Summit High School
Physics Curriculum
9th Grade (Sheltered ELL)

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Course Description:

Sheltered ELL Physics is a full year course that introduces students to the underlying laws and concepts of the physical world while developing content-specific English language competence. Summit High School English Language Learners' science sequence is on a cycle dependent on co-teacher support and course enrollment.

Throughout the year, units covered lay the foundation for the scientific processing, critical thinking, and mathematical skills necessary to succeed in subsequent science courses and beyond. The units provide a deeper understanding of the following concepts: Motion and Forces, Momentum, Energy, Gravitation and Orbital Motion, Electricity and Magnetism, Waves and Sound, Light and Optics, and relevant topics in Earth Science.

As a Sheltered course for English Language Learners with varying academic levels, the mathematical process is at an Algebra 1 level. Problem solving will reinforce solving for a variable in equations with one unknown. Students also review concepts related to graphing, slope, direct, inverse, and inverse square relationships. Learning activities and modifications can be found here.

The course is aligned with the New Jersey Student Learning Standards for Science (Science NJSLS) and the WIDA English Language Development Standard 4 (Language of Science) which uses an inquiry approach specifically designed to encourage scientific language acquisition. Aligning with the NGSS approach, instructional focuses relate to key scientific and critical thinking processes: 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.

This course is aligned with the Summit High School mainstream Physics curriculum. The course is modified accordingly to address the varying linguistic and academic needs of each individual enrolled in the course. Therefore, the course will include differentiated instruction as well as scaffolded materials to ensure the success of all nonnative speakers with varying academic and educational backgrounds.

Unit Pacing Guide

September	1-D Motion and Forces
October	Momentum
November	Energy
December	Circular Motion, Gravitation and Orbital Motion
January	
----------Midterm Exam----------	
February	Electricity and Magnetism
March	Waves and Sound
April	Light and Optics
May	Earth Science
June	

----------Final Exam----------

Course Structure, Timing, and Topical Outline

Unit 1: 1-D Motion and Forces (5 weeks)

- Uniform motion
- Velocity vs acceleration
- Accelerated motion
- Freefall Motion
- Forces and force diagrams
- Mass vs. weight
- Equilibrium of forces and Newton's First Law
- Disequilibrium of forces and Newton's Second Law

Unit 2: Momentum (4.5 weeks)

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

Unit 3: Energy (4.5 weeks)

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

Unit 4: Gravitation and Orbital Motion (4 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
- Centripetal acceleration
- Centripetal force
- Kepler's Laws
- Orbital speed of circular orbit
- Apparent weightlessness in orbit as freefall

----------Midterm Exam (covers units 1-4)----------

Unit 5: Electricity and Magnetism (6 weeks)

- Charge properties
- Methods of charging
- Van de Graaff generator
- Polarization effects

- Coulomb's Law
- Electric fields and field lines
- Potential and kinetic energy
- Particle accelerating between parallel plates
- Voltage and current
- Very simple circuits
- Household circuits and electricity
- Currents producing B-fields

Unit 6: Waves and Sound (4.5 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

Unit 7: Light and Optics (4.5 weeks)

- Reflection/Refraction of light
- Interference/Diffraction of light
- Optics of mirrors and lenses
- Absorption of electromagnetic radiation by biological tissues (sun screen)

Unit 8: 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

----------Final Exam (covers units 5-8)----------

Abbreviations used in this document

NGSS: Next Generation Science Standards
DCI: Disciplinary Core Idea
CCC: Crosscutting Concepts
SEP: Science and Engineering Practices
CNS: Connections to the Nature of Science
CETAS: Connections to Engineering Technology and Applications of Science

Unit 1: 1-D Motion and Forces

Students begin a Sheltered ELL Physics course exploring motion and the causes of motion. Concepts related to position, position changes, velocity and speed, and acceleration are introduced. Descriptions of motion are limited to one dimension and fairly simple situations. Students quickly move on to concepts related to force, force diagrams, mass and weight, and Newton's first and second laws. The key concept in this unit is Newton's second law. Emphasis should be placed on the fact that objects in equilibrium continue with their state of motion, that people can only feel changes in velocity, and why objects freefall at the same rate regardless of their mass.

