Bristol Public Schools

Office of Teaching & Learning

Department	Science
Department Philosophy	Bristol Public Schools science programing provides students with knowledge of the science and engineering practices, crosscutting concepts, and the core ideas of science and engineering to engage in public discussions on science related issues, to be critical consumers of scientific information related to their everyday lives, and continue to learn science throughout their lives. To ensure this level of scientific literacy, Bristol Public Schools anchor science units in phenomena, this practice promotes student ownership of learning and supports student application of the science content as it pertains to the real world. In each science unit, students work to explain phenomena through the applications of the three dimensions of the Next Generation Science Standards: (1) science and engineering practices, (2) disciplinary core ideas, and (3) cross cutting concepts. Bristol's use of phenom-based units and the three dimensions ensure that students connect with and build a deep conceptual understanding of science concepts. Throughout the kindergarten through grade 12 experience, this philosophy provides all Bristol students with the skills and concepts to be scientifically literate adults.
Course	Physics
Course Description for Program of Studies	This course is designed for students interested in a career in mathematics, science or engineering as well as those interested in a more extensive physical science background. The academic course provides a survey of physics concepts including: motion, mass, force, circular motion & torque, energy, momentum, simple harmonic motion, gravity, heat, electrostatics, electric circuits, magnets, waves and particle nature of light. The accelerated version of this course provides a deeper mathematical overview of these physics concepts. Rich laboratory activities are woven into student experiences for students enrolled at both the academic and accelerated levels.
Grade Level	11-12
Pre-requisites	Successful completion of Algebra 1 and Geometry
Credit (if applicable)	1.0

P indicates standard will be a priority for the unit; S indicates a supporting standard

District Learning Expectations and Standards	**Unit 1**	**Unit 2**	**Unit 3**	**Unit 4**	**Unit 5**	**Unit 6**	**Unit 7**	**Unit 8**	**Unit 9**	**Unit 10**	**Unit 11**	**Unit 12**	**Unit 13**
Next Generation Science Standards													
HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.									X				
Hs-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.	X						X						
HS-PS2-2: Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	X	X			X								
HS-PS2-3: Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*					X								
HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	X						X		X		X		
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.										X	X		
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*								X	X		X		
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.				X									
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 motion of particles (objects) and energy associated with the relative positions of particles (objects).			X	X				X					

HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.												X	
HS-PS4-3: 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. [												X	
HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.													X
HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*													X
HS-ESS1-4 4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.							X						
College Board AP Physics Enduring Understandings and Learning Objectives													
3.B.3.1: Predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.						X							
3.B.3.2: Design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.						X							
3.B.3.3: Analyze data to identify qualitative and quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion and use those data to determine the value of an unknown.						X							
3.B.3.4: Construct a qualitative and/or quantitative explanation of oscillatory behavior given evidence of a restoring force.						X							

UNIT 1: Motion

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Academic Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS2-1 Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.</td><td>SEP</td><td>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.</td><td rowspan="9">● Position
● Displacement
● Distance
● Speed
● Velocity
● Acceleration
● Vector
● Scaler
● Magnitude
● Resultant
● Vector composition
● Vector resolution
● Component
● Projectile
● Range
● Trajectory
● Free fall
● Air resistance
● kinematics</td></tr>
<tr><td>DCI</td><td>PS2.A: Forces and Motion
● Newton’s second law accurately predicts changes in the motion of macroscopic objects.</td></tr>
<tr><td>CCC</td><td>Cause and Effect
● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td rowspan="3">HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
● Use mathematical representations of phenomena to describe explanations.</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>Systems and System Models
● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.</td></tr>
<tr><td rowspan="3">HS-PS2-4 Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
● Use mathematical representations of phenomena to describe explanations.</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>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.</td></tr>
</table>

UNIT 1 DETAILS: Motion

Unit Narrative:
This unit introduces students to the methods of determining a quantitative description of our physical world through the analysis of moving particles.

