJSLS: HS-PS2-1	How can Newton's laws of motion be used to predict the behavior of objects? Why does the same push change the motion of a shopping cart more than the motion of a car?	The student can describe representations and models of natural or man-made phenomena and systems in the domain. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can apply mathematical routines to quantities that describe natural phenomena.	Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. Evaluate, using given data, whether all the forces on a system or all the parts of a system have been identified.	AP Physics I Workbook (College Board) Presentation Slides Flipping Physics nTIPERS	Multiple Choice Questions on Google forms Ranking Tasks (nTIPERS) AP Physics I workbook assignments Lab Reports

HS-ETS1-2 9.4.12.CT.2 9.4.12.TL.2		The student can estimate quantities that describe natural phenomena. The student can evaluate the evidence provided by data sets in relation to a particular scientific question. The student can make claims and predictions about natural phenomena based on scientific theories and models			Self-scored Free-Response Questions on AP Classroom

Robbinsville Public Schools

Unit 3: Uniform Circular Motion/Universal Gravitation

Enduring Understandings:	**Essential Questions:**
• 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. • Certain types of forces are considered fundamental. • At the macroscopic level, forces can be categorized as either long-range (action-at a-distance) forces or contact forces. A gravitational field is caused by an object with mass. • Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.	What is the difference between microscopic and macroscopic forces? How does changing the mass of an object affect the gravitational force? Why is a refrigerator hard to push in space? Why do we feel pulled toward Earth but not toward a pencil? How can the acceleration due to gravity be modified? What is the difference between inertial mass and gravitational mass? How can Newton's laws of motion be used to predict the behavior of objects? How can we use forces to predict the behavior of objects and keep us safe? How is the acceleration of the center of mass of a system related to the net force exerted on the system? Why is it more difficult to stop a fully loaded dump truck than a small passenger car?

Interdisciplinary Connections

High School Mathematics NJSLS Vector and Matrix Properties N-VM B. Perform operations on vectors: Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum.
Example: Students use vector addition to calculate net force.

ELA 11-12: NJSLSA.W1. Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
Example: Students will use valid reasoning and evidence while conducting laboratory investigations and writing lab reports.

Guiding / Topical Questions with Specific Standards		**Content, Themes, Concepts, and Skills**	**Teaching Strategies**	**Instructional Resources and Materials**	**Assessment Strategies**
Topic 3.1/3.2 Vector Fields and Fundamental Forces	What is the difference between microscopic and macroscopic forces?	The student can connect phenomena and models across spatial and temporal scales.	Articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored.	Presentation Slides	Think, Pair, Share

Science Practice: 7.1 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2					
Topic 3.3 Gravitational and Electric Forces Science Practice: 2.2, 7.2 NJSLS: HS-PS2-1 HS-ESS1-4 9.4.12.CT.2 9.4.12.TL.2	How can Newton's laws of motion be used to predict the behavior of objects? How does changing the mass of an object affect the gravitational force?	The student can apply mathematical routines to quantities that describe natural phenomena. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Use Newton's law of gravitation to calculate the gravitational force that two objects exert on each other and use that force in contexts other than orbital motion. Use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1).	AP Physics I Workbook (College Board) Presentation Slides nTIPERS PHET simulation lab	
Topic 3.4 Gravitational Field/Acceleration Due to Gravity on Different Planets Science Practice: 2.2, 7.2 NJSLS: HS-PS2-4 HS-ESS1-4 9.4.12.CT.2 9.4.12.TL.2	How can Newton's laws of motion be used to predict the behavior of objects? How does changing the mass of an object affect the gravitational force? Why do we feel pulled toward Earth but not toward a pencil? How can the acceleration due to gravity be modified?	The student can apply mathematical routines to quantities that describe natural phenomena. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Apply F=mg to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. Apply $g = \frac{Gm}{r^2}$ to calculate the gravitational field due to an object with mass m, where the field is a vector directed toward the center of the object of mass m. Approximate a numerical value of the gravitational field (g) near the surfaceof an object from its radius and mass relative to those of Earth or other reference objects.	AP Physics I Workbook (College Board) Presentation Slides nTIPERS PSI Physics Problem Sets (NJCTL)	