Anchor Standard: 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.

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.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
What are the requirements for motion? Can you tell if you are in motion? How do the differences between mass and weight affect astronauts? What are the causes and effects of acceleration? What impacts the rate of a falling object?	Newton's first Law of Motion: An object will continue in constant velocity naturally (inertia) unless a net force is applied. We feel forces (a push or a pull) these unbalanced forces cause accelerations. When forces are balanced even at a non zero velocity no acceleration occurs and you do not feel a net force. Astronauts experience the same mass (inertia) for their bodies, but very different amounts of weight. Velocity is a rate of change of position (how fast an object is moving) while acceleration is a rate of change of that velocity (how fast an object changes its velocity) Changes in velocity are caused by unbalanced forces. Objects with greater mass experience more gravitational force, but also have more inertia. These two effects exactly counteract one another.

Areas of Focus: Proficiencies (Progress Indicators)	Examples, Outcomes, Assessments
From 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	<u>Instructional Focus:</u> • Uniform motion • Velocity vs acceleration • Accelerated/Decelerated motion and equations • Freefall motion • Forces and free body diagrams • Mass vs. weight • Equilibrium of forces and Newton's First • Disequilibrium of forces and Newton's Second <u>Labs/Sample Assessments:</u> **Hallway motion graphing**: students time students moving in various ways down a hallway and use the data to graph their position vs time. **Sonic detector exploration**: students use sonic detectors to watch computer plots of the position or velocity vs time of their body as they move back and forth. **Acceleration along an inclined plane**: students use sonic detectors to watch computer plots of position or velocity vs time of a cart rolling down a ramp with constant acceleration. **1-D Motion and Forces Capstone Investigation**: Students investigate their own question related to the demonstration done at the beginning of the unit where it was observed that two objects with different masses fell to the floor at the same rate. **Unit Assessment/Show Me.** Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem

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	solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice. <u>Projects/Post Assessment</u> **Elevator weight explorations.** Standing on a scale in an elevator, students note how the accelerations/decelerations of their body affect their apparent weight. **Depicting Motion Project**. Students analyze the motion of two objects, making observations and taking data points (one in constant motion and the other in accelerated motion). Students represent this data in words, images, graphically and mathematically. Instructional Strategies • Interdisciplinary Connections Algebra 1 topics reviewed and practiced in solving for variables Driving safety Writing a lab report • Technology Integration Sonic detectors integrated with student computers Force sensors integrated with student computers

Key Vocabulary:	Key Syntax:

Observation Hypothesis Testing Experiment Prediction Evaluation Reference Frame Inertial Position Displacement Path Length Distance Velocity Speed Acceleration Force Mass Newton's 1st Law Newton's 2nd Law	"What do you observe?" "I observed this… based on the evidence…" "Come up with an explanation." "I believe… occured because…" "What is your hypothesis?" "Based on evidence, I believe…" "The hypothesis predicts that… should happen." "I can change my hypothesis to…"

Unit 2: Momentum

In this unit students are introduced to the concepts of Newton's 3rd Law, momentum and impulse. Situations are limited to 1-D cases. Students explore situations in which the Law of Conservation of momentum is obeyed and can be employed in problem solving. Students also learn about how changing the time interval for a force can affect the amount of force that acts on an object. As a culminating project, students design and build a device to minimize the force during a collision.

Anchor Standards:
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

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

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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. (secondary)

DCI ETS1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary)

CCC Systems and System Models When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

CCC Cause and Effect Systems can be designed to cause a desired effect.

