Glen Ridge Board of Education
Science
AP Physics I
Required
Full Year

New Jersey Student Learning Standards

Written by: Timothy Panebianco
### Science Mission Statement:

The Glen Ridge Public School’s science curriculum seeks to inspire scientifically-literate citizens who will be able to participate in a dynamic global community. Our program fosters a spirit of intellectual curiosity and collaborative problem solving that is innovative, experiential, thought-provoking, and developmentally appropriate. Our students will use scientific methodology to evaluate and critique global issues relating to Life Sciences, Physical Sciences, The Sciences of Earth & Space, and Engineering Sciences. Students will be challenged and will be encouraged to take risks and develop critical scientific thinking skills.

### Course Description:

This course is designed for a highly motivated student with strong mathematical ability. It is intended to provide further foundation in Physics for students intending to pursue college studies in physics as well as other sciences, engineering, and technology. The course is equivalent to a first-semester college course in algebra-based Physics. The course covers Newtonian Mechanics and Electricity in order to prepare students for the AP Physics I examination in May.

<table>
<thead>
<tr>
<th>Name of Course</th>
<th>Unit 1: Kinematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Allotted (days of instruction):</td>
<td>17 days</td>
</tr>
</tbody>
</table>

**New Jersey Student Learning Standards (NJSLS):** This unit provides necessary background and skills for the following units.

**AP Physics 1 and 2 Standards:**

- Essential Knowledge 3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
  - a. Displacement, velocity, and acceleration are all vector quantities.
  - b. Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.
  - c. A choice of reference frame determines the direction and the magnitude of each of these quantities.

  Learning Objective (3.A.1.1): The student is able to express the motion of an object using narrative, mathematical, and graphical representations.

  Learning Objective (3.A.1.2): The student is able to design an experimental investigation of the motion of an object.

  Learning Objective (3.A.1.3): The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.
<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Student Learning Objectives</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What is the difference between scalars and vectors?</td>
<td>● Student will be able to distinguish scalars from vectors</td>
<td>● 1D Kinematics</td>
</tr>
<tr>
<td>● Which physics quantities are vectors?</td>
<td>● Students will be able to add vectors graphically by using &quot;tail to tip&quot; or &quot;parallelogram&quot; methods.</td>
<td>● Adding vectors in 2D</td>
</tr>
<tr>
<td>● Which physics quantities are scalars?</td>
<td>● Students will be able to add vectors analytically by using vector components or law of cosine.</td>
<td>● Vector components</td>
</tr>
<tr>
<td>● How do we add vectors?</td>
<td>● Students will be able to find position, velocity and acceleration in two dimensional problems.</td>
<td>● Projectile motion</td>
</tr>
<tr>
<td>● How do we define position, velocity and acceleration in two dimensions?</td>
<td>● Students will be able to calculate: flying time, maximum range and maximum height in projectile motion.</td>
<td>● Kinematics Graphs Lab</td>
</tr>
<tr>
<td>● How do we calculate horizontal range in projectile motion?</td>
<td>● Students will be able to find relative velocity in different reference frames.</td>
<td>● Projectile Motion Lab</td>
</tr>
<tr>
<td>● How do we calculate maximum height in projectile motion?</td>
<td></td>
<td>● SMART Response multiple choice questions</td>
</tr>
<tr>
<td>● How do we calculate total flying time in projectile motion?</td>
<td></td>
<td>● Problem solving in groups</td>
</tr>
<tr>
<td>● What is the relationship between maximum range and angle in projectile motion?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>● What are real life applications of projectile motion?</td>
<td></td>
<td></td>
</tr>
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</table>

**Resources/Materials**  
Online textbook, homework, quizzes, tests and labs:  

**Interdisciplinary Connections**  
N-VM A. Represent and model with vector quantities  
N-VM B. Perform operations on vectors  
A-SSE B. Write expressions in equivalent forms to solve problems  
A-CED A. Create equations that describe numbers or relationships  
A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning  
A-REI B. Solve equations and inequalities on one variable  
A-REI C. Solve systems of equations  
A-REI D. Represent and solve equations and inequalities graphically

**21st Century Life and Careers**  
**Standard 6.3 Active Citizenship in the 21st Century**  
All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

**Standard 9.1 21st-Century Life & Career Skills**
All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

Technology Standards

**Standard 8.1 – Computer and Information Literacy**
All students will use computer applications to gather and organize information and to solve problems.

<table>
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<th>Assessments</th>
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<th>Benchmarks</th>
<th>Alternative</th>
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</table>
|             | - Kinematics graph lab  
- Projectile motion lab  
- Vectors Quiz  
- Free Response Quiz  
- SMART Response multiple choice questions | - Kinematics Test | - Marzano Scales | - Lab Performance Assessment  
- Oral problem explanation  
- Student Portfolio |

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|               | - Use Google Translate  
- Key vocabulary list provided  
- Lecture notes provided  
- Video lectures | - Preferential group seating  
- Extended time  
- Lecture notes provided  
- Homework posted online daily | - Lead content or problem reviews  
- Tutor other students  
- Leadership in cooperative groups  
- Review AP Physics C Kinematics 2D |

**Name of Course**

**Unit 2: Dynamics**

**New Jersey Student Learning Standards (NJSLS)**

**HS-PS2-1.** Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

**HS-PS2-2.** 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. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]
HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

[Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.][Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

AP Physics 1 and 2 Standards:

- **Essential Knowledge 3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
  a. Displacement, velocity, and acceleration are all vector quantities.
  b. Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.
  c. A choice of reference frame determines the direction and the magnitude of each of these quantities.

  Learning Objective (3.A.1.1): The student is able to express the motion of an object using narrative, mathematical, and graphical representations.

  Learning Objective (3.A.1.2): The student is able to design an experimental investigation of the motion of an object.

  Learning Objective (3.A.1.3): The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.

- **Essential Knowledge 3.A.2:** Forces are described by vectors.
  a. Forces are detected by their influence on the motion of an object.
  b. Forces have magnitude and direction.