Unit Essential Questions:

- What quantities are useful for describing motion, and what are their units or dimensions?
- How can these quantities be measured?
- What are the relationships between these quantities for various motions?
- Is the motion of an object predictable?
- How do models in physics simplify physical situations, and restrict range of applicability?

Learning Sequence	Learning Target(s): I can...	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) The Equations of Kinematics	• I can state, define, and differentiate between the quantities useful for the description of motion. • I can, given boundary conditions, use the equations of kinematics to determine, explain, or predict the state of motion of a particle at a different time or position. • I can identify the range of applicability of the equations developed. • I can apply the equations and methods to solve one dimension kinematics word problems.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Use mathematical representations of phenomena to describe explanations. • Newton's second law accurately predicts changes in the motion of macroscopic objects. • 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.	Reaction time lab Kinematics quiz ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
(2) Free Fall	• I can state Galileo's Law of Falling Bodies, and recognize the benefits and limitations of models in physics. • I can measure the acceleration of gravity near the Earth's surface. • I can recognize, infer, and apply symmetry in free fall problems.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • 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. • 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.	Accel of gravity lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
(3) Vectors	• I can recognize that some quantities used to describe motion have both direction and magnitude (Vector) , while others are completely described by a number (Scalar).	[ ] Selected Response	SEP / DCI / CCC • Newton's second law accurately predicts changes in the motion of macroscopic	Accel of gravity lab

	• *I can add/subtract vectors in two dimensions. (ACC)* • *I can resolve (split) vectors into x and y components. (ACC)*	x Constructed Response x Performance Observation	objects. • Use mathematical representations of phenomena to describe explanations.	ELA/Math Connection: CCSS.MATH.CONTENT.HSN.VM.A.1 (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes CCSS.MATH.CONTENT.HSN.VM.A.2 (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point. CCSS.MATH.CONTENT.HSN.VM.A.3 (+) Solve problems involving velocity and other quantities that can be represented by vectors.
(4) Projectile Motion	• I can synthesize previously studied 1-dimensional motions and vectors to analyse and solve projectile motion problems.	Selected Response Constructed Response Performance Observation	**SEP** | **DCI** | • Use mathematical representations of phenomena to describe explanations. • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.	Rocket lab.doc ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

<table>
<tr><th colspan="4">UNIT 2: Mass and Force</th></tr>
<tr><th colspan="4">UNWRAPPED STANDARDS</th></tr>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
● Use mathematical representations of phenomena to describe explanations.</td><td rowspan="3">● Mass
● Weight
● Inertia
● Law of inertia
● Newton’s 2nd Law
● Force
● Friction
● Static
● Kinetic
● Coefficient of friction
● Normal force
● Tension
● Equilibrium
● Non equilibrium
● Action
● Reaction
● Net force</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>Systems and System Models
● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.</td></tr>
</table>

UNIT 2 DETAILS: Mass and Force

Unit Narrative: Once students can successfully describe motion in 1 and 2 dimensions, our attention is now turned to what causes a particular motion.

Unit Essential Questions:
- What is a force?
- What is the role of force in the motion of a body?
- Where do forces come from?
- How do you model/represent forces using a free body diagram?
- What is the relationship between unbalanced forces, mass, and acceleration?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Newton's Laws	• I can recognize that net force changes motion, but is not required for motion. • I can identify mass as the measure of an object's inertia. • I can state the relationship between net force, mass, and acceleration verbally and mathematically. • I can model objects as point particles when using Newton's Second Law. • I can state that forces always occur in pairs, and identify those action/reaction pairs.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. • Use mathematical representations of phenomena to describe explanations.	Proving Newton's 2nd Law Apparent weight lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
(2) Equilibrium	• I can associate equilibrium with zero acceleration and balanced forces. • I can name and quantify the forces of mechanics • I can identify the forces acting on an object. • I can abstract a free body diagram from a given physical situation. • I can use the free body diagram to generate Newton's second law equations.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. • Use mathematical representations of phenomena to describe explanations. • 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.	Quiz on Newton's Laws ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
(3) Non-Equilibrium	• I can identify situations in which the forces are not balanced, and the acceleration of a body is not zero. • I can apply the methods above to analyze non-equilibrium situations.	[ ] Selected Response [x] Constructed Response [x] Performance	**SEP** | **DCI** | **CCC** • Use mathematical representations of phenomena to describe explanations. • 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.	