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

SEP Constructing Explanations and Designing Solutions Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
How can design minimize the impact of a collision?	Maximizing the time over which a force acts, minimizing the amount of force transmitted.
When striking an object in sports, what aspects of the strike will increase the speed of the object?	By increasing the magnitude of the force or the time that a force acts, the momentum of the object can be changed more easily. That is why following through is so important.
When is momentum conserved and how can it be observed?	Momentum conservation is based on Newton's 3rd **Law** of motion and is never violated. By measuring the change in momentum of objects before and after a
Is it possible to observe conservation of momentum in all cases? How do objects of	

differing masses obey the law of conservation of momentum? What sort of safety devices are employed in automobiles to keep people safe in the event of a collision and how do safety devices in automobiles use momentum concepts?	collision it can be shown that the value does not change. Because momentum is the product of mass x velocity, objects with greater mass will experience less change in speed when subjected to the same force. When a person jumps the Earth "recoils" in the opposite direction, although by an amount too small to measure. Automobiles are equipped with devices such as airbags, crumple zones and padded surfaces to increase the time that it takes a passenger to stop during a collision. This reduces the force and protects from injuries.
Areas of Focus: Proficiencies (Progress Indicators)	**Examples, Outcomes, Assessments**
From NGSS Evidence Statement for HS-PS2-2: 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.	<u>Instructional Focus:</u> • Interactions and Newton's 3rd law • Definition of momentum and impulse • Sports and car applications • Conservation of Momentum • Applying momentum conservation to various 1-D situations: explosions and collisions • Impulse as force*time • Impulse as momentum change • Cushioning as force reduction due to time interval extension <u>Labs/Sample Assessments:</u> **Newton's 3rd Law Project.** Students build a model demonstrating Newton's 3rd Law in action. **Collisions experiments.** Students use motion detectors or photogates to verify

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	law of conservation of momentum in collisions **Explosion experiments.** Students investigate the explosion between two spring loaded carts on a track to find that larger objects in an explosion recoil with a velocity inversely proportional to their mass. **Unit Assessment/Show Me.** Students are assessed on content either through a unit test or project assessment. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice. <u>Projects/Post Assessment</u> Egg drop or similar project to design a device that minimizes force Instructional Strategies • Interdisciplinary Connections Algebra 1 topics reviewed and practiced in solving for variables Driving safety • Technology Integration Photogates and Motion detectors integrated with computer software

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 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.	

Key Vocabulary:	Key Syntax:
Newton's 3rd Law Gravitational Force System Conserved Momentum Impulse Law of Conservation Time Interval Force Explosions Collisions Reduce Extend Time	"What do you observe?" "I observed this… based on the evidence…" "Come up with an explanation." "I believe… occured because…" "What is your hypothesis?" "My hypothesis is…" "Based on evidence, I believe…" "The hypothesis predicts that… should happen." "I can change my hypothesis to…" "If…, then…" "This represents…"

Unit 3: Energy

Students will review and further explore concepts related to energy, particularly forms of mechanical energy like potential and kinetic. Situations like roller coasters and swinging

pendulums are analyzed for which energy is a necessary tool. Emphasis is on the conservation of total mechanical energy and problem solving, and also situations for which external forces do with, transferring energy to thermal/internal energy. Optionally students may complete an energy related project such as a Rube Goldberg machine.

Anchor Standards:
NGSS 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.

NGSS 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.

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.
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.
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.
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.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
Phenomena: When a tennis ball is placed atop a basketball and dropped to the ground, the tennis ball shoots up to a height much greater than that from which it was dropped? How does conservation of energy determine the design of a traditional roller?	During the collision with the basketball at the ground, the basketball transfers some of its energy to the tennis ball, but the overall energy of the system is conserved. Without any losses or gains, the total mechanical energy of the rollercoaster remains constant. Therefore the potential energy on the first hill cannot be exceeded by any subsequent hills.

In our experience objects tend to eventually stop moving. How does that comply with the first law of thermodynamics which states that energy can neither be created nor destroyed? What are the different types of potential energy (PE)? Can PE be negative value? 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?	No! Mechanical energy is converted into thermal energy, or molecular vibrations within the object. Yes, because the "reference level" or zero height of an object is arbitrary. If an object goes below that level, its potential energy is negative. When an object doubles its speed its kinetic energy is four times higher. As long as the ball isn't pushed, it cannot swing to a level higher than its original level because its total energy remains constant.
Areas of Focus: Proficiencies (Progress Indicators)	**Examples, Outcomes, Assessments**
From Science NJSLS 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 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	<u>Instructional Focus:</u> Work Kinetic energy Gravitational potential energy Thermal energy Conservation of Mechanical energy Energy bar graphs Applications (roller coasters, etc) Losses to Thermal energy <u>Labs/Sample Assessments:</u> **Energy on Inclined Plane**: students discover that the amount of work required to lift an object to a certain height from different angles of an inclined plane is equal.

