Honors Physics (9th Grade)

Summit High School
Summit, NJ
2021

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Course Description

Physics (9th grade) is a full year course that introduces students to the underlying laws and concepts of the physical world. The Summit High School science sequence starts with physics because it includes the most fundamental concepts necessary to understand more complex phenomena in subsequent courses like chemistry and biology.

In Honors Physics (9th grade) we cover a broad survey of topics to lay the foundation for science literacy and further study. Covered units include: Motion, Dynamics, Energy, Electricity and Magnetism, Waves, and Earth Science. *Topics covered in the honors level are broadly similar to the regular level, but add a few along the way, most notably vectors and projectiles and circuits.*

As a course for 9th graders, mathematical analysis is largely limited to the Algebra 1 level. Problem solving will reinforce solving for a variable in equations with one unknown. Students also review ideas related to graphing, slope, direct, inverse, and inverse square relationships. *At the honors level, more challenging algebra concepts are introduced, including solving literal equations and solving simultaneous equations. To support our unit on projectile motion and vectors, students are taught the rudiments of right angle trigonometry so that they can calculate angles, resultants and vector components.*

The course is NJSLS-S aligned and uses an inquiry approach for each unit. In keeping with the NGSS approach, instructional focus includes: asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematical and computational thinking, constructing explanations, and engaging in arguments from evidence.

Course Structure, Timing, and Topical Outline

(Items in italics denote topics not included in regular level curriculum)

Unit 1: Motion in 1D and 2D

Part 1→ 1D Kinematics (4 weeks)

- Uniform motion
- Velocity vs acceleration
- *Analysis of position vs time and velocity vs time graphs including slopes and areas under graphs*
- Accelerated/Decelerated motion
- Freefall Motion
- *Kinematic problem solving including all equations of motion*

Part 2→ Vectors and Projectile Motion (2 weeks)

- *What is a vector? Vector vs scalar quantities*
- *Vector components*
- *Vector addition and subtraction*
- *Complex 1D and 2D vector addition problems*
- *Relative motion*
- *Projectile motion*
- *Projectile motion problem solving: horizontal, level ground, and general cases*

Unit 2: Dynamics

Part 1→ Newton's Laws and Dynamics (4 weeks)

- Forces and free body diagrams
- Mass vs. weight
- Equilibrium of forces and Newton's First Law
- Disequilibrium of forces and Newton's Second Law
- *Static and kinetic friction*
- *Dynamics applications: inclined planes, connected bodies, etc.*
- Centripetal acceleration
- Centripetal force and applications

Part 2→ Momentum (3 weeks)

- Interactions and Newton's 3rd
- Impulse as force*time
- Impulse as momentum change
- Cushioning as force reduction due to time interval extension (egg drop competition)
- What is momentum?
- Conservation of Momentum
- Applying momentum conservation to various 1-D situations: explosions and collisions
- *2-D Momentum conservation cases*

Unit 3: Energy

Part 1→ Work, Energy and Power (3 weeks)

- Work

- Kinetic energy
- *Work-energy theorem*
- Gravitational potential energy
- Thermal energy
- Conservation of Mechanical energy
- Energy bar graphs
- Applications (roller coasters, etc)
- Losses to Thermal energy
- Rube Goldberg Project

Part 2→ Gravitation and Orbital Motion (2 weeks)

- Inverse square nature of various things in nature (intensity of point light or sound source, etc)
- Calculating force with Newton's Gravity Law
- Inverse square comparisons and changes
- An object's weight as the force of gravity
- Kepler's Laws
- Orbital speed of circular orbit
- Apparent weightlessness in orbit as freefall

---------------------Midterm Exam--------------------

Unit 4: Electricity and Magnetism

Part 1→ Electrostatics (3 weeks)

- Charge properties
- Methods of charging
- Van de Graaff generator
- Polarization effects
- Coulomb's Law
- Complex Coulomb's Law problem solving
- Electric fields and field lines
- Electric potential energy
- Particle accelerating between parallel plates

Part 2→ Circuits (3 weeks)

- *Voltage and current*
- *Simple series and parallel circuits*
- *Complex (mixed) circuit analysis*
- *Household circuits*
- *Electric power*

Part 3→ Magnetism and Electromagnetism (3 weeks)

- Permanent magnetism and Earth's magnetic field
- *Lorentz force*
- Currents producing B-fields
- Right hand rule for B field surrounding long straight wire

- Right hand rule for determining poles of solenoid
- Electromagnetic induction
- Motors, generators, and transformers

Unit 5: Waves

Part 1→ Mechanical waves and sound (3 weeks)

- What is a wave?
- Longitudinal vs transverse
- Wavelength, frequency, speed, amplitude
- Wave equation: $v=f\cdot\lambda$
- Reflection, refraction, diffraction, interference effects, Doppler effect
- Sound waves
- Pitch/frequency; volume/intensity
- *Standing waves on strings and in closed pipes*
- *Resonance*

Part 2→ Light and Optics (3 weeks)

- Reflection/Refraction of light
- Interference/Diffraction of light
- Flat and spherical mirrors
- Converging and diverging lenses
- *Mirror and lens equations; magnification equation*
- Absorption of electromagnetic radiation by biological tissues (sun screen)
- How solar cells work
- Digital storage and transmission of information

Unit 6: Earth Science (3 weeks)

- Earth’s interior and layers
- Seismic waves and evidence for layers
- Continental drift
- Magnetic pole evidence for continental drift
- Seafloor spreading
- Plate tectonics and plate boundaries
- Earth’s changing surface
- Mechanical and chemical weathering

Topical Pacing Guide

Aug/September Unit 1: **1-D Kinematics (3 weeks)**

Vectors and Projectile motion (2 weeks)

October

Unit 2: **Newton's Laws and Applications (4 weeks)**

November

Momentum and Impulse (3 weeks)

December

Unit 3: **Energy (3 weeks)**

January

Gravitation and Orbital Motion (2 weeks)

--------------------------------------Midterm Exam---

February Unit 4: **Electrostatics (3 weeks)**

Circuits (3 weeks)

March

Magnetism and Electromagnetism (3 weeks)

April

Unit 5: **Mechanical Waves and Sound (3 weeks)**

May

Light and Optics (3 weeks)

June Unit 6: **Earth Science (3 weeks)**

---Final Exam--

Crosscutting Concepts (NGSS)

The following seven "crosscutting concepts" were identified by the Next Generation Science Standards. These core ideas bridge all academic disciplines of science and engineering and help students to develop a scientific approach to understanding.

1. **Patterns**. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

> *In grades 9-12, students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.*

2. **Cause and effect: Mechanism and explanation**. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

> *In grades 9-12, students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.*

3. **Scale, proportion, and quantity**. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

> *In grades 9-12, students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).*

4. **Systems and system models**. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

> *In grades 9-12, students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. They can also design systems to do specific tasks.*

5. **Energy and matter: Flows, cycles, and conservation**. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

> *In grades 9-12, students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.*

6. **Structure and function**. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

> *In grades 9-12, students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. They infer the functions and properties of natural and designed objects and systems from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.*

7. **Stability and change**. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

> *In grades 9-12, students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.*

Scientific Practices and Methods

Scientific practices and the scientific method are an integrated instructional focus for all six content units of the course. During weekly laboratory investigations students will deepen their understanding of the scientific practices and methods.

Big Ideas

The scientific method is a powerful tool for conducting controlled systematic observations to inquire about natural phenomena. The scientific method is useful in coming to the understanding that the natural world can be explained and is predictable which enables problem solving.

Asking Questions and Defining Problems. A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. (NGSS)

Developing and Using Models. A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. (NGSS)

Planning and Carrying Out Investigations. Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. (NGSS)

Analyzing and Interpreting Data. Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. (NGSS)

Using Mathematics and Computational Thinking. In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. (NGSS)

Constructing Explanations and Designing Solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. (NGSS)

Engaging in Argument from Evidence. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims. (NGSS)

Obtaining, Evaluating, and Communicating Information. Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs. (NGSS)

Unit 1: Motion

Part 1→ 1-D Kinematics

Students begin physics exploring motion and the causes of motion. Concepts related to position, position changes, velocity and speed, and acceleration are introduced. Students apply these ideas by solving problems to kinematics equations, including situations involving freefall. The course emphasizes motion graphing, including position vs time and velocity vs time graphs, and a focus is put on rates of change and areas under graphs, without reference to calculus language. Honors students also take on more challenging problems, such as “catch up” problems involving two objects and solving a system of kinematic equations.