  Learning Objective (3.A.2.1): The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

- **Essential Knowledge 3.A.3:** A force exerted on an object is always due to the interaction of that object with another object.
  a. An object cannot exert a force on itself.
  b. Even though an object is at rest, there may be forces exerted on that object by other objects.
  c. The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects.

  Learning Objective (3.A.3.1): The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.

  Learning Objective (3.A.3.2): The student is able to challenge a claim that an object can exert a force on itself.

  Learning Objective (3.A.3.3): The student is able to describe a force as an interaction between two objects and identify both objects for any force.

  Learning Objective (3.A.3.4): The student is able to make claims about the force on an object due to the presence of other objects with the same property:
mass, electric charge.

- **Essential Knowledge 3.A.4:** If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.

**Learning Objective (3.A.4.1):** The student is able to construct explanations of physical situations involving the interaction of bodies using Newton’s third law and the representation of action-reaction pairs of forces.

**Learning Objective (3.A.4.2):** The student is able to use Newton’s third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

**Learning Objective (3.A.4.3):** The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton’s third law to identify forces.

- **Essential Knowledge 3.B.1:** If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

**Learning Objective (3.B.1.1):** The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton’s second law in a variety of physical situations with acceleration in one dimension.

**Learning Objective (3.B.1.2):** The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.

**Learning Objective (3.B.1.3):** The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.

**Learning Objective (3.B.1.4):** The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton’s second law in a variety of physical situations.

- **Essential Knowledge 3.B.2:** Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
  a. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
  b. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  c. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.

**Learning Objective (3.B.2.1):** The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
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<tr>
<td>● How can an object be made to accelerate?</td>
<td>● Describe inertia using Newton’s First Law.</td>
<td>● Resolving forces in 2D</td>
</tr>
<tr>
<td>● How do forces interact?</td>
<td>● Relate force, mass and acceleration using Newton’s Second Law.</td>
<td>● Atwood Machine Lab</td>
</tr>
<tr>
<td>● How do objects respond to multiple forces acting on them?</td>
<td>● Solve problems in 1 and 2 dimensions using Newton’s Second Law.</td>
<td>● Inclined Plane</td>
</tr>
<tr>
<td>● How can you use Newton’s Laws of Motion to predict the behavior of objects?</td>
<td>● Describe inertial reference frames.</td>
<td>● Inclined Plane Lab</td>
</tr>
<tr>
<td>● How can free body or force diagrams be used to analyze interactions between objects?</td>
<td>● Differentiate between weight and mass.</td>
<td>● Static Equilibrium and Tension Force</td>
</tr>
<tr>
<td>● Why can’t an object exert a force on itself?</td>
<td>● Describe weight as a force in terms of mass and gravitational acceleration.</td>
<td>● SMART Response multiple choice questions</td>
</tr>
<tr>
<td></td>
<td>● Describe the normal force and understand the conditions in which it exists.</td>
<td>● Problem solving in groups</td>
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<td></td>
<td>● Identify a reaction force if given an action force.</td>
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<td></td>
<td>● Determine whether a frictional force is kinetic (moving) or static (not moving).</td>
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<td></td>
<td>● Solve problems in 1 and 2 dimensions involving static and kinetic friction.</td>
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<tr>
<td></td>
<td>● Identify and solve for tension force.</td>
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<td></td>
<td>● Draw free body diagrams in 1 and 2 dimensions.</td>
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</tr>
<tr>
<td></td>
<td>● Solve problems in 1 and 2 dimensions involving multiple forces and accelerations not restricted to one axis of motion.</td>
<td></td>
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**Resources/Materials**

- Online textbook, homework, quizzes, tests and labs: [https://njctl.org/courses/science/ap-physics-1/dynamics/](https://njctl.org/courses/science/ap-physics-1/dynamics/)

**Interdisciplinary Connections**

- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
### 21st Century Life and Careers

#### Standard 6.3 Active Citizenship in the 21st Century
All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

#### Standard 9.1 21st-Century Life & Career Skills
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### Technology Standards
#### Standard 8.1 – Computer and Information Literacy
All students will use computer applications to gather and organize information and to solve problems.

### Assessments

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<tbody>
<tr>
<td>Atwood Machine lab</td>
<td>Dynamics Test</td>
<td>Marzano Scales</td>
<td>Lab Performance Assessment</td>
</tr>
<tr>
<td>Inclined plane lab</td>
<td></td>
<td></td>
<td>Oral problem explanation</td>
</tr>
<tr>
<td>2D Forces Quiz</td>
<td></td>
<td></td>
<td>Student Portfolio</td>
</tr>
<tr>
<td>Free Response Quiz</td>
<td></td>
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<tr>
<td>SMART Response multiple choice questions</td>
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### Modifications

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<td>Use Google Translate</td>
<td>Preferential group seating</td>
<td>Lead content or problem reviews</td>
</tr>
<tr>
<td>Key vocabulary list provided</td>
<td>Extended time</td>
<td>Tutor other students</td>
</tr>
<tr>
<td>Lecture notes provided</td>
<td>Lecture notes provided</td>
<td>Leadership in cooperative groups</td>
</tr>
<tr>
<td>Video lectures</td>
<td>Homework posted online daily</td>
<td>Review AP Physics C Dynamics 2D</td>
</tr>
</tbody>
</table>

### Name of Course

#### Unit 3: Uniform Circular Motion

**Time Allotted (days of instruction):** 7 days

**New Jersey Student Learning Standards (NJSLS):** The topics in this unit are an essential part of understanding the later units and of physics as a whole.
AP Physics 1 and 2 Standards:

- **Essential Knowledge 3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
  
f. The kinematic equations only apply to constant acceleration situations. Circular motion and projectile motion are both included.
  
h. This also includes situations where there is both a radial and tangential acceleration for an object moving in a circular path.

- **Essential Knowledge 3.B.2:** Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
  
a. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
  
b. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  
c. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.