Topic 3.5 Inertial vs. Gravitational Mass Science Practice: 4.2 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2	What is the difference between inertial mass and gravitational mass?	The student can design a plan for collecting data to answer a particular scientific question.	Design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments.	Scale Set of known masses Unknown mass Inertial Balance	Lab Report in CER format Quiz
Topic 3.6 Centripetal Acceleration and Centripetal Force Science Practice: 5.3 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2	How can we use forces to predict the behavior of objects and keep us safe? How is the acceleration of the center of mass of a system related to the net force exerted on the system?	The students can evaluate the evidence provided by data sets in relation to a particular scientific question.	Evaluate, using given data, whether all the forces on a system or whether all the parts of a system have been identified.	AP Physics I Workbook (College Board) Presentation Slides nTIPERS	
Topic 3.7 Free-Body Diagrams for Objects in Uniform Circular Motion Science Practice: 1.1, 1.4, 1.5, 2.2, 4.2, 5.1 NJSLS: HS-PS2-1 HS-PS2-4 9.4.12.CT.2	How can we use forces to predict the behavior of objects and keep us safe? How is the acceleration of the center of mass of a system related to the net force exerted on the system?	The student can create representations and models of natural or man-made phenomena and systems in the domain. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can re-express key elements of natural phenomena across multiple representations in the domain. The student can apply mathematical routines to quantities that describe natural phenomena. The student can design a plan for collecting data to answer a particular scientific question.	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. Re-express a free-body diagram representation into a mathematical representation, and solve the mathematical representation for the acceleration of the object. Create and use free-body diagrams to analyze physical situations to solve	AP Physics I Workbook (College Board) Presentation Slides nTIPERS	Do Now/Exit Slips Circular Motion/Gravitation Progress Checks on AP Classroom

9.4.12.TL.2		The student can analyze data to identify patterns or relationships.*	problems with motion qualitatively and quantitatively.		
Topic 3.8 Applications of Circular Motion and Gravitation Science Practice: 1.1, 1.4, 1.5, 2.1, 2.2, 4.2, 5.1, 6.2, 6.4, 7.2 NJSLS: HS-PS2-1 HS-PS2-4 9.4.12.CT.2 9.4.12.TL.2	How can Newton's laws of motion be used to predict the behavior of objects? How can we use forces to predict the behavior of objects and keep us safe? How is the acceleration of the center of mass of a system related to the net force exerted on the system? Why is it more difficult to stop a fully loaded dump truck than a small passenger car?	The student can create representations and models of natural or man-made phenomena and systems in the domain. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can re-express key elements of natural phenomena across multiple representations in the domain. The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships. The student can construct explanations of phenomena based on evidence produced through scientific practices. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Express the motion of an object using narrative, mathematical, and graphical representations. Design an experimental investigation of the motion of an object. Analyze experimental data describing the motion of an object and express the results of the analysis using narrative, mathematical, and graphical representations. Represent forces in diagrams or mathematically, using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. 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. Describe a force as an interaction between two objects and identify both objects for any force. Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.	Circular Motion Lab Set of hooked masses Plastic tube, string, rubber stopper timer PSI Physics Problem set	Lab Report in CER format Lab Quiz Circular Motion/Graviatation Unit Test

			Analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.		

Unit 4: Energy

Enduring Understandings:	Essential Questions:
● 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. ● A force exerted on an object can change the kinetic energy of the object. ● Interactions with other objects or systems can change the total energy of a system. ● The energy of a system is conserved.	● How does pushing something give it energy? ● How is energy exchanged and transformed within or between systems? ● How does the choice of system influence how energy is stored or how work is done? ● How does energy conservation allow the riders in the back car of a rollercoaster to have a thrilling ride? ● How can the idea of potential energy be used to describe the work done to move celestial bodies? ● How is energy transferred between objects or systems? ● How does the law of conservation of energy govern the interactions between objects and systems?

Interdisciplinary Connections

ELA 11-12 NJSLSA.W7. Conduct short as well as more sustained research projects, utilizing an inquiry-based research process, based on focused questions, demonstrating understanding of the subject under investigation.
Example: Students conduct inquiry-based research to find an experimental value for the coefficient of kinetic friction between a wooden block and the ramp upon which it slides.

High School Mathematics NJSLS Vector and Matrix Quantities N-VM A. Represent and model with vector quantities.
Example: Students will solve problems involving velocity, force and other quantities that can be represented by vectors.