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

Stopping distance. Students find that the stopping distance of an object having twice the initial speed is four times farther. Applications with driving safety.

Unit Assessment/Show Me. Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice.

<u>Projects/Post Assessment</u>

Rube Goldberg Project: students construct a complex device to perform a task where energy transfers several times.

Instructional Strategies

- Interdisciplinary Connections

Algebra 1 topics reviewed and practiced in solving for variables

Driving safety (stopping distance)

- Technology Integration

Computational models of energy flow through a system

Sonic Detectors integrated with student computers

Force Sensors integrated with student computers

freely moving particles (e.g., inert gas atoms, molecules) in liquids and gasses. c. The total energy of the system and 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. 2. 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. 3. 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.	

Key Vocabulary:	Key Syntax:
Force Work Gravitational Potential Energy Kinetic Energy Elastic Potential Energy Internal Energy Elastic Inelastic Power Work-Energy Principle	"What do you observe?" "I observed this… based on the evidence…" "Come up with an explanation." "I believe… happened because…" "What is your hypothesis?" "My hypothesis is…" "Based on evidence, I believe…" "The hypothesis predicts that… should happen." "I can change my hypothesis to…" "If…, then…" "The energy [increases/decreases]... because…"

Unit 4: Circular Motion, Gravitation and Orbital Motion

The final unit in semester one is circular motion, gravitation and orbits. Although there are no specific NGSS standards related to circular motion, students are introduced to critical kinematic and dynamic concepts of circular motion so that they can fully appreciate the nature of orbiting bodies. Students solve problems related to centripetal acceleration and force, then apply that knowledge to orbits. Newton's Gravitational Law is introduced, with a focus on the mathematical nature of inverse-square laws. Students explore Kepler's Laws with particular emphasis on the nature of elliptical orbits, orbital

velocity and period, and the relationship between periods and orbital distances in Kepler's 3rd Law.

Anchor Standards:
NGSS 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.

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

Big Ideas:*Course Objectives/Content Statement(s)*

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

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 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 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"?	The Cavendish experiment allowed scientists to "weigh" the Earth and other bodies. When G was measured, they could apply to Newton's gravity law and Kepler's laws to solve for masses. The orbit of the moon is caused by gravity, just as falling objects at the surface of the Earth. Inverse square laws can be found in many of the field forces in nature, such as gravity and electricity. When the distance between two objects is doubled, the force between them is divided by four. It is a result of the nature of 3-dimensional space. Objects in circular motion (or elliptical motion) must have a force directed toward the center of the circle (or focus of the ellipse). Because of the elliptical orbit of the moon, at times it is closer to the Earth and other times farther.
Areas of Focus: Proficiencies (Progress Indicators)	**Examples, Outcomes, Assessments**
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	<u>Instructional Focus:</u> ● Centripetal acceleration/force ● Newton's Gravitation Law ● Gravitation as a centripetal force agent ● Inverse-square laws ● Kepler's Laws

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

- Properties of ellipses
- Kepler's third law relations
- Orbital speed of circular orbit
- Apparent weightlessness in orbit as freefall

Labs/Sample Assessments:
Elliptical orbits. Students use real data about the orbit of a planet such as mercury to explore properties of an ellipse.

Newton's cannon simulator. Students use a simulator of Newton's cannon on a mountain to explore what it means to be in orbit.

Projects/Post Assessment

Unit Assessment/Show Me. Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice.

Astronomical observations. Students meet during evening hours to observe planets, the moon, and other celestial objects. Students can also use a specialized solar telescope to view the Sun.

Instructional Strategies
- Interdisciplinary Connections

Social studies: history surrounding Copernicus, Galileo, Brahe, Kepler, Newton, Cavendish and others involved in Astrophysical discoveries.