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</thead>
<tbody>
<tr>
<td>How do we use Free Body diagrams and Newton’s Laws to solve circular motion problems?</td>
<td>How to relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration. How to describe the direction of the particle’s velocity and acceleration at any instant during the motion. How to analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as the following: (1) Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a</td>
<td>Kinematics of Circular Motion Dynamics of Circular Motion Banked and unbanked curves Conical Pendulum Circular Motion Lab SMART Response multiple choice questions Problem solving in groups</td>
</tr>
</tbody>
</table>
banked curve). (2) Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).

**Resources/Materials**

Online textbook, homework, quizzes, tests and labs:


**Interdisciplinary Connections**

N-VM A. Represent and model with vector quantities
N-VM B. Perform operations on vectors
A-SSE B. Write expressions in equivalent forms to solve problems
A-CED A. Create equations that describe numbers or relationships
A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
A-REI B. Solve equations and inequalities on one variable
A-REI C. Solve systems of equations
A-REI D. Represent and solve equations and inequalities graphically

**21st Century Life and Careers**

Standard 6.3 Active Citizenship in the 21st Century
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**Technology Standards**

Standard 8.1 – Computer and Information Literacy
All students will use computer applications to gather and organize information and to solve problems.

<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td><strong>Formative</strong></td>
</tr>
<tr>
<td>Circular Motion Quiz</td>
</tr>
<tr>
<td>Circular Motion Lab</td>
</tr>
<tr>
<td>Free Response Quiz</td>
</tr>
<tr>
<td>SMART Response multiple choice questions</td>
</tr>
<tr>
<td><strong>Summative</strong></td>
</tr>
<tr>
<td>Circular Motion Test</td>
</tr>
<tr>
<td><strong>Benchmarks</strong></td>
</tr>
<tr>
<td>Marzano Scales</td>
</tr>
<tr>
<td><strong>Alternative</strong></td>
</tr>
<tr>
<td>Lab Performance Assessment</td>
</tr>
<tr>
<td>Oral problem explanation</td>
</tr>
<tr>
<td>Student Portfolio</td>
</tr>
</tbody>
</table>

**Modifications**

Name of Course

Unit 4: Universal Gravitation

Time Allotted (days of instruction): 9 days

New Jersey Student Learning Standards (NJSLS)

HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.

AP Physics 1 and 2 Standards:

- Enduring Understanding 2.A: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.

  Essential Knowledge 2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector. Vector fields are represented by field vectors indicating direction and magnitude. When more than one source object with mass or electric charge is present, the field value can be determined by vector addition. Conversely, a known vector field can be used to make inferences about the number, relative size, and location of sources.

- Enduring Understanding 2.B: A gravitational field is caused by an object with mass.

  Essential Knowledge 2.B.1: A gravitational field \( g \) at the location of an object with mass \( m \) causes a gravitational force of magnitude \( mg \) to be exerted on the object in the direction of the field. On the Earth, this gravitational force is called weight. The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force. If the gravitational force is the only force exerted on the object, the observed free-fall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in newtons/kilogram) at that location.

  Learning Objective (2.B.1.1): The student is able to 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.

  Essential Knowledge 2.B.2: The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object. The gravitational field caused by a spherically symmetric object is a vector whose magnitude outside the object is equal to \( \frac{GM}{r^2} \).

  b. Only spherically symmetric objects will be considered as sources of the gravitational field.
Learning Objective (2.B.2.1): The student is able to apply $g = GM/r^2$ to calculate the gravitational field due to an object with mass $M$, where the field is a vector directed toward the center of the object of mass $M$.

Learning Objective (2.B.2.2): The student is able to approximate a numerical value of the gravitational field ($g$) near the surface of an object from its radius and mass relative to those of the Earth or other reference objects.

Essential Knowledge 1.C.2: Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields. The gravitational mass of an object determines the amount of force exerted on the object by a gravitational field. Near the Earth’s surface, all objects fall (in a vacuum) with the same acceleration, regardless of their inertial mass.

Essential Knowledge 1.C.3: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

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<tr>
<td>● How are mass, separation, and gravitational force related? ● How does the mass of a planet relate to its gravitational force? ● How do we explain the apparent weightlessness of orbiting objects? ● How is the motion of a falling apple like the motion of the moon? ● How is Newton’s second law related to his universal law of gravitation?</td>
<td>● Determine the force that one spherically symmetrical mass exerts on another. ● Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass. ● Recognize that the motion does not depend on the object’s mass ● Describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit ● Derive expressions for the velocity and period of revolution in such an orbit.</td>
<td>● Gravitational Force ● Gravitational Field and Surface Gravity ● Gravitational Field in Space and Orbital Motion ● Kepler’s 3rd Law of Motion ● Gravitation Lab ● SMART Response multiple choice questions ● Problem solving in groups</td>
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Resources/Materials

### Interdisciplinary Connections

- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
- A-REI B. Solve equations and inequalities on one variable
- A-REI C. Solve systems of equations
- A-REI D. Represent and solve equations and inequalities graphically

### 21st Century Life and Careers

**Standard 6.3 Active Citizenship in the 21st Century**

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**Standard 9.1 21st-Century Life & Career Skills**

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### Technology Standards

**Standard 8.1 – Computer and Information Literacy**

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<td>SMART Response multiple choice questions</td>
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<table>
<thead>
<tr>
<th>Modifications</th>
<th>English Language Learners</th>
<th>Special Education/504</th>
<th>Gifted and Talented</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use Google Translate</td>
<td>Preferential group seating</td>
<td>Lead content or problem reviews</td>
</tr>
<tr>
<td></td>
<td>Key vocabulary list provided</td>
<td>Extended time</td>
<td>Tutor other students</td>
</tr>
<tr>
<td></td>
<td>Lecture notes provided</td>
<td>Lecture notes provided</td>
<td>Leadership in cooperative groups</td>
</tr>
<tr>
<td></td>
<td>Video lectures</td>
<td>Homework posted online daily</td>
<td>Review AP Physics C Gravitation</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Name of Course</th>
<th>Unit 5: Work and Energy</th>
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</thead>
</table>

Time Allotted (days of instruction): 13 days

New Jersey Student Learning Standards (NJSLS)
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2. 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 position of particles (objects).