Guiding / Topical Questions with Specific Standards		Content, Themes, Concepts, and Skills	Teaching Strategies	Instructional Resources and Materials	Assessment Strategies
Topic 4.1: Open and Closed Systems: Energy	How is energy exchanged and transformed within or between systems?	The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate	Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.	Presentation Slides	Classroom Discussion Think-Pair-Share Do Now/Exit Slip

Science Practice: 6.4, 7.2 NJSLS: 9.4.12.CT.2 9.4.12.TL.2		in and/or across enduring understandings and/or big ideas.			
Topic 4.2: Work and Mechanical Energy Science Practice: 1.4, 2.1, 2.2, 6.4, 7.2 NJSLS HS-PS3-1 HS-PS3-2 9.4.12.CT.2 9.4.12.TL.2	How does pushing something give it energy? How is energy exchanged and transformed within or between systems? How does the choice of system influence how energy is stored or how work is done?	The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	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. Use net force and velocity vectors to determine qualitatively whether the kinetic energy of an object would increase, decrease, or remain unchanged. Use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether the kinetic energy of that object would increase, decrease, or remain unchanged. 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. Calculate the total energy of a system and justify the mathematical routines used in the calculation of componenttypes of energy within the system whose sum is the total energy. Predict changes in the total energy of a system due to changes in position	AP Physics I Workbook (College Board) Presentation Slides nTIPERS PSI Physics Problem Sets Flipping Physics	Quiz Progress Check on AP Classroom

			and speed of objects or frictional interactions within the system. Make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass. Apply the concepts of conservation of energy and the work-energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system.		
Topic 4.3: Conservation of Energy, the Work-Energy Principle, and Power Science Practice: 1.4, 1.5, 2.1,2.2, 4.2 NJSLS HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-ETS1-2 9.4.12.CT.2 9.4.12.CI.1 9.4.12.GCA.1	How does energy conservation allow the riders in the back car of a rollercoaster to have a thrilling ride? How is energy transferred between objects or systems? How does the law of conservation of energy govern the interactions between objects and systems?	The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can re-express key elements of natural phenomena across multiple representations in the domain. The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships.	Create 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. 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. 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	AP Physics I Workbook (College Board) Presentation Slides nTIPERS PHET Energy Skate Park Energy Lab: Determine an experimental value for the coefficient of kinetic friction between a block and a plank of wood Solar Oven Project	Quiz Progress Check on AP Classroom Lab Report in CER format Energy Unit Test

9.4.12.TL.2		The student can make claims and predictions about natural phenomena based on scientific theories and models.	internal structure because the object is actually a system. Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. Make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. Apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. Describe and make predictions about the internal energy of systems. Calculate changes in kinetic energy and potential energy of a system using information from representations of that system. Design an experiment and analyze data to determine how a force exerted on an object or system does work on the object or system as it moves through a distance. Design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system. 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. 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). 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.		

Unit 5: Momentum

Enduring Understandings:	**Essential Questions:**
● A force exerted on an object can change the momentum of the object ● Interactions with other objects or systems can change the total linear momentum of a system. ● The linear momentum of a system is conserved.	● How does pushing an object change its momentum? ● How do interactions with other objects or systems change the linear momentum of a system? ● How is the physics definition of momentum different from how momentum is used to describe things in everyday life? ● How does the law of the conservation of momentum govern interactions between objects or systems? ● How can momentum be used to determine fault in car crashes?

Interdisciplinary Connections

High School Mathematics NJSLS Standards for Mathematical Practice 4: Model with mathematics.
Example: Students can apply the mathematics they know to solve problems arising in everyday life such as designing car safety structures.

ELA 11-12 NJSLSA.R7. Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
Example: Students analyze graphs of Force vs. Time for airbags deployed during a crash and identify the airbag that is most likely to save a passengers life

Guiding / Topical Questions with Specific Standards		**Content, Themes, Concepts, and Skills**	**Teaching Strategies**	**Instructional Resources and Materials**	**Assessment Strategies**
Topic 5.1: Momentum and Impulse Science Practice: 2.1, 4.1, 4.2, 5.1, 6.4 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2	How does pushing an object change its momentum? How do interactions with other objects or systems change the linear momentum of a system?	The student can justify the selection of a mathematical routine to solve problems. The student can justify the selection of the kind of data needed to answer a particular scientific question. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships.	Justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force. 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 the object and the interval	Presentation Slides AP Workbook (College Board) PSI Physics Problem Sets Phet simulation lab	Do Now/Exit Slips Quizzes