Part 2→ Vectors and Projectiles

Vector concepts and math are introduced, including finding resultants and angles and vector components. Students are taught enough right angle trigonometry to analyze vector and projectile situations. Students analyze projectile situations, including horizontally launched projectiles and projectiles launched at angles. Students solve problems for time of flight, maximum height, range and other parameters.

<table>
<tr><td colspan="2">NJSLS-S Anchor Standard (s):

None specifically relevant</td></tr>
<tr><td colspan="2">Big Ideas:Course Objectives/Content Statement(s)

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
CNS: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena: Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.</td></tr>
<tr><td>Essential Questions
What provocative questions will foster inquiry, understanding, and transfer of learning?</td><td>Enduring Understandings
What will students understand about the big ideas?</td></tr>
<tr><td>● Who is really moving?</td><td>Students will understand that…</td></tr>
</table>

• Why is it difficult to determine whether your train or the adjacent train is moving? • When can you see acceleration? • How can a sailboat move into the wind? • How do trajectories change as we move through the universe? • What type of acceleration should you experience at a yellow light? • How did a cannoneer predict the trajectory of his artillery? • Does an object require a net force to continue in motion? • Do we feel velocity? • What is the difference between velocity and acceleration?	• An object is in motion when its position is changing. The motion of an object can be described by the kinematic quantities of position, velocity and acceleration and mathematical functions which relate these quantities. • An object's position can be described by locating the object relative to other objects or a background. The description of an object's motion from one observer's view may be different from that reported from a different observer's view. • Neglecting air resistance, objects in free fall accelerate at the same rate regardless of mass. • Perpendicular motion components can be treated independently, allowing for analysis of projectile motion.
Areas of Focus: Proficiencies (Cumulative Progress Indicators)	**Examples, Outcomes, Assessments**
No specific NGSS standards *Furthermore, students will:* • Describe the distinction between distance and displacement • Draw a clear distinction between the concepts of velocity and acceleration. • Distinguish between average and instantaneous quantities. • Distinguish between vector and scalar quantities and list examples of each.	**<u>Instructional Focus:</u>** • Science Practices and the Nature of Science • Kinematic definitions • Equations of motion for uniform velocity and acceleration • Algebraic problem solving including solving quadratics • Freefall • Graphing of kinematic quantities and relationships between graphs • Practical applications of kinematics • Introduction to right angle trigonometry

- Measure the distance and time that various objects move in and outside the classroom
- Calculate the relationship between the position of moving objects and the elapsed in time.
- Calculate speed, velocity, and acceleration for objects moving under uniform acceleration (including freefall)
- Graph distance vs. time and displacement vs. time for objects moving at constant velocity.
- Graph distance vs. time, velocity vs. time and acceleration vs. time for objects moving under uniform acceleration.
- Analyze motion graphs for objects moving under uniform acceleration, and describe the motion that is represented by the graph.
- Calculate velocities using slopes of position vs time graphs and displacements using the area of a velocity vs time graph.
- Describe the area under a velocity vs time curve as displacement.
- Relate velocity and acceleration to natural motions such as simple harmonic motion of a mass-spring system and a pendulum
- Describe, calculate, and graph the motion of an object caused by the acceleration due to gravity of another object
- Utilize right angle trigonometry to solve vector problems
- Resolve motion into independent horizontal and vertical motions.
- Describe and calculate the trajectory, position, velocity, acceleration, and time in the air of a vertical projectile near the surface of the Earth.

- Vectors and independence of perpendicular motion components
- Motion viewed from different reference frames

Sample Assessments:

- Daily homework assignments from textbook or supplementary material
- Short in-class quizzes
- Unit tests including:
  - Relevant multiple choice items
  - Open-ended free response problems
- Relevant items on Midterm/Final exam
- Lab activity questions
- Lab reports

Labs and hands on activities:

- Students time and plot motion of walking and running classmates
- Graph Matching (sonic detectors and computers)
- Graphing accelerated motion
- Measuring g with a stopwatch
- Diluted gravity: ball rolling down incline or car along track (photo gates or sonic detectors and computers)
- Spaced washers (inverse square relationship)
- Horizontally launched projectiles
- Projectiles inquiry lab
- Projectiles: monkey and hunter

Instructional Strategies:

Interdisciplinary Connections

Astronomy: Variation of ‘g’ on different planets

Math: Slopes of lines, averages, scatter plotting, quadratic formula.

History: Revolutionary experimental scientific methods of Galileo

• Describe and calculate the trajectory, position, velocity, acceleration, and time in the air of a horizontal projectile near the surface of the Earth. • Describe and calculate the trajectory characteristics (maximum height, range, time of flight) for general projectile cases. • Describe, calculate and measure the motion of an object in different reference frames and relate those reference frames to one another.	History: Knowledge of velocity, distance and time allowed the ancient Greeks to accurately estimate the circumference of the Earth **Technology Integration** Use motion sensors, photo gates, and video cameras to record motion data. Use computers to store motion data, and calculate displacements, velocities, and accelerations. **Global Perspectives** Explore travel distances and velocities of various international modes of transportation. Explore the concept of planetary travel to the Moon, Mars, and beyond **21st Century Skills:** **Critical Thinking and Problem Solving** Students analyze complex kinematic systems and solve for various quantities (e.g. finding the intersection of position of time for two objects) **21st Century Themes:** **S.T.E.A.M.** • Students use slow motion video capabilities of phones to analyze linear and projectile motion

Unit 2: Dynamics

Part 1→ Newton's Laws and Applications

Students study the fundamentals of Newton's three laws of motion. Those three laws are applied to situations of equilibrium as well as constant acceleration. Inclined planes, connected bodies and other classic dynamics problems are analyzed. We focus on problem solving strategy always starting with free body diagrams. Students also study static and dynamic friction and how it affects situations, as well as centripetal acceleration, force and its applications.

Part 2→ Impulse and Momentum

Students learn the definition of impulse and momentum and how Newton's Laws lead to the Impulse-momentum theorem. These concepts are explored in the context of cushioning, often including an egg-drop competition. Students also study the conservation of linear momentum and its application in collisions and explosions. 1-D and 2-D collisions are analyzed.

NJSLS-S Anchor Standards: **HS-PS2-1: Newton's Second Law of Motion** 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. **HS-PS2-2: Conservation of Momentum** Use mathematical representation 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: Minimize Force in a Collision** Apply scientific and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision.
Big Ideas:*Course Objectives/Content Statement(s)* **DCI PS2.A: Forces and Motion**: Newton's second law accurately predicts changes in the motion of macroscopic objects. **CCC: Cause and Effect**: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **SEP: Analyzing and Interpreting Data**: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **CNS: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**: Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.

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What provocative questions will foster inquiry, understanding, and transfer of learning?</th><th>Enduring Understandings
What will students understand about the Big Ideas?</th></tr>
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How can one explain and predict interactions between objects and within systems of objects?
Why are seatbelts and airbags necessary?
How is it possible to juggle on an airplane moving at 500mph?
What is the difference between an object in motion and an object at rest?
What factors affect the amount of friction or air drag between objects?
What do Conservation Laws have to do with Newton’s Laws?
What does a spaceship push on in the vacuum of space?
How did Newton put a man on the moon?
How do car crash investigators reconstruct the elements of an accident?
How is momentum conserved when an object accelerates toward the Earth?