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

AP Physics 1 and 2 Standards:

- Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.

  Essential Knowledge 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the interval that the force is exerted. Only the component of the net force exerted on an object parallel or antiparallel to the displacement of the object will increase (parallel) or decrease (antiparallel) the kinetic energy of the object. The magnitude of the change in the kinetic energy is the product of the magnitude of the displacement and of the magnitude of the component of force parallel or antiparallel to the displacement. The component of the net force exerted on an object perpendicular to the direction of the displacement of the object can change the direction of the motion of the object without changing the kinetic energy of the object. This should include uniform circular motion and projectile motion.

  Learning Objective (3.E.1.1): The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.

  Learning Objective (3.E.1.2): The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged.

  Learning Objective (3.E.1.3): The student is able to use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged.

  Learning Objective (3.E.1.4): The student is able to apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object.

- Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.

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

  Learning Objective (4.C.1.1): The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.

  Learning Objective (4.C.1.2): The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.
Essential Knowledge 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work. If the force is constant during a given displacement, then the work done is the product of the displacement and the component of the force parallel or antiparallel to the displacement.

Work (change in energy) can be found from the area under a graph of the magnitude of the force component parallel to the displacement versus displacement.

Learning Objective (4.C.2.1): The student is able to 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.

Learning Objective (4.C.2.2): The student is able to 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.

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

Learning Objective (5.A.2.1): The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.

Essential Knowledge 5.B.1: Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.

Learning Objective (5.B.1.1): The student is able to set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy.

Learning Objective (5.B.1.2): The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies.

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

Learning Objective (5.B.2.1): The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.

Essential Knowledge 5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that
system interact with conservative forces.
The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system.
Changes in the internal structure can result in changes in potential energy. Examples should include mass-spring oscillators, objects falling in a gravitational field.
The change in electric potential in a circuit is the change in potential energy per unit charge.

Learning Objective (5.B.3.1): The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

Learning Objective (5.B.3.2): The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

Learning Objective (5.B.3.3): The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Student Learning Objectives</th>
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</tr>
</thead>
<tbody>
<tr>
<td>• How to interactions with other objects or systems change the total energy of a</td>
<td>• Calculate the work done by a specified constant force on an object that undergoes a specified displacement.</td>
<td>• Work and Energy with 1D forces</td>
</tr>
<tr>
<td>system?</td>
<td>• Relate the work done by a force to the area under a graph of force as a function of position and calculate this work in the case where the force is a linear function of position.</td>
<td>• 2D Forces and Work</td>
</tr>
<tr>
<td>• How is the definition of work in physics different than everyday life? How do we</td>
<td>• Use the scalar product operation to calculate the work performed by a specified constant force F on an object that undergoes a displacement in a plane.</td>
<td>• Gravitational Potential Energy</td>
</tr>
<tr>
<td>describe mechanical energy?</td>
<td>• Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.</td>
<td>• Work and Energy Lab</td>
</tr>
<tr>
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<td>• Calculate the work performed by the net force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy.</td>
<td>• Kinetic Energy</td>
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<td>• Elastic Potential Energy</td>
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<td>• Problem solving in groups</td>
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Apply the theorem to determine the change in an object’s kinetic energy and speed which results from the application of specified forces, or to determine the force that is required in order to bring an object to rest in a specified distance.

- Describe examples of conservative forces and non-conservative forces.
- Write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring.
- Calculate the potential energy of one or more objects in a uniform gravitational field.
- State and apply the relation between the work performed on an object by non-conservative forces and the change in an object’s mechanical energy.
- Describe and identify situations in which mechanical energy is converted to other forms of energy.
- Analyze situations in which an object’s mechanical energy is changed by friction or by a specified externally applied force.
- Identify situations in which mechanical energy is or is not conserved.
- Apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood’s machine.
- Apply conservation of energy in analyzing the motion of objects that move under the influence of springs.
- Recognize and solve problems that call for application both of conservation of energy and Newton’s Laws.
- Calculate the power required to maintain the motion of an object with constant acceleration (e.g., to move an object along a level surface, to raise an object at a constant rate, or to overcome friction for an object that is moving at a constant speed).
- Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work.

**Resources/Materials**

Online textbook, homework, quizzes, tests and labs:

**Physics. 6th Edition. Giancoli.**

**Interdisciplinary Connections**

- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
- A-REI B. Solve equations and inequalities on one variable
- A-REI C. Solve systems of equations
- A-REI D. Represent and solve equations and inequalities graphically

**21st Century Life and Careers**

**Standard 6.3 Active Citizenship in the 21st Century**
All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

**Standard 9.1 21st-Century Life & Career Skills**
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**Name of Course**

**Unit 6: Momentum**

**Time Allotted (days of instruction): 9 days**

**New Jersey Student Learning Standards (NJSLS)**

HS-PS2-2. 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.

HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

**AP Physics 1 and 2 Standards:**

- Enduring Understanding 3.D: A force exerted on an object can change the momentum of the object.

  Essential Knowledge 3.D.1: The change in momentum of an object is a vector in the direction of the net force exerted on the object.

  Learning Objective (3.D.1.1): The student is able to justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force.

  Essential Knowledge 3.D.2: The change in momentum of an object occurs over a time interval. The force that one object exerts on a second object changes the momentum of the second object (in the absence of other forces on the second object). The change in momentum of that object depends on the impulse, which is the product of the average force and the time interval during which the interaction occurred.

  Learning Objective (3.D.2.1): The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.

  Learning Objective (3.D.2.2): The student is able to predict the change in momentum of an object from the average force exerted on the object and the
interval of time during which the force is exerted.

Learning Objective (3.D.2.3): The student is able to analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.

Learning Objective (3.D.2.4): The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.

- Enduring Understanding 4.B: Interactions with other objects or systems can change the total linear momentum of a system.