		The student can make claims and predictions about natural phenomena based on scientific theories and models.	of time during which the force is exerted. 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. Design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.		
Topic 5.2: Representa-tions of Changes in Momentum Science Practice: 1.4, 2.2, 5.1 NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.IML.3 9.4.12.TL.2	How do interactions with other objects or systems change the linear momentum of a system?	The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can apply mathematical routines to quantities that describe natural phenomena. The student can analyze data to identify patterns or relationships.	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.). 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. 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. Perform an analysis on data presented as a force-time graph and predict the change in momentum of a system.	Presentation Slides AP Workbook (College Board) PSI Physics Problem Sets Air Bag Test Data	Do Now/Exit Slip Quiz Analysis of air bag test data
Topic 5.3: Open and Closed Systems: Momentum Science Practice: 6.4, 7.2	How do interactions with other objects or systems change the linear momentum of a system?	The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.	Presentation Slides AP Workbook (College Board) PSI Physics Problem Sets	Think-Pair-Share

NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2					
Topic 5.4: Conservation of Linear Momentum Science Practice: 2.1, 2.2, 3.2, 4.1, 4.2, 4.4, 5.1, 5.3, 6.4, 7.2 NJSLS: HS-PS2-2 HS-PS2-3 HS-ETS1-4 9.4.12.CT.2 9.4.12.CI.1 9.4.12.IML.3 9.4.12.TL.2	How does the law of the conservation of momentum govern interactions between objects or systems?	The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can refine scientific questions. The student can justify the selection of the kind of data needed to answer a particular scientific question. The student can design a plan for collecting data to answer a particular scientific question. The student can evaluate sources of data to answer a particular scientific question. The student can analyze data to identify patterns or relationships. The student can evaluate the evidence provided by data sets in relation to a particular scientific question. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. Apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and qualitatively in two-dimensional situations. 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. Design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.	Presentation Slides PSI Physics Problem Set AP Workbook (College Board)	Project (Accident Reconstruction) Egg Crash Project Progress Checks (AP Classroom) Momentum Unit Test

			Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values. 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. 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. Apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. Analyze data that verify conservation of momentum in collisions with and without an external frictional force. Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.		

			Predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center-of-mass motion of the system and is able to determine that there is no external force).		

Robbinsville Public Schools

Unit 6: Simple Harmonic Motion

Enduring Understandings:	Essential Questions:
● Classically, the acceleration of an object interacting with other objects can be predicted by using $a = \frac{\Sigma F}{m}$ ● The energy of a system is conserved.	● How does a restoring force differ from a "regular" force? ● How does the presence of restoring forces predict and lead to harmonic motion? ● How does a spring cause an object to oscillate? ● How can oscillations be used to make our lives easier? ● How does the law of conservation of energy govern the interactions between objects and systems? ● How can energy stored in a spring be used to create motion?

Interdisciplinary Connections

High School Mathematics. NJSLS Trigonometric Functions F-TF: Model periodic phenomena with trigonometric functions: Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.
Example: Students use Sine or Cosine wave functions to study objects undergoing Simple Harmonic Motion.

ELA 11-12: NJSLSA.W1. Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
Example: Students will write a lab report in CER format upon completion of the Spring Constant Lab

Guiding / Topical Questions with Specific Standards		Content, Themes, Concepts, and Skills	Teaching Strategies	Instructional Resources and Materials	Assessment Strategies
Topic 6.1: Period of Simple Harmonic Oscillators Science Practice: 2.2, 4.2, 5.1, 6.2, 6.4, 7.2	How does a restoring force differ from a "regular" force? How does the presence of restoring forces predict and lead to harmonic motion? How does a spring cause an object to oscillate?	The student can apply mathematical routines to quantities that describe natural phenomena. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships.	Predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. 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.	Presentation Slides PSI Physics Problem Set Spring Constant Lab: Springs, Lab stand, Hooked Masses, Stopwatch, Meter Stick	Do Now/Exit Slips Think-Pair-Share Lab Report in CER format Quiz

NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2		The student can construct explanations of phenomena based on evidence produced through scientific practices. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Analyze data to identify qualitative and 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 and use those data to determine the value of an unknown. Construct a qualitative and/ or quantitative explanation of oscillatory behavior given evidence of a restoring force.	AP Workbook (College Board)	
Topic 6.2: Energy of a Simple Harmonic Oscillator Science Practice: 1.4, 2.1, 2.2, 6.4, 7.2 NJSLS: HS-PS3-1 HS-PS3-3 9.4.12.CT.2 9.4.12.TL.2	How can oscillations be used to make our lives easier? How does the law of conservation of energy govern the interactions between objects and systems? How can energy stored in a spring be used to create motion?	The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	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. Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. Make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. Apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. Describe and make predictions about the internal energy of systems.	Presentation Slides PSI Physics Problem Set AP Workbook (College Board) Marble Launcher Lab: Marble launcher, marbles, timer, meter stick	Do Now/Exit Slips Lab Report in CER Format Lab Quiz AP Classroom Progress Checks Unit Test

			Calculate changes in kinetic energy and potential energy of a system using information from representations of that system.		

Unit 7: Torque and Rotational Motion

Enduring Understandings:	Essential Questions:
• All forces share certain common characteristics when considered by observers in inertial reference frames. • A force exerted on an object can cause a torque on that object. • A net torque exerted on a system by other objects or systems will change the angular momentum of the system. • The angular momentum of a system is conserved.	• How does a system at rotational equilibrium compare to a system in translational equilibrium? • How does the choice of system and rotation point affect the forces that can cause a torque on an object or a system? • How can balanced forces cause rotation? • Why does it matter where the door handle is placed? • Why are long wrenches more effective? • How can an external net torque change the angular momentum of a system? • Why is a rotating bicycle wheel more stable than a stationary one? • How does the conservation of angular momentum govern interactions between objects and systems? • Why do planets move faster when they travel closer to the sun?

Interdisciplinary Connections

Visual and Performing Arts Grades 9-12 1.2.12acc.Cr1c: Critique plans, prototypes, constraint of resources, and production processes considering purposeful and expressive artistic intention and personal aesthetic.
Example: Students will choose a theme and create a mobile to demonstrate zero net torque (static equilibrium)

High School Mathematics. NJSLS Standards for Mathematical Practice: Attend to precision.
Example: Students communicate precisely when solving word problems about Conservation of Angular Momentum. They calculate accurately and efficiently and express numerical answers with a degree of precision appropriate for the problem context.

Guiding / Topical Questions with Specific Standards		Content, Themes, Concepts, and Skills	Teaching Strategies	Instructional Resources and Materials	Assessment Strategies
Topic 7.1: Rotational Kinematics Science Practice: 1.5, 2.1	How does a system at rotational equilibrium compare to a system in translational equilibrium?	The student can re-express key elements of natural phenomena across multiple representations in the domain. The student can justify the selection of a mathematical routine to solve problems.	Express the motion of an object using narrative, mathematical, and graphical representations.	Presentation Slides	Think-Pair-Share Do Now/Exit Slips

NJSLS: HS-PS2-1 9.4.12.CT.2 9.4.12.TL.2		The student can apply mathematical routines to quantities that describe natural phenomena.			
Topic 7.2 : Torque and Angular Acceleration Science Practice: 1.4, 2.1, 2.2, 2.3, 4.1, 4.2, 5.1, 5.3, 6.4, 7.2 NJSLS: HS-PS2-1 HS-PS2-2 9.4.12.CT.2 9.4.12.TL.2	How does the choice of system and rotation point affect the forces that can cause a torque on an object or a system? How can balanced forces cause rotation? Why does it matter where the door handle is placed? Why are long wrenches more effective?	The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can estimate quantities that describe natural phenomena. The student can justify the selection of the kind of data needed to answer a particular scientific question. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships. The student can evaluate the evidence provided by data sets in relation to a particular scientific question. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Use representations of the relationship between force and torque. Compare the torques on an object caused by various forces. Estimate the torque on an object caused by various forces in comparison with other situations. Design an experiment and analyze data testing a question about torques in a balanced rigid system. Calculate torques on a two-dimensional system in static equilibrium by examining a representation or model (such as a diagram or physical construction). 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. 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. 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.	Presentation Slides PSI Physics Problem Set AP Workbook (College Board) Mass of the meter stick lab Hooked masses, pivot, meter stick “Torque Feeler” activity	Quiz Lab Report in CER format