</td><td>
Students will understand that…

Forces have magnitude and direction. Force vectors can be added. The net force on an object is the sum of all the forces acting on the object.
A free body diagram is a useful starting place for analyzing static and dynamic physical situations.
An object at rest will remain at rest unless acted on by an unbalanced force; an object in motion at constant velocity will continue at the same velocity unless acted on by an unbalanced force.
During interactions every action force is countered by an equal and opposite reaction force.
The motion of an object changes only when a net force is applied. The magnitude of acceleration of an object depends directly on the strength of the net force, and inversely on the mass of the object. This relationship ($a=F_{net}/m$) is independent of the nature of the force.
Mass and weight are different quantities: mass is a measurement of inertia while weight is the gravitational force on an object.
Friction and fluid drag forces tend to slow or prevent the motion of objects.
Momentum is the product of an object’s mass and velocity. During isolated interactions, the total momentum of a system is conserved. The Law of Conservation of Linear Momentum

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	is derived from Newton's Laws of motion. • The impulse acting on an object is equal to the change in its momentum. Cushioning minimizes the force acting on an object by increasing the time interval of a momentum change. • An inward "centripetal force" is required to keep bodies in circular motion because their direction is always changing.
Areas of Focus: Proficiencies (Cumulative Progress Indicators)	**Examples, Outcomes, Assessments**

From NGSS Evidence Statement
Students will:
1. Students organize data that represent the net force on a macroscopic object, its mass (which is held constant), and its acceleration (e.g., via tables, graphs, charts, vector drawings).
2. Students use tools, technologies, and/or models to analyze the data and identify relationships within the datasets, including: i. A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration; and ii. The result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant.
3. Students use the analyzed data as evidence to describe that the relationship between the observed quantities is accurately modeled across the range of data by the formula a = Fnet/m (e.g., double force yields double acceleration, etc.).
4. Students use the data as empirical evidence to distinguish between causal and correlational relationships linking force, mass, and acceleration.
5. Students express the relationship Fnet=ma in terms of causality, namely that a net force on an object causes the object to accelerate
 	
From NGSS Evidence Statement for HS-PS2-2:
	<u>Instructional Focus:</u>
	• Science Practices and the Nature of Science
	• Mass vs weight
	• Free body diagrams
	• Newton's Laws of Motion
	• Solving simple and complex dynamic problems
	• Impulse and momentum change
	• Analyzing 1D and 2D interactions in terms of momentum conservation
	• Centripetal acceleration and force
	
	<u>Sample Assessments:</u>
	• Daily homework assignments from textbook or supplementary material
	• Short in-class quizzes
	• Unit tests including:
	  • Relevant multiple choice items
	  • Open-ended free response problems
	• Relevant items on Midterm/Final exam
	• Lab activity questions
	• Lab reports
	
	<u>Labs and hands-on activities:</u>

1. Students clearly define the system of the two interacting objects that is represented mathematically, including boundaries and initial conditions. 2. Students identify and describe the momentum of each object in the system as the product of its mass and its velocity, $p = mv$ (p and v are restricted to one-dimensional vectors), using the mathematical representations. 3. Students identify the claim, indicating that the total momentum of a system of two interacting objects is constant if there is no net force on the system. 4.Students use the mathematical representations to model and describe the physical interaction of the two objects in terms of the change in the momentum of each object as a result of the interaction. 5. Students use the mathematical representations to model and describe the total momentum of the system by calculating the vector sum of momenta of the two objects in the system. 6. Students use the analysis of the motion of the objects before the interaction to identify a system with essentially no net force on it. 7. Based on the analysis of the total momentum of the system, students support the claim that the momentum of the system is the same before and after the interaction between the objects in the system, so that momentum of the system is constant. 8. Students identify that the analysis of the momentum of each object in the system indicates that any change in momentum of one object is balanced by a change in the momentum of the other object, so that the total momentum is constant. ***From NGSS Evidence Statement for HS-PS2-3:*** 1. Students design a device that minimizes the force on a macroscopic object during a collision. In the design, students: i. Incorporate the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision ($F\Delta t = m\Delta v$); and ii. Explicitly make use of the principle above so that the device has the desired effect of reducing the net force applied to the object by extending the time the force is applied to the object during the collision. 2. In the design plan, students describe the scientific rationale for their choice of materials and for the structure of the device. 3. Students describe and quantify (when appropriate) the criteria and constraints, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost, mass, the maximum force applied to the object, and requirements set by society for widely used collision-mitigation devices (e.g., seatbelts, football helmets). 4. Students systematically evaluate the proposed	• Measuring mass by shaking various weights from side to side (inertial balances) • Force equilibrium tables • Friction explorations • Atwood machine demonstration • The Inclined Plane • Connected bodies • Egg Drop Project • The Centerpoint (explosions) • Perfectly inelastic collisions • The Whirligig (circular motion) **Instructional Strategies:** **Interdisciplinary Connections** • Mathematics: algebraic manipulation of single variable equations (average speed, wave equation); solution of systems of two equations using substitution or elimination • History: put Isaac Newton's 1687 magnum opus, *The Principia*, into its historical context; frame Copernicus, Brahe, Kepler, and Newton in their historical context • Biology: Discuss the maximum boundaries of acceleration on the human body, particularly in roller coasters, airplanes, and spaceships. • Sports: describe collisions in various sports (football, billiards, auto racing) in terms of momentum **Technology Integration** • Collect force data using computer based lab devices • Using infrared based timing devices to measure velocity • Research applications of Newton's laws on the internet

device design or design solution, including describing the rationales for the design and comparing the design to the list of criteria and constraints. 5. Students test and evaluate the device based on its ability to minimize the force on the test object during a collision. Students identify any unanticipated effects or design performance issues that the device exhibits. 6. Students use the test results to improve the device performance by extending the impact time, reducing the device mass, and/or considering cost-benefit analysis. Furthermore, students will: ● Describe the effect on motion of objects in terms of forces. ● Define mass in terms of inertia. ● Compare forces of different magnitudes and common vs SI units for force. ● Measure weight and show that it is directly proportional to mass. ● Calculate the net force resulting from force combinations. ● Draw free body diagrams for objects in static and dynamic situations. ● Compare the motion of an object acted on by balanced forces with the motion of an object acted on by unbalanced forces in a given specific scenario. ● Describe motion and changes in motion in terms of Newton's Three Laws. ● Create simple models to demonstrate the benefits of seatbelts and headrests in terms of the First Law. ● Measure and describe the relationship between the force acting on an object and the resulting acceleration. ● Demonstrate and explain the frictional force acting on an object with the use of a physical model. ● Identify and measure the effects, if any, that weight, roughness, surface area, and speed have on friction forces. ● Solve complex dynamics problems: inclined planes, connected bodies, and situations with friction. ● Identify action-reaction pairs. ● Observe various types of collisions and explosions, explain results in terms of energy and momentum conservation. ● Relate impulse with change in momentum. ● Solve 2-D momentum conservation problems by solving a system of equations. ● Verify the centripetal force rule experimentally. ● Apply Newton's Laws to uniform circular motion cases.	**Global Perspectives** ● The laws of mechanics—equivalent throughout the universe—transcend geographical and cultural borders. ● Inertia and relative motion as a reference frame phenomena--metaphor for Point of View. ● Historical background of Newton's life and work **<u>21st Century Skills:</u>** **Critical Thinking and Problem Solving** ● Students analyze complex dynamics systems and solve for various quantities (e.g. predicting the velocity of an object given forces acting and mass) ● Students design an egg drop apparatus using pre-defined materials **<u>21st Century Themes:</u>** **S.T.E.A.M.** ● Students use the accelerometer capabilities of their smart phones to measure angles and dynamic quantities

Unit 3: Energy

Part 1→ Work, Energy, Power

Students are introduced to the concept of mechanical work, including examples of positive, negative and zero work. Kinetic energy is reviewed and the connection between net work and kinetic energy is shown from Newton's Laws. Students also review the idea of potential energy and how energy can change from one form to another using the law of conservation of energy. Students analyze many situations from an energy perspective and make corrections for situations where mechanical energy is lost to thermal energy. Students also explore power and its importance in various applications.

Part 2→ Gravitation and Orbital Motion

Students are introduced to Newtons' law of universal gravitation, including much of the history surrounding its discovery. Students practice calculations with the inverse square law and also calculate more abstract "changes" that happen in an inverse square law when distance increases or decreases by some factor. The nature of "weightlessness" in orbit is discussed from the perspective of freefall. Students then derive equations for orbital speed and period using centripetal force concepts and apply to astronomy and space flight applications. Students also study Kepler's Laws and make insights into the scientific milieu of the early enlightenment period.

NJSLS-S Anchor Standards:

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 positions 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.