Essential Knowledge 4.B.1: The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.

Learning Objective (4.B.1.1): The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).

Learning Objective (4.B.1.2): The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.

Essential Knowledge 4.B.2: The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted. The units for momentum are the same as the units of the area under the curve of a force versus time graph. The changes in linear momentum and force are both vectors in the same direction.

Learning Objective (4.B.2.1): The student is able to apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system.

Learning Objective (4.B.2.2): The student is able to perform analysis on data presented as a force-time graph and predict the change in momentum of a system.

- Essential Knowledge 5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
  In a closed system, the linear momentum is constant throughout the collision.

Learning Objective (5.D.1.1): The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.

Learning Objective (5.D.1.2): The student is able to apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the
interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations.

Learning Objective (5.D.1.3): The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.

Learning Objective (5.D.1.4): The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.

Learning Objective (5.D.1.5): The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.

Learning Objective (5.D.1.6): The student is able to make predictions of the dynamical properties of a system undergoing a collision by application of the principle of linear momentum conservation and the principle of the conservation of energy in situations in which an elastic collision may also be assumed.

Learning Objective (5.D.1.7): The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.

● Essential Knowledge 5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
   In a closed system, the linear momentum is constant throughout the collision.
   In a closed system, the kinetic energy after an inelastic collision is different from the kinetic energy before the collision.

Learning Objective (5.D.2.1): The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.

Learning Objective (5.D.2.2): The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.

Learning Objective (5.D.2.3): The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.

Learning Objective (5.D.2.4): The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force.

Learning Objective (5.D.2.5): The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum.
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.

Learning Objective (5.D.2.6): The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>● What factors affect the collision of two objects?</td>
<td>● Perfectly elastic collisions of objects moving in arbitrary directions</td>
<td>● Momentum and Impulse</td>
</tr>
<tr>
<td>● How can you determine if a collision is elastic or inelastic?</td>
<td>● The effect of impulse at an arbitrary angle to initial velocity</td>
<td>● Momentum of a system of objects</td>
</tr>
<tr>
<td>● How can changes in momentum be used to determine the net force applied to an object?</td>
<td>● Inelastic collisions of objects moving in arbitrary directions</td>
<td>● Conservation of momentum</td>
</tr>
<tr>
<td></td>
<td>● Collisions: Perfectly elastic, perfectly inelastic, inelastic</td>
<td>● Types of collisions</td>
</tr>
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<td></td>
<td>● Conservation of momentum with objects moving in arbitrary directions</td>
<td>● Collisions in 2D</td>
</tr>
<tr>
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<td></td>
<td>● Momentum Lab</td>
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<td></td>
<td>● SMART Response multiple choice questions</td>
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<td></td>
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| Interdisciplinary Connections | N-VM A. Represent and model with vector quantities  
N-VM B. Perform operations on vectors  
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A-CED A. Create equations that describe numbers or relationships  
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### Assessments

<table>
<thead>
<tr>
<th>Formative</th>
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<th>Benchmarks</th>
<th>Alternative</th>
</tr>
</thead>
</table>
| ● Momentum Quiz  
● Momentum Lab  
● Free Response Quiz  
● SMART Response multiple choice questions | ● Momentum Test  |
| ● MarzANO Scales | ● Lab Performance Assessment  
● Oral problem explanation  
● Student Portfolio |

### Modifications

<table>
<thead>
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● Key vocabulary list provided  
● Lecture notes provided  
● Video lectures | ● Preferential group seating  
● Extended time  
● Lecture notes provided  
● Homework posted online daily | ● Lead content or problem reviews  
● Tutor other students  
● Leadership in cooperative groups  
● Review AP Physics C Momentum |

### Name of Course

**Unit 7: Rotational Motion**

**Time Allotted (days of instruction): 17 days**

**New Jersey Student Learning Standards (NJSLS):** Exceed Standards

**AP Physics 1 and 2 Standards:**

- Essential Knowledge 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
  - An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
  - A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  - A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.

**Learning Objective (3.B.2.1):** The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion.
qualitatively and quantitatively.

- Essential Knowledge 3.F.1: Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.
The lever arm is the perpendicular distance from the axis of rotation or revolution to the line of application of the force.
The magnitude of the torque is the product of the magnitude of the lever arm and the magnitude of the force.
The net torque on a balanced system is zero.

Learning Objective (3.F.1.1): The student is able to use representations of the relationship between force and torque.
Learning Objective (3.F.1.2): The student is able to compare the torques on an object caused by various forces.
Learning Objective (3.F.1.3): The student is able to estimate the torque on an object caused by various forces in comparison to other situations.
Learning Objective (3.F.1.4): The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.
Learning Objective (3.F.1.5): The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction).

- Essential Knowledge 3.F.2: The presence of a net torque along any axis will cause a rigid system to change its rotational motion or an object to change its rotational motion about that axis.
Rotational motion can be described in terms of angular displacement, angular velocity, and angular acceleration about a fixed axis.
Rotational motion of a point can be related to linear motion of the point using the distance of the point from the axis of rotation.
The angular acceleration of an object or rigid system can be calculated from the net torque and the rotational inertia of the object or rigid system.

Learning Objective (3.F.2.1): The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.
Learning Objective (3.F.2.2): The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.

- Essential Knowledge 3.F.3: A torque exerted on an object can change the angular momentum of an object.
a. Angular momentum is a vector quantity, with its direction determined by a right-hand rule.
b. The magnitude of angular momentum of a point object about an axis can be calculated by multiplying the perpendicular distance from the axis of rotation to the line of motion by the magnitude of linear momentum.
c. The magnitude of angular momentum of an extended object can also be found by multiplying the rotational inertia by the angular velocity.
d. The change in angular momentum of an object is given by the product of the average torque and the time the torque is exerted.

Learning Objective (3.F.3.1): The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze
linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.

Learning Objective (3.F.3.2): In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.

Learning Objective (3.F.3.3): The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.