Topic 7.3: Angular Momentum and Torque Science Practice: 1.2, 1.4, 2.2, 3.2, 4.1, 4.2, 5.1, 5.3 NJSLS: HS-PS2-1 HS-PS2-2 9.4.12.CT.2 9.4.12.TL.2	How can an external net torque change the angular momentum of a system? Why is a rotating bicycle wheel more stable than a stationary one?	The student can describe representations and models of natural or man-made phenomena and systems in the domain. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. The student can apply mathematical routines to quantities that describe natural phenomena. The student can refine scientific questions. The student can justify the selection of the kind of data needed to answer a particular scientific question. The student can design a plan for collecting data to answer a particular scientific question. The student can analyze data to identify patterns or relationships. The student can evaluate the evidence provided by data sets in relation to a particular scientific question.	In an unfamiliar context or using representations beyond equations, justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object. 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. Describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system. Plan data-collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data. 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. Plan a data-collection and analysis strategy to determine the change in angular momentum of a system and	Presentation Slides PSI Physics Problem Sets AP Physics I Workbook (College Board)	Do Now/Exit Slips Think-Pair-Share Quiz AP Classroom Progress Checks

			relate it to interactions with other objects and systems. Use appropriate mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum. 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.		
Topic 7.4: Conservation of Angular Momentum Science Practice: 2.1, 2.2, 6.4, 7.2 NJSLS: HS-PS2-2 9.4.12.CT.2 9.4.12.TL.2	How does the conservation of angular momentum govern interactions between objects and systems? Why do planets move faster when they travel closer to the sun?	The student can justify the selection of a mathematical routine to solve problems. The student can apply mathematical routines to quantities that describe natural phenomena. The student can make claims and predictions about natural phenomena based on scientific theories and models. The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.	Make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque. Make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero. 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. Use qualitative reasoning with compound objects and perform calculations with a fixed set of extended objects and point masses.	Presentation Slides PSI Physics Problem Sets AP Physics I Workbook (College Board)	Rotational Motion Unit Test AP Classroom Progress Checks

General Differentiated Instruction Strategies

• Leveled texts • Chunking texts • Choice board • Socratic Seminar • Tiered Instruction • Small group instruction • Guided Reading • Sentence starters/frames • Writing scaffolds • Tangible items/pictures • Adjust length of assignment	• Repeat, reword directions • Brain breaks and movement breaks • Brief and concrete directions • Checklists for tasks • Graphic organizers • Assistive technology (spell check, voice to type) • Study guides • Tiered learning stations • Tiered questioning • Data-driven student partnerships • Extra time

Possible Additional Strategies for Special Education Students, 504 Students, At-Risk Students, and English Language Learners (ELLs)			
Time/General	**Processing**	**Comprehension**	**Recall**
• Extra time for assigned tasks • Adjust length of assignment • Timeline with due dates for reports and projects • Communication system between home and school • Provide lecture notes/outline	• Extra Response time • Have students verbalize steps • Repeat, clarify or reword directions • Mini-breaks between tasks • Provide a warning for transitions • Reading partners	• Precise step-by-step directions • Short manageable tasks • Brief and concrete directions • Provide immediate feedback • Small group instruction • Emphasize multi-sensory learning	• Teacher-made checklist • Use visual graphic organizers • Reference resources to promote independence • Visual and verbal reminders • Graphic organizers
Assistive Technology	**Assessments and Grading**	**Behavior/Attention**	**Organization**
• Computer/whiteboard • Tape recorder	• Extended time • Study guides	• Consistent daily structured routine	• Individual daily planner • Display a written agenda

• Spell-checker • Audio-taped books	• Shortened tests • Read directions aloud	• Simple and clear classroom rules • Frequent feedback	• Note-taking assistance • Color code materials

Enrichment

The goal of Enrichment is to provide learners with the opportunity to participate in extension activities that are differentiated and enhance the curriculum. All enrichment decisions will be based upon individual student needs.