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

HS-ESS1-4 Orbiting Objects
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

Big Ideas

Big Ideas:*Course Objectives/Content Statement(s)*
DCI PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

DCI PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

DCI ETS1.A Defining and Delimiting an Engineering Problem Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

DCI PS2.B: Types of Interactions

- Newton's law of universal gravitation provides the mathematical models to describe and predict the effects of gravitational forces between distant objects.

- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

DCI ESS1.B: Earth and the Solar System Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

CCC Energy and Matter:
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

CCC Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.
CCC Patterns Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
CCC Scale, Proportion, and Quantity Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

SEP Developing and Using Models: Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
SEP Constructing Explanations and Designing Solutions Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
SEP Using Mathematics and Computational Thinking: Create a computational model or simulation of a phenomenon, designed device, process, or system.
CNS Scientific Knowledge Assumes an Order and Consistency in Natural Systems: Science assumes the universe is a vast single system in which basic laws are consistent.
CNS Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena
CETAS Influence of Science, Engineering and Technology on Society and the Natural World Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while

decreasing costs and risks. **CETAS Interdependence of Science, Engineering, and Technology** Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
● How is energy transferred and conserved? ● Why does energy seem to be lost in some events and created in others? ● When mechanical energy is “lost”, where does it go? ● Why are the concepts of work and energy necessary and useful to physicists? ● Do energy transformations cause disasters? ● Is it possible to break even in an energy transformation? ● If energy can never be created or destroyed, why is there an “energy crisis”? ● When a tennis ball is placed atop a basketball and dropped to the ground, why does the tennis ball shoot up to a height much greater than that from which it was dropped? ● Why must the first hill of a traditional roller coaster be higher than all of the subsequent hills?	*Students will understand that…* ● Energy cannot be created or destroyed. ● Energy is constantly being transferred and transformed in the natural and man-made world. ● Thermodynamic processes tend to increase disorder. ● The potential energy of an object on Earth’s surface is increased when the object’s position is changed from one closer to Earth’s surface to one farther from Earth’s surface. ● Energy may be transferred from one object to another during collisions. ● The net work done on an object during a process is equal to its change in kinetic energy. This is a relationship that can be derived from Newton’s Laws of Motion. ● Collisions may be classified as elastic or inelastic according to their conservation or loss of mechanical energy. ● The force of gravitation between two bodies is directly proportional to

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- When an object experiences friction, is energy lost?
- Can the potential energy of an object be negative?
- When an object doubles its speed, how much more kinetic energy does it have?
- Will a bowling ball on a pendulum released from just in front of someone's nose come back and hit them?
- How do scientists know the mass of the Earth, Moon and Sun?
- What does the orbit of the moon have to do with a falling apple?
- What is an inverse square law, and why are they so important?
- How do objects maintain motion in circles or ellipses?
- Why are some full moons called "super"?

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their masses and inversely proportional to the square of the distance between them.

- Kepler's Laws describe the orbits of bodies in space; Kepler's Laws can be derived from Newton's Laws of Motion.

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<th>Areas of Focus: Proficiencies (Cumulative Progress Indicators)</th>
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From NGSS Evidence Statement for HS-PS-1

1. Students identify and describe the components to be computationally modeled, including:
    a. The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero);
    b. The initial energies of the system's components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description to calculate

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<u>Instructional Focus:</u>

- Science Practices and the Nature of Science
- Work and types of energy
- Problem solving with energy methods in mechanical systems
- Energy conservation
- Energy considerations in collisions
- 1^{st} and 2^{nd} Laws of Thermodynamics
- Newton's Law of Gravitation
- Kepler's Laws and connection to Newton's Law of Gravitation

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the total initial energy of the system;

c. The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and
d. The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system.

2. Students use the algebraic descriptions of the initial and final energy state of the system, along with the energy flows to create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy.
3. Students use the computational model to calculate changes in the energy of one component of the system when changes in the energy of the other components and the energy flows are known.
4. Students use the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows.
5. Students identify and describe the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system.

From NGSS Evidence Statement for HS-PS-2

1. Students develop models in which they identify and describe the relevant components, including:
    a. All the components of the system and the surroundings, as well as energy flows between the system and the surroundings;
2. Students describe the relationships between components in their models, including:
    a. Changes in the relative position of objects in gravitational, magnetic or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy).
    b. Thermal energy includes both the kinetic and potential energy of particle vibrations in solids or molecules and the kinetic energy of freely moving particles (e.g., inert gas atoms, molecules) in liquids and gases.
    c. The total energy of the system and

Sample Assessments:

- Daily homework assignments from textbook or supplementary material
- Short in-class quizzes
- Unit tests including:
    - Relevant multiple choice items
    - Open-ended free response problems
- Relevant items on Midterm/Final exam
- Lab activity questions
- Lab reports

Labs and hands-on activities:

- Sliding eraser
- Rube Goldberg device project
- Predict and measure the kinetic energy gain of a dropped object
- Coefficient of restitution
- Calorimetry and the 2nd law of thermodynamics
- Plot the path of a planet about the sun using real data and verify Kepler's Laws of planetary motion.
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Instructional Strategies:

Interdisciplinary Connections

- Biology: Biological basis of roller coaster design constraints – g forces.
- Math: Calculations of energies, velocities, forces at various points in a roller coaster.
- Social studies: How does the existence of high concentrations of potential energy (oil) affect global politics?

Technology Integration

- Use computers to collect data on fast moving objects.

surroundings is conserved at a macroscopic and molecular/atomic level. d. As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields. 3. Students use their models to show that in closed systems the energy is conserved on both the macroscopic and molecular/atomic scales so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the system. 4. Students use their models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects on both the macroscopic and microscopic scales. **From the evidence statement for HS-PS3-3:** 1. Students design a device that converts one form of energy into another form of energy. 2. Students develop a plan for the device in which they: i. Identify what scientific principles provide the basis for the energy conversion design; ii. Identify the forms of energy that will be converted from one form to another in the designed system; iii. Identify losses of energy by the design system to the surrounding environment; iv. Describe the scientific rationale for choices of materials and structure of the device, including how student-generated evidence influenced the design; and v. Describe that this device is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing costs and risk. 3. Students describe and quantify (when appropriate) prioritized criteria and constraints for the design of the device, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost and efficiency of energy conversion. 4. Students build and test the device according to the plan. 5. Students systematically and quantitatively evaluate the performance of the device against the criteria and constraints. 6. Students use the results of the tests to improve the device performance by increasing the efficiency of energy conversion, keeping in mind the criteria and constraints, and noting any modifications in tradeoffs. **From NGSS Evidence Statement for HS-PS2-4**	• Use computer simulations to observe and create unique energy transfer systems. **Global Perspectives** • Compare and contrast classroom energy transformations with those within our solar system, our galaxy, and the universe. • Investigate the geopolitical effects of energy policy. **<u>21st Century Skills:</u>** **Critical Thinking and Problem Solving** • Students analyze complex energy systems and solve for various quantities (e.g. predicting object velocities after various energy changes) • Students design a Rube Goldberg mechanism to carry out a specific task **<u>21st Century Themes:</u>** **S.T.E.A.M.** • Students use the slow motion capabilities of their smart phones to assist in measuring coefficients of restitution