- Technology Integration

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.	Computer simulations of orbits Computer simulations of Kepler's Laws

Key Vocabulary:	Key Syntax:
Orbit Law of Universal Gravitation Gravitation Inverse-square laws Kepler's Laws Ellipse Period Kepler's third law relations Orbital speed of circular orbit Freefall Weightless	"What do you observe?" "I observed this… based on the evidence…" "Come up with an explanation." "I believe… happened because…" "What is your hypothesis?" "My hypothesis is…" "Based on evidence, I believe…" "The hypothesis predicts that… should happen." "I can change my hypothesis to…" "If…, then…" "This formula/calculation represents…"

Circular motion	“Based on the graph/representation,...”

Unit 5: Electricity and Magnetism

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 explore basic circuits to understand the difference between voltage and current, then study how electric currents produce magnetic fields and changing magnetic fields can produce electric currents. An optional culminating project would be to build a model generator.

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?*
Why does the Van de Graaff generator cause hair to stand up?	The Van de Graaff efficiently separates charge, depositing negative charge on the metal ball. A person touching the ball conducts that charge on their body. It spreads out in a way to move as far from other charge as possible. Hairs are an ideal place, and that negative charge repels other negative charge.

Why does rubbing socks on carpet allow for static electric shocks? What is lightning? 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 potential difference and current? How can electricity be used to build a magnet?	When different materials are rubbed together they often separate charge, with more electrons collecting on one object. Objects then have a net charge and can discharge when coming in contact with other objects. A high energy discharge of static electricity. Any natural phenomenon that decreases as the square of the distance between objects. This can be seen in gravitation, electricity, magnetism, intensity from light and sound sources, etc. You must find a way to create a loop, or circuit for the current to flow around. Potential difference moves charge in a circuit. Current is the measurement of the charge flow rate in that circuit. Current produces a magnetic field, and a current carrying wire coiled around a ferromagnetic material will create an electromagnet.
Areas of Focus: Proficiencies (Progress Indicators)	**Examples, Outcomes, Assessments**
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	<u>Instructional Focus:</u> • Charge properties • Methods of charging • Van de Graaff generator • Polarization effects • Coulomb's Law • Electric fields and field lines • Potential and kinetic energy • Particle accelerating between parallel plates • Voltage and current • Very simple circuits • Currents producing B-fields

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.

- Right hand rule for B field surrounding long straight wire
- Right hand rule for determining poles of solenoid
- Electromagnetic induction

<u>Labs and Sample Assessments:</u>

Sticky Tape Lab: Students use two pieces of tape and various other electrostatics materials to make observations and draw conclusions about the charge of various objects based on their reactions.

Charging explorations: Students use plastic and glass rods with silk and fur to explore charge interactions and polarization effects. They also observe polarization effects with rubber balloons. They use electroscopes and/or a electrophorus to study charging by conduction and induction.

Van der Graaf generator explorations. Students interact with static electricity generator to observe charging/discharge phenomena.

Electromagnet building. Students will apply the knowledge of how electrical current produces a magnetic field to build an effective electromagnet.

Unit Assessment/Show Me. Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice.

<u>Projects/Post Assessment</u>

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. 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	**Generator building.** Students construct model generators from magnets, wire, and low power light bulbs. Instructional Strategies • Interdisciplinary Connections Uses of electricity and magnetism in common equipment such as computers, and other technology. Algebra 1 topics reviewed and practiced in solving for variables • Technology Integration Use of calculators to solve problems with numbers in scientific notation

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 magnetic field near the circuit can provide the required evidence.	

Key Vocabulary:	Key Syntax:
Electrons Electric Charge Friction	“What do you observe?” “I observed this… based on the evidence…” “Come up with an explanation.”

Conductor Insulator Induction Coulomb's Law Superposition Principle Polarization E Field/Electric Field V Field/Electric Potential Magnets B Field/Magnetic Field Right-Hand Rules Electric Current Resistance Circuit Series Parallel Potential Difference Generator	"I believe… happened because…" "What is your hypothesis?" "My hypothesis is…" "Based on evidence, I believe…" "The hypothesis predicts that… should happen." "I can change my hypothesis to…" "If…, then…" "Why do you think… happens? "How can we make this work?"