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<tr>
<td>● What are the conditions necessary for two objects with significant differences in mass to balance on a meter stick?</td>
<td>● How linear motion and rotational motion are related</td>
<td>● Angular Quantities</td>
</tr>
<tr>
<td>● What are the conditions necessary for static equilibrium?</td>
<td>● The relationships among angular quantities and linear quantities</td>
<td>● Angular Acceleration</td>
</tr>
<tr>
<td>● How are linear motion and rotational motion related?</td>
<td>● What it means for an object to be in static equilibrium</td>
<td>● Rotational Kinematics</td>
</tr>
<tr>
<td>● What are the relationships among angular momentum, angular velocity, angular acceleration, rotational inertia and torque?</td>
<td>● Solve problems using equations for angular momentum, angular velocity, angular acceleration, rotational inertia and torque</td>
<td>● Rotational Dynamics</td>
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<td>● Rotational Kinetic Energy and Angular Momentum</td>
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<td>● Rotational Lab</td>
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Resources/Materials

Online textbook, homework, quizzes, tests and labs:


Interdisciplinary Connections

N-VM A. Represent and model with vector quantities
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21st Century Life and Careers

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cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

**Standard 9.1 21st-Century Life & Career Skills**
All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures

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<table>
<thead>
<tr>
<th>Assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formative</strong></td>
</tr>
<tr>
<td>Rotational Kinematics Quiz</td>
</tr>
<tr>
<td>Rotational Lab</td>
</tr>
<tr>
<td>Free Response Quiz</td>
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<tr>
<td>SMART Response multiple choice questions</td>
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</tbody>
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<table>
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<tr>
<th>Modifications</th>
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<tbody>
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**Name of Course**

**Unit 8: Simple Harmonic Motion**

**Time Allotted (days of instruction): 8 days**

**New Jersey Student Learning Standards (NJSLS)**

**HS-PS3-1.** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

**HS-PS3-2.** 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 position of particles (objects).

**AP Physics 1 and 2 Standards:**

- Essential Knowledge 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an
equilibrium position, the object will undergo a special type of motion called simple harmonic motion. For a spring that exerts a linear restoring force the period of a mass-spring oscillator increases with mass and decreases with spring stiffness. For a simple pendulum oscillating the period increases with the length of the pendulum.

Minima, maxima, and zeros of position, velocity, and acceleration are features of harmonic motion. Students should be able to calculate force and acceleration for any given displacement for an object oscillating on a spring.

Learning Objective (3.B.3.1): The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.

Learning Objective (3.B.3.2): The student is able to design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.

Learning Objective (3.B.3.3): The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.

Learning Objective (3.B.3.4): The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force.

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<tr>
<th>Essential Questions</th>
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<tbody>
<tr>
<td>● What is simple harmonic motion?</td>
<td>● How energy changes from potential to kinetic during simple harmonic motion</td>
<td>● Period, Frequency, SHM &amp; UCM</td>
</tr>
<tr>
<td>● How do we determine the energy, position, speed, acceleration, frequency, and period of a physical system?</td>
<td>● How a spring pendulum works</td>
<td>● Simple Pendulum and Spring Pendulum</td>
</tr>
<tr>
<td>● What is the sinusoidal nature of simple harmonic motion?</td>
<td>● How a simple pendulum work</td>
<td>● Sinusoidal Nature of SHM</td>
</tr>
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<td>● How to graph position, velocity, and acceleration as functions of time for simple harmonic motion</td>
<td>● SHM Lab</td>
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<td>● SMART Response multiple choice questions</td>
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<td>● Problem solving in groups</td>
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**Resources/Materials**


**Interdisciplinary Connections**

- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
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<tbody>
<tr>
<td>SHM Graph Quiz</td>
<td>SHM Test</td>
<td>Marzano Scales</td>
<td>Lab Performance Assessment</td>
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<td>SHM Lab</td>
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<tr>
<td>Lecture notes provided</td>
<td>Lecture notes provided</td>
<td>Leadership in cooperative groups</td>
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<tr>
<td>Video lectures</td>
<td>Homework posted online daily</td>
<td>Review AP Physics C SHM</td>
</tr>
</tbody>
</table>

### Name of Course

**Unit 9: Waves**

### Time Allotted (days of instruction): 7 days

### New Jersey Student Learning Standards (NJSLS)

**HS-PS4-1.** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

### AP Physics 1 and 2 Standards:

Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model...
for the description of other phenomena.

- Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.

  Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves. Electromagnetic waves are transverse waves. Transverse waves may be polarized.

  Learning Objective (6.A.1.1): The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.

  Learning Objective (6.A.1.2): The student is able to describe representations of transverse and longitudinal waves.

  Learning Objective (6.A.1.3): The student is able to analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation.

  Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.

  Learning Objective (6.A.3.1): The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.

  Essential Knowledge 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.

  Learning Objective (6.B.1.1): The student is able to use 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.

  Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.

  Learning Objective (6.B.2.1): The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.

  Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.
Learning Objective (6.B.4.1): The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.

Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

- Essential Knowledge 6.C.1: When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.

Learning Objective (6.C.1.1): The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves.

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<tbody>
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<td>What are the properties of waves?</td>
<td>Various concepts dealing with vibrations and waves.</td>
<td>Wave Motion, Types of Waves, and Interference</td>
</tr>
<tr>
<td>How do we distinguish the difference between longitudinal and transverse waves, and give at least one example of each?</td>
<td>The difference between longitudinal and transverse waves.</td>
<td>Standing Waves on a String</td>
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<tr>
<td>What happens when two waves overlap?</td>
<td>What happens when waves interact</td>
<td>Waves Lab</td>
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<td></td>
<td>The relationship between wave speed, frequency, and length</td>
<td>SMART Response multiple choice questions</td>
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<td></td>
<td>How waves are created</td>
<td>Problem solving in groups</td>
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Resources/Materials

Online textbook, homework, quizzes, tests and labs:
https://njctl.org/courses/science/ap-physics-1/waves/


Interdisciplinary Connections

N-VM A. Represent and model with vector quantities
N-VM B. Perform operations on vectors
A-SSE B. Write expressions in equivalent forms to solve problems
A-CED A. Create equations that describe numbers or relationships
A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
A-REI B. Solve equations and inequalities on one variable
A-REI C. Solve systems of equations
A-REI D. Represent and solve equations and inequalities graphically
**21st Century Life and Careers**

**Standard 6.3 Active Citizenship in the 21st Century**
All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

**Standard 9.1 21st-Century Life & Career Skills**
All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

**Technology Standards**

**Standard 8.1 – Computer and Information Literacy**
All students will use computer applications to gather and organize information and to solve problems.