1. Students clearly define the system of the interacting objects that is mathematically represented. 2. Using the given mathematical representations, students identify and describe the gravitational attraction between two objects as the product of their masses divided by the separation distance squared ($F_g = -G\, m_1 m_2/d^2$), where a negative force is understood to be attractive. 3. Students correctly use the given mathematical formulas to predict the gravitational force between objects 4. Based on the given mathematical models, students describe that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance. 5. Students describe that the mathematical representation of the gravitational field ($F_g = -G\, m_1 m_2/ d^2$) only predicts an attractive force because mass is always positive. 6. Students use the given formulas for the forces as evidence to describe that the change in the energy of objects interacting through gravitational forces depends on the distance between the objects. **From NGSS Evidence Statement for HS-ESS1-4:** 1. Students identify and describe the following relevant components in the given mathematical or computational representations of orbital motion: the trajectories of orbiting bodies, including planets, moons, or human-made spacecraft; each of which depicts a revolving body's eccentricity e = f/d, where f is the distance between foci of an ellipse, and d is the ellipse's major axis length (Kepler's first law of planetary motion). 2. Students use the given mathematical or computational representations of orbital motion to depict that the square of a revolving body's period of revolution is proportional to the cube of its distance to a gravitational center ($T^2 \propto R^3$, where T is the orbital period and R is the semimajor axis of the orbit — Kepler's third law of planetary motion). 3. Students use the given mathematical or computational representation of Kepler's second law of planetary motion (an orbiting body sweeps out equal areas in equal time) to predict the relationship between the distance between an orbiting body and its star, and the object's orbital velocity (i.e., that the closer an orbiting body is to a star, the larger its orbital velocity will be). 4. Students use the given mathematical or computational representation of Kepler's third law of planetary motion ($T^2 \propto R^3$, where T is the orbital period and R is the semi-major axis of the orbit) to predict how either the orbital distance or orbital period changes given a change in the other variable. 5. Students use Newton's law of gravitation plus his	

third law of motion to predict how the acceleration of a planet towards the sun varies with its distance from the sun, and to argue qualitatively about how this relates to the observed orbits --- Furthermore, students will…. ● Define work, kinetic energy, and potential energy ● Review dynamics problems, including those with friction, using the work-kinetic energy theorem. ● Apply energy calculations to interaction problems and classify accordingly. ● Practice describing and calculating the continuous transfer of energy in a closed system. ● Draw parallels between local and universal energy transfers. ● Identify and describe Potential and Kinetic energy in a variety of natural and designed contexts ● Describe the process of energy transformation in a variety of natural and designed contexts ● Explain common natural and designed motions involving energy transformation. ● Explain and use the Law of Conservation of Energy ● Describe and explain the meaning of energy ● Construct a Rube-Goldberg device ● Calculate the gravitational force between pairs of masses. ● Use Kepler's Laws to predict the motion of planets and satellites	

<u>Unit 4: Electricity and Magnetism</u>

Part 1→ Electrostatics

In this unit students begin with qualitative explorations of electric charging phenomena. Students perform experiments related to charging by friction, conduction, induction, polarization to understand how electrons move and the meaning of positively and negatively charged objects. The real focus is on Coulomb's Law and reinforcement of the inverse square relationship, as already studied in the gravitation unit. Students calculate complex problems such as equilibrium and 2D force vector problems.

Part 2→ Circuits

Students explore basic concepts of voltage and current as well as series and parallel circuits. In honors students will analyze complex mixed circuits. An emphasis is also placed on practical applications, such as circuit breakers, ground wires, and using multimeters.

Part 3→ Magnetism and Electromagnetism

Students learn about the properties of permanent magnets and Earth's magnetic field. They then explore electromagnetic phenomena such as the Lorentz force, the magnetism surrounding currents, and electromagnetic induction. Students focus on practical applications like motors, generators and transformers.

NJSLS-S Anchor standards: **HS-PS2-4** Use mathematical representations of Coulomb's Law to describe and predict the electrostatic forces between objects. **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. **HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current
Big Ideas:*Course Objectives/Content Statement(s)* **DCI PS2.B: Types of Interactions** ● Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. ● Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

DCI PS3.C: Relationship Between Energy and Forces When two objects interacting through a field change relative position, the energy stored in the field is changed.

DCI PS3.A: Definitions of Energy “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary)

CCC Patterns Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

CCC Cause and Effect

- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

SEP Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to describe explanations.

SEP Developing and Using Models: Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

SEP Planning and Carrying Out Investigations Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

CNS Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
● How do we know that atoms exist?	*Students will understand that….* ● Electrons, protons, and neutrons are parts of the atom and have

• How big is an atom?
Why does the Van de Graaff generator cause hair to stand up?
 	
• Why does rubbing socks on carpet allow for static electric shocks?
 	
• What is lightning?
 	
• Why are homes wired in parallel?
 	
• What is an inverse-square law and where do we see them in nature?
 	
• How can you light a bulb with only a lightbulb, a battery, and a single wire?
 	
• What is the difference between voltage (potential difference) and current?
 	
• How can electricity be used to build a magnet?
 	
• What is a force field?
 	
• Do field lines really exist?
• How do moving electric and magnetic fields cause change?
 	
• How do my ear bud speakers work?
 	
• How are the relationships between electric and magnetic fields used to shape society?
 	
• How have magnetic fields impacted human history and shed light on the natural history of the earth?
 	
• How do animals use magnetic fields to navigate?
	measurable properties like mass and charge. In a neutral atom, a nucleus with positively charged particles is surrounded by an electron cloud with the same number of negatively charged electrons.
	• Objects can be charged negatively or positively by adding or removing electrons from their atoms. Methods of charging include friction, conduction, induction, and polarization.
	• Electrostatic forces are described by Coulomb's inverse square law. Electrostatic forces can be attractive or repulsive.
	• Electric fields surround charged objects. Electric field lines give a visual description of the field.
	    • Electric potential energy difference across a closed conducting circuit will cause charge to flow, producing current.
	    • Electrical circuits require a complete loop through conducting materials in which an electrical current can pass.
	    • All matter has internal resistance to the flow of charge. Resistance depends on the physical properties of matter, the shape and size of the object, and its temperature.
	    • Current flowing through an object (with resistance) results in the conversion of electrical energy into other forms of energy, such as light, heat, sound, or motion.
	    • The flow of current in an electric circuit depends upon the components of the circuit and their arrangement, such as in

• How is electricity produced, and what is the difference between AC and DC? • What is that big gray cylinder at the top of the telephone pole?	series or parallel. Electricity flowing through an electrical circuit produces magnetic effects. • Moving electric charges produce magnetic fields. • Magnetic fields put forces on moving electric charges. • Magnetic fields are shaped by the north and south magnetic poles of a magnetized object. • Magnetic poles always occur in pairs and cannot be separated – unlike electric charge where positive and negative charges can be separated. • Magnetic poles can attract and repel, as electric charges can; their magnitude obeys an inverse square law. • The earth has a magnetic field that is detectable at the surface with a compass. • The earth's magnetic field has north and south poles and lines of force that are used for navigation. • Evidence from lava flows and ocean-floor rocks shows that Earth's magnetic field reverses (North – South) over geologic time. • The directional relationship between currents, magnetic fields, and magnetic forces can be predicted by the right hand rule. • Electric motors use magnetic forces to transfer electrical potential energy into kinetic energy. • Generators use magnetic forces to transfer mechanical energy into electric potential energy.
Areas of Focus: Proficiencies	**Examples, Outcomes, Assessments**

(Cumulative Progress Indicators)	

From NGSS Evidence Statement for HS-PS2-4

1. Students clearly define the system of the interacting objects that is mathematically represented
2. Using the given mathematical representations, students identify and describe the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared ($F_e = kq_1q_2 / d^2$), where a negative force is understood to be attractive.
3. Students correctly use the given mathematical formulas to predict the gravitational force between objects or predict the electrostatic force between charged objects.
4. Based on the given mathematical models, students describe that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance.
5. Students describe that the mathematical representation of the electric field ($F_e = kq_1q_2/d^2$) predicts both attraction and repulsion because electric charge can be either positive or negative.
6. Students use the given formulas for the forces as evidence to describe that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects.

From NGSS Evidence Statement for HS-PS3-5

1. Students develop a model in which they identify and describe the relevant components to illustrate the forces and changes in energy involved when two objects interact, including:
    a. The two objects in the system, including their initial positions and velocities (limited to one dimension).
    b. The nature of the interaction (electric or magnetic) between the two objects.
    c. The relative magnitude and the direction of the net force on each of the objects.
    d. Representation of a field as a quantity that has a magnitude and direction at all points in space and which contains energy.
2. In the model, students describe the relationships between components, including the change in the energy of the objects, given the initial and final positions and velocities of the objects.