- Show a high degree of intellectual, creative and/or artistic ability and demonstrate this ability in multiple ways.
- Pose questions and exhibit sincere curiosity about principles and how things work.
- The ability to grasp concepts and make real world and cross-curricular connections.
- Generate theories and hypotheses and pursue methods of inquiry.
- Produce products that express insight, creativity, and excellence.
- Possess exceptional leadership skills.
- Evaluate vocabulary
- Elevate Text Complexity
- Inquiry based assignments and projects
- Independent student options
- Tiered/Multi-level activities
- Purposeful Learning Center
- Open-ended activities and projects
- Form and build on learning communities
- Providing pupils with experiences outside the 'regular' curriculum
- Altering the pace the student uses to cover regular curriculum in order to explore topics of interest in greater depth/breadth within their own grade level
- A higher quality of work than the norm for the given age group.
- The promotion of a higher level of thinking and making connections.
- The inclusion of additional subject areas and/or activities (cross-curricular).
- Using supplementary materials in addition to the normal range of resources.

English Language Learner (ELL) Resources

- Learning style quiz for students- http://www.educationplanner.org/students/self-assessments/learning-styles-quiz.shtml
- "Word clouds" from text that you provide-http://www.wordle.net/
- Bilingual website for students, parents and educators: http://www.colorincolorado.org/
- Learn a language for FREE-www.Duolingo.com
- Time on task for students-http://www.online-stopwatch.com/
- Differentiation activities for students based on their Lexile-www.Mobymax.com
- WIDA-http://www.wida.us/
- Everything ESL - http://www.everythingESL.net
- ELL Tool Box Suggestion Site http://www.wallwisher.com/wall/elltoolbox
- Hope4Education - http://www.hope4education.com
- Learning the Language http://blogs.edweek.org/edweek/learning-the-language/
- FLENJ (Foreign Language Educators of NJ) 'E-Verse' wiki: http://www.flenj.org/Publications/?page=135
- OELA - http://www.ed.gov/offices/OBEMLA
- New Jersey Department of Education- Bilingual Education information http://www.state.nj.us/education/bilingual/

Special Education Resources

- Animoto -Animoto provides tools for making videos by using animation to pull together a series of images and combining with audio. Animoto videos or presentations are easy to publish and share. https://animoto.com
- Bookbuilder -Use this site to create, share, publish, and read digital books that engage and support diverse learners according to their individual needs, interests, and skills. http://bookbuilder.cast.org/
- CAST -CAST is a non-profit research and development organization dedicated to Universal Design for Learning (UDL). UDL research demonstrates that the challenge of diversity can and must be met by making curriculum flexible and responsive to learner differences. http://www.cast.org
- CoSketch -CoSketch is a multi-user online whiteboard designed to give you the ability to quickly visualize and share your ideas as images. http://www.cosketch.com/
- Crayon -The Crayon.net site offers an electronic template for students to create their own newspapers. The site allows you to bring multiple sources together, thus creating an individualized and customized newspaper. http://crayon.net/ Education Oasis -Education Oasis offers a collection of graphic organizers to help students organize and retain knowledge – cause and effect, character and story, compare and contrast, and more! http://www.educationoasis.com/printables/graphic-organizers/
- Edutopia -A comprehensive website and online community that increases knowledge, sharing, and adoption of what works in K-12 education. We emphasize core strategies: project-based learning, comprehensive assessment, integrated studies, social and emotional learning, educational leadership and teacher development, and technology integration. http://www.edutopia.org/

- Glogster -Glogster allows you to create "interactive posters" to communicate ideas. Students can embed media links, sound, and video, and then share their posters with friends. http://edu.glogster.com/?ref=personal
- Interactives – Elements of a Story -This interactive breaks down the important elements of a story. Students go through the series of steps for constructing a story including: Setting, Characters, Sequence, Exposition, Conflict, Climax, and Resolution. http://www.learner.org/interactives/story/index.html
- National Writing Project (NWP) -Unique in breadth and scale, the NWP is a network of sites anchored at colleges and universities and serving teachers across disciplines and at all levels, early childhood through university. We provide professional development, develop resources, generate research, and act on knowledge to improve the teaching of writing and learning in schools and communities. http://www.nwp.org
- Pacecar -Vocab Ahead offers videos that give an active demonstration of vocabulary with audio repeating the pronunciation, definition, various uses, and synonyms. Students can also go through flash cards which give a written definition and visual representation of the word. http://pacecar.missingmethod.com/