Unit 6: Waves and Sound

During this unit, students explore various wave characteristics and behaviors. The primary focus is on the relationship between wave speed, frequency and wavelength. During experiments on water wave tables, slinkies, and resonance tubes, students can directly measure wave characteristics and watch wave-like behaviors such as reflection, refraction, diffraction and interference. Interesting phenomena associated with sound waves are studied in more detail.

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.
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. **CCC Cause and Effect** 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 or design solutions to describe and/or support claims and/or explanations.

Essential Questions *What provocative questions will foster inquiry, understanding, and transfer of learning?*	**Enduring Understandings** *What will students understand about the big ideas?*
Why is there no sound in outer space?	Mechanical waves require a medium to be transmitted, and outer space is essentially a vacuum.
How can a person distinguish a guitar playing a certain note from a piano playing the same exact note?	Plucked strings vibrate in multiple modes (harmonics) and the relative mixture of those harmonic modes gives particular instruments their unique timbre.
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?	The speed of sound is independent of the frequency/wavelength, but is rather a characteristic of the properties of the medium, such as the air. High and low, loud and soft noises are all propagating on the same medium, thus they have the same speeds.
What are waves?	A wave is a disturbance in a medium or vacuum that carries energy from one place to another.
How can waves change their speed?	The speed of a wave is dependent solely on the medium through which it is traveling. The only way to change the speed of a wave is to propagate it through a different medium.
How do sound waves differ from waves sent through a string or ripples in water?	Sound waves travel through collision of particles so that the particles are vibrated parallel to the direction the wave is traveling. Waves sent through a string or ripples in water vibrate particles perpendicular to the direction the wave is traveling.
How do waves interact with one another?	Waves can add or cancel as they cross but they do not affect the original waves and will continue unaffected after crossing.
Areas of Focus: Proficiencies	**Examples, Outcomes, Assessments**

(Progress Indicators)	
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 traveling in various specified media. 7. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.	Instructional Focus: • What is a wave? • Longitudinal vs transverse • Wavelength, frequency, speed, amplitude • $v = f\lambda$ • Reflection, refraction, diffraction, interference effects, Doppler effect • Sound waves • Pitch/frequency; volume/intensity • Standing waves Labs/Sample Assessments: **Slinky Explorations.** Students use long slinkies to explore different types of waves, standing waves, wave speed, frequency and wavelength relationships. **Speed of sound.** Students use a resonance tube to calculate the speed of sound in a room. **Speed of sound direct measurement video.** Students observe delays in sound waves to calculate the speed of sound. **Water wave tables.** Students produce waves on water wave tables to explore frequency wavelength and speed, interference, diffraction, reflection, refraction and other wave behaviors. Projects/Post Assessment **Unit Assessment/Show Me.** Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice.

	Instructional Strategies • Interdisciplinary Connections Algebra 1 topics reviewed and practiced in solving for variables • Technology Integration Use of recording technology to time the delay in a sound being made and a sound being heard. Use of imaging technology to better observe wave behaviors

Key Vocabulary:	Key Syntax:
Speed Frequency Wavelength Wave Amplitude Period Reflection Refraction Diffraction Sound Pitch Volume Intensity	“What do you observe?” “I observed this… based on the evidence…” “Come up with an explanation.” “I believe… happened because…” “What is your hypothesis?” “My hypothesis is…” “Based on evidence, I believe…” “The hypothesis predicts that… should happen.” “I can change my hypothesis to…” “If…, then…” “Why do you think… happens? “...causes…because…” “This data explains/demonstrates…”

Unit 7: Light and Optics

Students look at wave-like phenomena associated with light, such as refraction, reflection, diffraction and interference. This can be contrasted (in less detail) with particle-like behavior as seen in the photoelectric effect, although students will learn more about that in chemistry. Some miscellaneous standards are grouped in this unit, and can be satisfied by learning about how sunscreen protects skin from solar radiation, how solar cells work, and the advantages of digital transmission and storage of information.