Instructional Focus

- Structure of the Atom
- Electrostatic phenomena and ways to charge objects
- Quantitative calculations of electrostatic forces and fields
- Electric fields and applications
    - Basic definitions and units in circuits (voltage, current, power, volts, amps, watts)
    - Solving simple circuits: series, parallel and combination
    - Permanent magnetism
    - Magnetic fields from currents
    - Forces on moving charges in a magnetic field
    - Induction and motional emf
    - The operation of electromagnetic devices such as motors, generators, and transformers

Sample Assessments:

- Daily homework assignments from textbook or supplementary material
- Short in-class quizzes
- Unit tests including:
    - Relevant multiple choice items
    - Open-ended free response problems
- Relevant items on Midterm/Final exam
- Lab activity questions
- Lab reports

Labs and hands-on activities:

- Static electricity explorations (Van der Graaff, electroscopes, balloons, rods/fur, etc)
- The Electrophorus
- Electric field hockey (computer simulation)
- Electric field mapping (computer simulation)
- Measuring current and voltage

3. Students use the model to determine whether the energy stored in the field increased, decreased, or remained the same when the objects interacted. 4. Students use the model to support the claim that the change in the energy stored in the field (which is qualitatively determined to be either positive, negative, or zero) is consistent with the change in energy of the objects. 5. Using the model, students describe the cause and effect relationships on a qualitative level between forces produced by electric or magnetic fields and the change of energy of the objects in the system. **From the evidence statement for HS-PS2-5:** 1. Students describe the phenomenon under investigation, which includes the following idea: that an electric current produces a magnetic field and that a changing magnetic field produces an electric current. 2. Students develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data about 1) an observable effect of a magnetic field that is uniquely related to the presence of an electric current in the circuit, and 2) an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the circuit. Students describe why these effects seen must be causal and not correlational, citing specific cause-effect relationships. 3. In the investigation plan, students include: i. The use of an electric circuit through which electric current can flow, a source of electrical energy that can be placed in the circuit, the shape and orientation of the wire, and the types and positions of detectors; ii. A means to indicate or measure when electric current is flowing through the circuit; iii. A means to indicate or measure the presence of a local magnetic field near the circuit; and iv. A design of a system to change the magnetic field in a nearby circuit and a means to indicate or measure when the magnetic field is changing. 4. In the plan, students state whether the investigation will be conducted individually or collaboratively. 5. Students measure and record electric currents and magnetic fields. 6. Students evaluate their investigation, including an evaluation of: i. The accuracy and precision of the data collected, as well as limitations of the investigation; and ii. The ability of the data to provide the evidence required. 7. If necessary, students refine the investigation plan to produce more accurate, precise, and useful data such that the measurements or indicators of the presence of an electric current in the circuit and a	• Resistance and Ohm's Law • Voltage divider (series circuit) • Parallel circuits • Model and describe magnetic field lines with a bar magnet and iron filings • Oersted effect or solenoids, electromagnets. • Making electromagnets with nails and wire • Making a simple motor • Generators & Transformers **Instructional Strategies:** **Interdisciplinary Connections** • History: Integration of atomic theory timeline with historical events. Engineering: how nuclear devices work • Biology: biological basis of animal navigation by magnetic fields; electrical nature of nervous systems • Astronomy: magnetic fields surrounding the sun and stars, such as neutron stars • Math: calculations of a circuit's resistance, voltage and current; algebraic manipulations of simple one-variable, linear equations. • History: investigate the use of magnetic fields in human navigation over the centuries. • History: Galvani and "animal electricity" **Technology Integration** • Use of a real Geiger counter for radioactive investigations. • Statistical analysis utilizing spreadsheet programming and visualization. • Computer simulations of nuclear reactors. • Use of computer simulations to model electric fields.

magnetic field near the circuit can provide the required evidence. *Furthermore, students will….* ● Describe the properties of the atom and nucleus ● Calculate net electrostatic forces on objects in configurations of two, three, and four charges ● Qualitatively describe and draw electric field lines for various simple configurations ● Calculate electric field strengths for configurations of two, three, and four charges ● Calculate the force and direction of a known charge in a known electric field ● Explain differences in resistance in terms of material, length, and cross-section. ● Calculate voltages and currents with Ohm's Law. ● Measure current and voltage with digital multimeters. ● Compare and contrast series, parallel, and combination circuits and explain why homes are wired in parallel. ● Fully analyze simple circuits for quantities of voltage, current, and power. ● Explain the purpose of a circuit breaker or fuse in a home. ● Build a simple electromagnetic, refining various designs, to pick up metal objects. ● Compare and contrast the production and usefulness of AC vs DC power. ● Calculate motional emf, the force on charges moving through magnetic fields, and the forces on currents in magnetic fields. ● Use right hand rules to predict field lines and particle forces. ● Explain the operation of motors, generators, and transformers.	**Global Perspectives** ● International effort of developing atomic/nuclear theory ● Variation in exploitation of nuclear power in different countries ● Differing perspectives around the world (e.g. France vs. US) on nuclear power. ● Radioactive natural resources and their relative geographic abundance around the world. ● Human and geopolitical effects of nuclear weapons, as seen in Japan in 1945 and in the post-war world. ● Explore global magnetic fields interacting with solar magnetic winds. ● Investigate the use of magnetic fields in human navigation over the centuries, and the mapping of local magnetic deviations. ● Find evidence of the earth's magnetic field reversing approximately every 10 million years. **21st Century Skills:** **Critical Thinking and Problem Solving** ● Students analyze and design simple and intermediate resistive circuits **21st Century Themes:** **S.T.E.A.M.** ● Students program Arduino based circuits to light up LED's, operate motors, and integrate touch and sound inputs

Unit 5: Waves

Part 1→ Mechanical Waves and Sound

Students explore the properties of mechanical waves. Emphasis is given to the wavelength, speed, frequency relationship in waves and how to describe them. Students experiment with waves on slinkies and water wave tables, then turn their attention to sound. Sound wave properties such as frequency/pitch, amplitude/volume, resonance and standing waves are analyzed in depth. Students in honors physics explore the properties of standing waves on strings and resonance tubes closed at one end.

Part 2→ Light and Optics

After exploring mechanical waves, students turn their attention to electromagnetic waves and their properties. Students review the electromagnetic spectrum, then turn their focus to visible light and applications such as mirrors and lenses. In honors physics students fully analyze with ray diagrams as well as formulas for lenses, mirrors, and magnification. We also explore important technological applications such as solar cells, sunscreen, and digital transmission of information.

NJSLS-S Anchor Standard: **HS-PS4-1.** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. **HS-PS4-3: Wave-Particle Duality of Electromagnetic Radiation** Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. **HS-PS4-4: Absorption of Electromagnetic Radiation** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. **HS-PS4-5: Waves and Information Technology** Communicate technical information about about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. **HS-PS4-2: Digital Transmission and Storage of Information** Evaluate questions about the advantages of using a digital transmission and storage of information.
Big Ideas:*Course Objectives/Content Statement(s)*

DCI PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

DCI PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

DCI PS3.D: Energy in Chemical Processes Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

DCI PS4.C: Information Technologies and Instrumentation Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

CCC Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.
- Systems can be designed to cause a desired effect.

CCC Systems and System Models Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales.

CCC Stability and Change Systems can be designed for greater or lesser stability.

SEP Using Mathematics and Computational Thinking Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.
SEP Engaging in Argument from Evidence Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

SEP Obtaining, Evaluating, and Communicating Information
- Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.
- Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

SEP Asking Questions and Defining Problems Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design.

CNS Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

CETAS Engineering, and Technology Science and engineering complement each other in the cycle known as research and development (R&D).

CETAS Influence of Engineering, Technology, and Science on Society and the Natural World
- Modern civilization depends on major technological systems.
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
• How are waves used to transfer energy and send and store information? • What is light? • Why do waves break on the shore? • Why is it quiet after a snowfall? • Why do objects appear shifted in position under water? • What causes a rainbow? • In what ways does light behave like a wave? • Is it possible to hear in outer space? • Why does light, but not sound, travel through outer space? • How do we see a mirage? • Why is there no sound in outer space? • How can a person distinguish a guitar playing a certain note from a piano playing the same exact note? • When sitting at the back of an auditorium during a concert, the various instruments sound "in sync" just as they would on the stage. Why? • What are waves? • How can waves change their speed? • How do sound waves differ from waves sent through a string or ripples in water?	• Waves transfer energy without transferring matter. • Waves can be described in terms of wavelength, frequency, amplitude, and energy. • Waves tend to travel at constant speed through media of constant consistency; the speed of a wave depends only on the physical properties of the medium in which it propagates. • Waves can exhibit reflection, refraction, diffraction, and interference. • Sound waves are pressure waves moving through media. • Our perception of loudness is related to amplitude while our perception of pitch is related to frequency. The human auditory system is not a true interpreter of sound wave amplitude or frequency. • Relative motion between receiver and source can cause perceptible apparent changes in wave properties, such as frequency. • All electromagnetic waves, including visible light, travel at 300,000,000 m/s in a vacuum; • Electromagnetic waves of different wavelengths have different effects, ranging from safe to dangerous, on biological tissues. • Visible light waves comprise a small part of the electromagnetic spectrum. Our perception of color is related to wavelength.