		☐ Observation		ELA/Math Connection:

UNIT 3: Circular Motion and Torque

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">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 motion of particles (objects) and energy associated with the relative positions of particles (objects).</td><td>SEP</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td rowspan="3">• Radius
• Circumference
• Tangential
• Radial
• Inward
• Centripetal
• Period
• Frequency
• Hertz
• Critical speed
• Torque
• Leverage
• Lever Arm
• Axis of rotation
• Center of mass
• Uniform</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>Energy and Matter
• Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.</td></tr>
</table>

UNIT 3 Circular Motion and Torque

Unit Phenomenon:
Storyline: This unit expands on material previously studied. Students expand their definition of acceleration to include a change in velocity direction (not speed) and investigate the effects of a net force acting perpendicular to the instantaneous direction of motion. Students also expand their understanding of equilibrium to include rotational equilibrium and zero net torque.

Unit Essential Questions:
- How do you define and mathematically describe circular motion?
- What is the relationship between centripetal acceleration and circular motion?
- What is the relationship between force and torque?
- What condition is required for rotational equilibrium?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Uniform circular motion	• I can understand that circular motion is caused by a net inward force. • I can explain how an object can accelerate even if it is moving with constant speed. • I can use Newton's Second Law and the expression for centripetal acceleration to analyze circular motion. • I can use a model to relate speed, period, and frequency for a body in circular motion.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. • 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.	Circular motion lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
(2) Torque and rotational equilibrium	• I can explain how a small force can cause a big torque. • I can determine how to achieve rotational equilibrium.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • 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.	Torque lab Quiz on circular motion ELA/Math Connection:

UNIT 4: Energy

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">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.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
Create a computational model or simulation of a phenomenon, designed device, process, or system.</td><td rowspan="5">Work
Joule
Power
Watt
Horse Power
Energy
Kinetic Energy
Gravitational Potential Energy
Law of Conservation of Energy
Mechanical energy</td></tr>
<tr><td>DCI</td><td>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.
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.</td></tr>
<tr><td>CCC</td><td>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.</td></tr>
<tr><td rowspan="2">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 motion of particles (objects) and energy associated with the relative positions of particles (objects).</td><td>SEP</td><td>Developing and Using Models
Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td></tr>
<tr><td>DCI</td><td>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</td></tr>
</table>

		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.	
	CCC	**Energy and Matter** • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.	

UNIT 4 Energy

Unit narrative: Newton's Laws are not the only means of analyzing motion. Students are introduced to the concept of the Conservation law. The bridge between Newton's Laws and energy is the concept of work. The Newton's Laws approach is compared to the new conservation of energy approach.

Unit Essential Questions:

- What is energy?
- What is work?
- What is the relationship between work and force?
- What is the relationship between net work and the change in kinetic energy of a body?
- What is power?
- What does it mean to conserve energy?
- How can you determine if energy has been conserved in a system?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Work	• I can model how work is done when a force acts through a displacement. • I can recognize and explain the work done by a force is a scalar, whose value can be (+), (-), or zero. • I can calculate the net work done on an object.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** / **DCI** / **CCC** • Create a computational model or simulation of a phenomenon, designed device, process, or system. • 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.	Work Model ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
(2) Energy	• I can calculate the net work changes on the energy of a body. • I can calculate the kinetic energy of an object. • I can calculate gravitational potential energy.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** / **DCI** / **CCC** • Create a computational model or simulation of a phenomenon, designed device, process, or system. • 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.	Energy calculations ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