Anchor Standards:

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

- 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.A: Wave Properties

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 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 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.
- Systems can be designed to cause a desired effect.

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

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?*
What is light and how do we know?	Light can be thought of as having wave and particle characteristics. Light behaves as a wave in certain situations, and as a particle in others.
How does sunscreen work? Are tanning beds safe?	Students will learn how sunscreens protect skin from UV rays and the dangers of sun and tanning bed exposure.
How do the solar cells on my roof work?	Solar cells convert the energy from the Sun to electrical energy using special materials.
What does it mean to be “digitized”?	Digital information is transmitted as a code of 0’s and 1’s, while analog information is continuous in its range of amplitudes.
How does a light wave differ from a sound wave?	A light wave is propagated through perpendicular vibrating electric and

	magnetic fields. A sound wave is propagated through collisions of particles. Light waves can travel through a vacuum while sound waves cannot.
How and what do we see?	We see light that is reflected in particular ways off of objects and is focused by the lens in our eye to create images.
How do light waves create things such as rainbows and mirages?	When light bends due to a change in the property of the medium through which it is traveling, it can separate, creating a rainbow, and it can create images.
Areas of Focus: Proficiencies (Progress Indicators)	**Examples, Outcomes, Assessments**
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	<u>Instructional Focus:</u> • Reflection/Refraction of light • Interference/Diffraction of light • Optics of mirrors and lenses • Absorption of electromagnetic radiation by biological tissues • How solar cells work • Digital storage and transmission of information <u>Labs/Sample Assessments:</u> **Refraction experiments.** Students observe refraction of light through water to calculate its index of refraction. **Unit Assessment/Show Me.** Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice. <u>Projects/Post Assessment</u>

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**	**Sunscreen literature analysis.** Students read various sources about the effectiveness of sunscreen, the dangers of sun exposure and tanning beds. Instructional Strategies • Interdisciplinary Connections Biology: the effects of radiation on biological systems. Computers: the meaning of digital codes Chemistry: the types of molecules used in sunscreen; the photoelectric effect Algebra 1 topics reviewed and practiced in solving for variables • Technology Integration

1. Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate technical information and ideas, 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.	

Key Vocabulary:	Key Syntax:
Light Refraction Reflection Total Internal Reflection Image Diffraction Interference Optics of mirrors and lenses Electromagnetic Field Radiation Absorption	“What do you observe?” “I observed this… based on the evidence…” “Come up with an explanation.” “I believe… happened because…” “What is your hypothesis?” “My hypothesis is…” “Based on evidence, I believe…” “The hypothesis predicts that… should happen.” “I can change my hypothesis to…” “If…, then…” “Why do you think… happens? “...causes…because…” “This data explains/demonstrates…” “I am curious about…”

Unit 8: 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? What evidence exists of plate tectonics? How does matter cycle within Earth's interior?	The earth has a solid Crust, a liquid outer core and a solid inner core. We experience earthquakes, the ocean floor topography is varied and includes volcanoes, 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. These 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 ocean floor 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	<u>Instructional Focus:</u> • 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 <u>Labs/Sample Assessments:</u> **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.

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 of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center).	**Unit Assessment/Show Me.** Students are assessed on content either through a unit assessment or project. The unit test assesses content using multiple choice items, problem solving, and written descriptions of phenomena. The project assessment has students demonstrate content mastery and essential academic skills through any representation of their choice. <u>Projects/Post Assessment</u> **Earth Science Field Visit.** Students take a field trip to a geologically significant site in NJ to study 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.

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 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.	

Key Vocabulary:	Key Syntax:
Earth's interior Seismic waves Layers Continental drift Magnetic poles Sea floor spreading Plate tectonics Plate boundaries Mechanical and chemical weathering Geology	"What do you observe?" "I observed this… based on the evidence…" "Come up with an explanation." "I believe… happened because…" "What is your hypothesis?" "My hypothesis is…" "Based on evidence, I believe…" "The hypothesis predicts that… should happen." "I can change my hypothesis to…" "If…, then…" "Why do you think… happens? "...causes…because…" "This data explains/demonstrates…" "I am curious about…"