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**Name of Course**

**Unit 10: Sound Waves**

**Time Allotted (days of instruction):** 10 days

**New Jersey Student Learning Standards (NJSLS)**

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

**AP Physics 1 and 2 Standards:**

- Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves.

- Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.
Learning Objective (6.A.2.1): The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.

Essential Knowledge 6.A.4: Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.

Learning Objective (6.A.4.1): The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.

Learning Objective (6.C.4.1): The student is able to 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.

- Essential Knowledge 6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes.

<table>
<thead>
<tr>
<th>Essential Questions</th>
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<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do we define the nature of sound waves?</td>
<td>the properties of sound</td>
<td>Characteristics of Sound &amp; Sources of Sound</td>
</tr>
<tr>
<td>How do different musical instruments such at open and closed tubes create sound?</td>
<td>sound wave interference and diffraction</td>
<td>Open and Closed Tubes</td>
</tr>
<tr>
<td>What happens when two sound waves interact?</td>
<td>how open and closed tubes create sound</td>
<td>Interference</td>
</tr>
<tr>
<td>What happens when either the source of a sound or the observer moves?</td>
<td>how the Doppler effect changes how we hear sounds</td>
<td>Doppler Effect</td>
</tr>
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<td>Sound Lab</td>
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**Resources/Materials**

Online textbook, homework, quizzes, tests and labs: [https://njctl.org/courses/science/ap-physics-1/waves/](https://njctl.org/courses/science/ap-physics-1/waves/)

**Physics. 6th Edition. Giancoli.**

**Interdisciplinary Connections**

N-VM A. Represent and model with vector quantities  
N-VM B. Perform operations on vectors  
A-SSE B. Write expressions in equivalent forms to solve problems  
A-CED A. Create equations that describe numbers or relationships  
A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning  
A-REI B. Solve equations and inequalities on one variable
### 21st Century Life and Careers

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### Technology Standards

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● Interference Quiz  
● Sound Lab  
● Free Response Quiz  
● SMART Response multiple choice questions | ● Sound Test | ● Marzano Scales | ● Lab Performance Assessment  
● Oral problem explanation  
● Student Portfolio |

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● Extended time  
● Lecture notes provided  
● Homework posted online daily | ● Lead content or problem reviews  
● Tutor other students  
● Leadership in cooperative groups |

### Name of Course

**Unit 11: Electric Charge and Force**

**Time Allotted (days of instruction): 6 days**

**New Jersey Student Learning Standards (NJSLS)**

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.

- Essential Knowledge 1.A.4: Atoms have internal structures that determine their properties. The number of protons in the nucleus determines the number of electrons in a neutral atom. The number and arrangements of electrons cause elements to have different properties.

- Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.

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

  Learning Objective (1.B.1.1): The student is able to make claims about natural phenomena based on conservation of electric charge.

  Essential Knowledge 1.B.2: There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.

  Learning Objective (1.B.2.1): The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices.

  Learning Objective (1.B.2.2): The student is able to make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes.

  Learning Objective (1.B.2.3): The student is able to challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object.

  Essential Knowledge 1.B.3: The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge. The magnitude of the elementary charge is equal to $1.6 \times 10^{-19}$ coulombs. Electrons have a negative elementary charge; protons have a positive elementary charge of equal magnitude, although the mass of a proton is much larger than the mass of an electron.

- Essential Knowledge 1.E.4: Matter has a property called electric permittivity. Free space has a constant value of the permittivity that appears in physical relationships. The permittivity of matter has a value different from that of free space.

- Enduring Understanding 2.A: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.
Essential Knowledge 2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector. Vector fields are represented by field vectors indicating direction and magnitude. When more than one source object with mass or electric charge is present, the field value can be determined by vector addition. Conversely, a known vector field can be used to make inferences about the number, relative size, and location of sources.

Essential Knowledge 2.A.2: A scalar field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a scalar. In Physics 2, this should include electric potential. Scalar fields are represented by field values. When more than one source object with mass or charge is present, the scalar field value can be determined by scalar addition. Conversely, a known scalar field can be used to make inferences about the number, relative size, and location of sources.

Enduring Understanding 2.C: An electric field is caused by an object with electric charge.

Essential Knowledge 2.C.1: The magnitude of the electric force \( F \) exerted on an object with electric charge \( q \) by an electric field \( E \) is \( F = qE \). The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distribution, and uniformly charged parallel plates.

Learning Objective (2.C.1.1): The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge \( q \) placed in an electric field \( E \).

**Essential Questions**

- Why is it that when you take off a sweater in a dark room you can see tiny sparks and hear a crackling sound?
- A student touches an electroscope with his hand at the same time he brings a positively charged rod close to the electroscope without touching. When he removes his hand first and then moves the rod away from the electroscope the leaves move apart. Why? What type of charge is on the leaves?

**Student Learning Objectives**

- By the end of this unit, students will know:
  - The two types of electric charges
  - The law of conservation of charge
  - How charges interact
  - How to charge various object using conduction and induction
  - Use Coulomb’s Law to solve problems
  - Make predictions about charges

**Activities**

- Charged rod and various object
- Electroscope
- Van De Graaf generator

**Resources/Materials**

Online textbook, homework, quizzes, tests and labs:
## Interdisciplinary Connections

- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
- A-REI B. Solve equations and inequalities on one variable
- A-REI C. Solve systems of equations
- A-REI D. Represent and solve equations and inequalities graphically

## 21st Century Life and Careers

**Standard 6.3 Active Citizenship in the 21st Century**

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## Technology Standards

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All students will use computer applications to gather and organize information and to solve problems.