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- How do waves interact with one another?
- What is light and how do we know?
- How does sunscreen work? Are tanning beds safe?
- How do the solar cells on my roof work?
- What does it mean to be “digitized”?
- How does a light wave differ from a sound wave?
- How and what do we see?
- How do light waves create things such as rainbows and mirages?

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- Light rays tend to travel in straight lines but can change direction when reflecting from surfaces of refracting through transparent mediums, providing the possibility of real or virtual images.
- The refracted angle of a light wave from one transparent medium into another can be predicted exactly with Snell’s Law.
- Light exhibits wave-like properties and particle-like properties.
- Lenses and mirrors are found in many practical devices: eyeglasses, the human eye, microscopes, binoculars, cameras, telescopes, etc.

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From NGSS Evidence Statement for HS-PS4-1:

1. Students identify and describe the relevant components in the mathematical representations: i. Mathematical values for frequency, wavelength, and speed of waves traveling in various specified media; and ii. The relationships between frequency, wavelength, and speed of waves traveling in various specified media.
2. Students show that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and identify this relationship as the wave speed according to the mathematical relationship $v = f\lambda$.
3. Students use the data to show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes.
4. Students predict the relative change in the wavelength of a wave when it moves from one medium to another (thus different wave speeds using the mathematical relationship $v = f\lambda$).
5. Students express the relative change in terms of cause (different media) and effect (different wavelengths but same frequency).
6. Using the mathematical relationship $v = f\lambda$, students assess claims about any of the three quantities when the other two quantities are known for waves travelling in various specified media.
7. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

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Instructional Focus:

- Wave phenomena of various mechanical and electromagnetic waves: diffraction, interference, reflection, and refraction.
- Hands-on activities with waves on slinkies, water waves, and sound waves
- Evidence for wave and particle properties of light
- Operation of the human ear and eye
- Practical optical instruments such as eyeglass lenses, telescopes, and microscopes

Sample Assessments:

- Daily homework assignments from textbook or supplementary material
- Short in-class quizzes
- Unit tests including:
  - Relevant multiple choice items
  - Open-ended free response problems

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From NGSS Evidence Statement for HS-PS4-3 **1.** Students identify the given explanation that is to be supported by the claims, evidence, and reasoning to be evaluated, and that includes the following idea: Electromagnetic radiation can be described either by a wave model or a particle model, and for some situations one model is more useful than the other. b Students identify the given claims to be evaluated. c Students identify the given evidence to be evaluated, including the following phenomena: i. Interference behavior by electromagnetic radiation; and ii. The photoelectric effect. d Students identify the given reasoning to be evaluated. Students evaluate the given evidence for interference behavior of electromagnetic radiation to determine how it supports the argument that electromagnetic radiation can be described by a wave model. 2. Students evaluate the phenomenon of the photoelectric effect to determine how it supports the argument that electromagnetic radiation can be described by a particle model. 3. Students evaluate the given claims and reasoning for modeling electromagnetic radiation as both a wave and particle, considering the transfer of energy and information within and between systems, and why for some aspects the wave model is more useful and for other aspects the particle model is more useful to describe the transfer of energy and information. **From NGSS Evidence Statement for HS-PS4-4** 1. Students obtain at least two claims proposed in published material (using at least two sources per claim) regarding the effect of electromagnetic radiation that is absorbed by matter. One of these claims deals with the effect of electromagnetic radiation on living tissue. 2. Students use reasoning about the data presented, including the energies of the photons involved (i.e., relative wavelengths) and the probability of ionization, to analyze the validity and reliability of each claim. 3. Students determine the validity and reliability of the sources of the claims. 4. Students describe the cause and effect reasoning in each claim, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g., extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism). **From NGSS Evidence Statement for HS-PS4-5** 1. Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate technical information and ideas,	• Relevant items on Midterm/Final exam • Lab activity questions • Lab reports **<u>Labs and Hands-on Activities:</u>** • Pendulums and Simple Harmonic Motion • Slinky Explorations • Standing Waves • Water wave table activities • Resonance Tubes • Plane Mirrors • Refraction through water • Converging Lenses **<u>Instructional Strategies:</u>** **Interdisciplinary Connections** • Mathematics: algebraic manipulation of single variable equations (average speed, wave equation) • History: development of measurements of the speed of light • Biology: how eyes and ears function **Technology Integration** • Use cell phone cameras to capture data about wave table shadows • Use computer based data collection software for sound and light demonstrations • Utilize lasers for refraction and reflection demonstrations. • Research the history of light theories on the internet. • Fiber optics technology • Solar cells **Global Perspectives**

including fully describing at least two devices and the physical principles upon which the devices depend. One of the devices must depend on the photoelectric effect for its operation. Students cite the origin of the information as appropriate. 2. When describing how each device operates, students identify the wave behavior utilized by the device or the absorption of photons and production of electrons for devices that rely on the photoelectric effect, and qualitatively describe how the basic physics principles were utilized in the design through research and development to produce this functionality (e.g., absorbing electromagnetic energy and converting it to thermal energy to heat an object; using the photoelectric effect to produce an electric current). 3. For each device, students discuss the real-world problem it solves or need it addresses, and how civilization now depends on the device. 4. Students identify and communicate the cause and effect relationships that are used to produce the functionality of the device. **From NGSS Evidence Statement for HS-PS4-5** 1. Students evaluate the given questions in terms of whether or not answers to the questions would: i. Provide examples of features associated with digital transmission and storage of information (e.g., can be stored reliably without degradation over time, transferred easily, and copied and shared rapidly; can be easily deleted; can be stolen easily by making a copy; can be broadly accessed); and 2. In their evaluation of the given questions, students: i. Describe the stability and importance of the systems that employ digital information as they relate to the advantages and disadvantages of digital transmission and storage of information; and ii. Discuss the relevance of the answers to the question to real-life examples (e.g., emailing your homework to a teacher, copying music, using the internet for research, social media). 3. Students evaluate the given questions in terms of whether or not answers to the questions would provide means to empirically determine whether given features are advantages or disadvantages. *Furthermore, students will:* ● Observe that waves can affect objects across distances through a medium without the direct transfer of any matter. ● Produce and observe pulse, periodic, longitudinal, transverse, and standing waves and measure their characteristics. ● Compare and contrast mechanical waves with electromagnetic waves.	● Speed of light as *universal* constant for electromagnetic radiation ● 2005 Indonesian tsunami and other tidal waves; ocean waves on shores around the world ● Archimedes lens weapon (Mythbusters episode) ● Color as a diversely perceived feature historically, culturally, and by different species. ● Light as a cultural metaphorical construct **<u>21st Century Skills:</u>** **Critical Thinking and Problem Solving** ● Students explore the possibilities of solar power and design a hypothetical solar power system for their school. **<u>21st Century Themes:</u>** **S.T.E.A.M.** ● Students create an art-based project using light and sound to explore color theory and sound effects.

• Categorize wave types as either longitudinal or transverse. • Cite evidence that mechanical waves require media while electromagnetic waves do not. • Measure wavelength, frequency, and amplitude of various types of waves and label those parts on a diagram. • Observe for various types of waves that wave velocity is only a function of the medium and explain why this fact is important for the enjoyment of music. • Calculate wave speeds, wavelengths, or frequencies for problems or predictions. • Qualitatively describe pitch and volume changes in terms of frequency and amplitude changes. • Predict changes in apparent received pitch for various relative motion situations. • Describe colors in terms of wavelength, and visible light's wavelength within the context of the larger EM spectrum. • Explain reflection and refractions in terms of Huygen's principle and wave speeds. • Verify Snell's Law for refracted angles for various optical media, such as glass, water, and oil. • Calculate wavelength of monochromatic source(s) using a diffraction grating and equations. • Predict and observe image characteristics using ray diagrams for light that has reflected from plane or spherical mirrors or refracted through transparent materials or lenses. • Explain the optical function of common optical systems, such as microscopes, magnifying glasses, and the human eye based on fundamental physical concepts.	

Unit 6: Earth Science

During our final unit in physics, students apply their knowledge of forces and energy to Earth's geophysical history. The focus is on Earth's interior structure and how we know about it, the creation of landforms, and evidence of plate tectonics. Earthquake waves, sonar mapping of the seafloor and the energy associated with plate tectonics provide excellent opportunities for review of topics covered earlier in the year. If possible, students should visit a local site of geological interest.

Anchor Standard: **HS-ESS2-1. The Creation of Landforms** Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. **HS-ESS2-3. Cycling of Matter in the Earth's Interior** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. **HS-ESS1-5. Evidence of Plate Tectonics** Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.
Big Ideas:*Course Objectives/Content Statement(s)* **DCI ESS2.A: Earth Materials and Systems** ● Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. ● Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. **DCI ESS2.B: Plate Tectonics and Large-Scale System Interactions** ● Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. ● The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. **DCI ESS1.C: The History of Planet Earth** Continental rocks, which can be older than 4 billion years,

are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

DCI PS1.C: Nuclear Processes Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)

CCC Stability and Change Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

CCC Energy and Matter Energy drives the cycling of matter within and between systems.

CCC Patterns Empirical evidence is needed to identify patterns.

SEP Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

SEP Engaging in Argument from Evidence Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.

CETAS Interdependence of Science, Engineering, and Technology Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.

CNS Scientific Knowledge is Based on Empirical Evidence Science knowledge is based on empirical evidence. Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Science includes the process of coordinating patterns of evidence with current theory.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
How do we know about Earth's layers?	Evidence from seismographic data after Earthquakes is the most important for understanding Earth's layers.
Why is the interior of the Earth still warm?	Heat remains from the initial forming of the Earth and from ongoing nuclear processes.
What is the accepted model of the Earth's interior?	The earth has a solid Crust, a liquid outer core and a solid inner core.
What evidence exists of plate tectonics?	We experience earthquakes, the ocean floor topography is varied and includes volcanoes,

How does matter cycle within Earth's interior?	mountains, trenches and faults, and fossilized objects that likely came from the same location can be found across oceans. Through a process called Thermal Convection, matter closest to Earth's core gains energy and moves toward the crust allowing cooler matter to take its place. This cycles matter and heats Earth's outer core.
Areas of Focus: Proficiencies (Progress Indicators)	**Examples, Outcomes, Assessments**
From the evidence statement fro HS-ESS2-1: 1. Students use evidence to develop a model in which they identify and describe the following components: i. Descriptions and locations of specific continental features and specific ocean-floor features; ii. A geographic scale, showing the relative sizes/extents of continental and/or oceanfloor features; iii. Internal processes (such as volcanism and tectonic uplift) and surface processes (such as weathering and erosion); and iv. A temporal scale showing the relative times over which processes act to produce continental and/or ocean-floor features. 2. In the model, students describe the relationships between components, including: i. Specific internal processes, mainly volcanism, mountain building or tectonic uplift, are identified as causal agents in building up Earth's surface over time. ii. Specific surface processes, mainly weathering and erosion, are identified as causal agents in wearing down Earth's surface over time. iii. Interactions and feedbacks between processes are identified (e.g., mountain-building changes weather patterns that then change the rate of erosion of mountains). iv. The rate at which the features change is related to the time scale on which the processes operate. Features that form or change slowly due to processes that act on long time scales (e.g., continental positions due to plate drift) and features that form or change rapidly due to processes that act on short time scales (e.g., volcanic eruptions) are identified. 3. Students use the model to illustrate the relationship between 1) the formation of continental and ocean floor features and 2) Earth's internal and surface processes operating on different temporal or spatial scales. **From the evidence statement for ESS2-3:** 1. Students develop a model (i.e., graphical, verbal, or mathematical) in which they identify and describe the components based on both seismic and magnetic evidence (e.g., the pattern of the geothermal gradient or heat flow measurements) from Earth's interior, including: i. Earth's interior in cross-section and radial layers (crust, mantle, liquid outer core, solid inner core) determined by density; ii. The plate activity in the outer part of the geosphere; iii. Radioactive decay and residual thermal energy from the formation of the Earth as a source of energy; iv. The loss of heat at the surface of the earth as an output of energy; and v. The process	Instructional Focus: ➢ Earth's interior and layers ➢ Seismic waves and evidence for layers ➢ Continental drift ➢ Magnetic pole evidence for continental drift ➢ Seafloor spreading ➢ Plate tectonics and plate boundaries ➢ Earth's changing surface ➢ Mechanical and chemical weathering Labs/Sample Assessments: **Rock identification lab:** Students identify different types of rocks and their sources. **Earthquake data graphing.** Students analyze earthquake data from seismographic sites around the world to model the interior of the Earth. **Unit Test.** Students are assessed for content mastery using multiple choice items, problem solving, and written descriptions of phenomena. Projects/Post Assessment **Earth Science Field Visit.** Students take a field trip to a geologically significant site in NJ to study

of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center). 2. Students describe the relationships between components in the model, including: i. Energy released by radioactive decay in the Earth's crust and mantle and residual thermal energy from the formation of the Earth provide energy that drives the flow of matter in the mantle. ii. Thermal energy is released at the surface of the Earth as new crust is formed and cooled. iii. The flow of matter by convection in the solid mantle and the sinking of cold, dense crust back into the mantle exert forces on crustal plates that then move, producing tectonic activity. iv. The flow of matter by convection in the liquid outer core generates the Earth's magnetic field. v. Matter is cycled between the crust and the mantle at plate boundaries. Where plates are pushed together, cold crustal material sinks back into the mantle, and where plates are pulled apart, mantle material can be integrated into the crust, forming new rock. 3. Students use the model to describe the cycling of matter by thermal convection in Earth's interior, including: i. The flow of matter in the mantle that causes crustal plates to move; ii. The flow of matter in the liquid outer core that generates the Earth's magnetic field, including evidence of polar reversals (e.g., seafloor exploration of changes in the direction of Earth's magnetic field); iii. The radial layers determined by density in the interior of Earth; and iv. The addition of a significant amount of thermal energy released by radioactive decay in Earth's crust and mantle. **From the evidence statement for HS-ESS1-5:** 1. Students identify the given explanation, which includes the following idea: that crustal materials of different ages are arranged on Earth's surface in a pattern that can be attributed to plate tectonic activity and formation of new rocks from magma rising where plates are moving apart. 2. Students identify the given evidence to be evaluated. 3. Students identify and describe additional relevant evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given evidence, including: i. Measurement of the ratio of parent to daughter atoms produced during radioactive decay as a means for determining the ages of rocks; ii. Ages and locations of continental rocks; iii. Ages and locations of rocks found on opposite sides of mid-ocean ridges; and iv. The type and location of plate boundaries relative to the type, age, and location of crustal rocks. 4. Students use their additional evidence to assess and evaluate the validity of the given evidence. 5. Students evaluate the reliability, strengths, and weaknesses of the given evidence along with its ability to support logical and reasonable arguments about the motion of crustal plates. 6. Students describe how the following patterns observed from the evidence support the explanation about the ages of crustal rocks: i. The pattern of the continental crust being older than the oceanic crust; ii. The pattern that the oldest continental rocks are located at the center of continents, with the ages decreasing from their centers to their margin; and iii. The pattern that the ages of oceanic crust are greatest nearest the continents and decrease in age with proximity to the mid-ocean ridges. 7. Students synthesize the relevant evidence to describe the relationship between the motion of continental plates and the	its formations and local history. Instructional Strategies ● Interdisciplinary Connections History/Social Studies: The formation of the current state of Earth's crust and how it developed over time ● Technology Integration Computer models of earthquakes and seismograph data.

patterns in the ages of crustal rocks, including that: i. At boundaries where plates are moving apart, such as mid-ocean ridges, material from the interior of the Earth must be emerging and forming new rocks with the youngest ages. ii. The regions furthest from the plate boundaries (continental centers) will have the oldest rocks because new crust is added to the edge of continents at places where plates are coming together, such as subduction zones. iii. The oldest crustal rocks are found on the continents because oceanic crust is constantly being destroyed at places where plates are coming together, such as subduction zones.	