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### Name of Course

**Unit 12: Electric Current and Circuits**
**Time Allotted (days of instruction): 16 days**

**New Jersey Student Learning Standards (NJSLS)**

**AP Physics 1 and 2 Standards:**

- **Essential Knowledge 1.B.1:** Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
  - An electrical current is a movement of charge through a conductor.
  - A circuit is a closed loop of electrical current.

  *Learning Objective (1.B.1.2):*
The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.

- **Essential Knowledge 1.E.2:** Matter has a property called resistivity.
  - The resistivity of a material depends on its molecular and atomic structure.
  - The resistivity depends on the temperature of the material.

  *Learning Objective (1.E.2.1):* The student is able to choose and justify the selection of data needed to determine resistivity for a given material.

- **Essential Knowledge 4.E.4:** The resistance of a resistor, and the capacitance of a capacitor, can be understood from the basic properties of electric fields and forces, as well as the properties of materials and their geometry.
  - The resistance of a resistor is proportional to its length and inversely proportional to its cross-sectional area. The constant of proportionality is the resistivity of the material.
  - The capacitance of a parallel plate capacitor is proportional to the area of one of its plates and inversely proportional to the separation between its plates. The constant of proportionality is the product of the dielectric constant, \( \kappa \), of the material between the plates and the electric permittivity, \( \varepsilon_0 \).
  - The current through a resistor is equal to the potential difference across the resistor divided by its resistance \( R \). The magnitude of charge of one of the plates of a parallel plate capacitor is directly proportional to the product of the potential difference across the capacitor and the capacitance. The plates have equal amounts of charge of opposite sign.

  *Learning Objective (4.E.4.1):* The student is able to make predictions about the properties of resistors and/or capacitors when placed in a simple circuit, based on the geometry of the circuit element and supported by scientific theories and mathematical relationships.

  *Learning Objective (4.E.4.2):* The student is able to design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.

  *Learning Objective (4.E.4.3):* The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.

- **Essential Knowledge 4.E.5:** The values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors.

  *Learning Objective (4.E.5.1):* The student is able to make and justify a quantitative prediction of the effect of a change in values or arrangements of one or
two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

Learning Objective (4.E.5.2): The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

Learning Objective (4.E.5.3): The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors.

- Essential Knowledge 5.B.9: Kirchhoff’s loop rule describes conservation of energy in electrical circuits. The application of Kirchhoff’s laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors. Energy changes in simple electrical circuits are conveniently represented in terms of energy change per charge moving through a battery and a resistor. Since electric potential difference times charge is energy, and energy is conserved, the sum of the potential differences about any closed loop must add to zero. The electric potential difference across a resistor is given by the product of the current and the resistance. The rate at which energy is transferred from a resistor is equal to the product of the electric potential difference across the resistor and the current through the resistor. Energy conservation can be applied to combinations of resistors and capacitors in series and parallel circuits.

Learning Objective (5.B.9.1): The student is able to construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff’s loop rule).

Learning Objective (5.B.9.2): The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff’s loop rule ($\sum \Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches.

Learning Objective (5.B.9.3): The student is able to apply conservation of energy (Kirchhoff’s loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch.

(To add more rows, right click and choose Insert Row Below)

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Student Learning Objectives</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are voltage, current, and resistance?</td>
<td>That current is defined as charge over time</td>
<td>Ohm’s Law Lab</td>
</tr>
<tr>
<td>How are voltage, current, and resistance related?</td>
<td>The relationship between voltage, current, and resistance</td>
<td>Resistivity Lab</td>
</tr>
<tr>
<td>What factors affect resistivity?</td>
<td>Ohm’s Law</td>
<td>Series and Parallel Lamps Circuit</td>
</tr>
</tbody>
</table>
- Kirchoff’s Rules (the rules will not be named but they will be applied)
- The relationship between voltage/current/resistance and power in circuits
- The relationship between emf and terminal voltage

**Resources/Materials**

- Online textbook, homework, quizzes, tests and labs: [https://njctl.org/courses/science/ap-physics-1/electric-current-circuits/](https://njctl.org/courses/science/ap-physics-1/electric-current-circuits/)

**Interdisciplinary Connections**

- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
- A-REI B. Solve equations and inequalities on one variable
- A-REI C. Solve systems of equations
- A-REI D. Represent and solve equations and inequalities graphically

**21st Century Life and Careers**

- **Standard 6.3 Active Citizenship in the 21st Century**
  All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

- **Standard 9.1 21st-Century Life & Career Skills**
  All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures

**Technology Standards**

- **Standard 8.1 – Computer and Information Literacy**
  All students will use computer applications to gather and organize information and to solve problems.

### Assessments

<table>
<thead>
<tr>
<th>Formative</th>
<th>Summative</th>
<th>Benchmarks</th>
<th>Alternative</th>
</tr>
</thead>
</table>
| - Ohm’s Law Quiz  
- Series and Parallel Circuits Quiz  
- Free Response Quiz  
- SMART Response multiple | - Circuits Test | - Marzano Scales | - Lab Performance Assessment  
- Oral problem explanation  
- Student Portfolio |
<table>
<thead>
<tr>
<th>Modifications</th>
<th>English Language Learners</th>
<th>Special Education/504</th>
<th>Gifted and Talented</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>● Use Google Translate</td>
<td>● Preferential group seating</td>
<td>● Lead content or problem reviews</td>
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<tr>
<td></td>
<td>● Key vocabulary list provided</td>
<td>● Extended time</td>
<td>● Tutor other students</td>
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<td></td>
<td>● Lecture notes provided</td>
<td>● Lecture notes provided</td>
<td>● Leadership in cooperative groups</td>
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<tr>
<td></td>
<td>● Video lectures</td>
<td>● Homework posted online daily</td>
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