(3) Power	• I can associate power with the rate at which work is done. • I can calculate power.	[ ] Selected Response [x] Constructed Response [ ] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • Create a computational model or simulation of a phenomenon, designed device, process, or system.	Power calculations ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
(4) Conservation of mechanical energy	• I can identify situations in which total mechanical energy is conserved. • I can use the conservation of mechanical energy to analyze problems. • I can model/represent the ideas that the conservation laws depend only on initial and final conditions and are independent of the details of the in-between processes.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • Create a computational model or simulation of a phenomenon, designed device, process, or system. • 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.	Conservation of energy lab Razor blade lab Energy quiz ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

UNIT 5: Momentum

UNWRAPPED STANDARDS

Standard	Dimensions of the NGSS Standard		Concepts and Disciplinary-Specific Vocabulary
HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	**SEP**	**Using Mathematics and Computational Thinking** ● Use mathematical representations of phenomena to describe explanations.	● Momentum ● Collision ● Impulse ● Inelastic collision ● Elastic collision ● Velocity ● Vector ● Law of Conservation of Momentum ● Perfectly inelastic collision ● Total momentum ● Action force ● Reaction force
	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.	
	CCC	**Systems and System Models** ● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.	
HS-PS2-3 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*	**SEP**	**Constructing Explanations and Designing Solutions** ● Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.	
	DCI	**PS2.A: Forces and Motion** ● 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.	
	CCC	**Cause and Effect** ● Systems can be designed to cause a desired effect.	

UNIT 5 Momentum

Unit Narrative: Some situations, such as collisions, involve interactions, the details of which are very complicated, making Newton's Laws analysis intractable. In addition, mechanical energy is not conserved during most collisions. A new conservation law is introduced to handle collisions.

Unit Essential Questions:

- What is momentum?
- How does the law of conservation of momentum help us analyze collisions?
- What is the difference between energy and momentum?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Impulse/Momentum	• I can calculate the momentum of an object of mass *m* moving with velocity *v* as *mv*. • I can identify the momentum of a body as a vector. • I can explain the relationship between impulse and the change in momentum.	Selected Response x Constructed Response x Performance Observation	**SEP** | **DCI** | **CCC** • Use mathematical representations of phenomena to describe explanations. • 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.	Quiz on collisions ELA/Math Connection: CCSS.MATH.CONTENT.HSN.VM.A.1 (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v). CCSS.MATH.CONTENT.HSN.VM.A.2 (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point. CCSS.MATH.CONTENT.HSN.VM.A.3 (+) Solve problems involving velocity and other quantities that can be represented by vectors.
(2) Conservation of Momentum/Collisions	• I can apply the conservation of momentum to solve collision problems. • I can differentiate between energy and momentum, and calculate the loss of kinetic energy in an inelastic collision. • I can make a claim about what happens to the lost kinetic energy.	Selected Response x Constructed Response x Performance Observation	**SEP** | **DCI** | **CCC** • Use mathematical representations of phenomena to describe explanations. • 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. • Apply scientific ideas to solve a design	Collision problems ELA/Math Connection: CCSS.MATH.CONTENT.HSN.VM.A.1 (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v,

			problem, taking into account possible unanticipated effects.	|v|, ||v||, v). CCSS.MATH.CONTENT.HSN.VM.A.2 (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point. CCSS.MATH.CONTENT.HSN.VM.A.3 (+) Solve problems involving velocity and other quantities that can be represented by vectors.

UNIT 6: Simple Harmonic Motion

UNWRAPPED STANDARDS

Standard	Dimensions of the NGSS Standard		Concepts and Disciplinary-Specific Vocabulary
College Board Enduring Understandings 3. B Classically the acceleration of an object interacting with other objects can be predicted. 5.B The energy of a system is conserved	**CB**	**Learning Objectives** ● 3.B.3.1: Predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. ● 3.B.3.2: Design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force. ● 3.B.3.3: Analyze data to identify qualitative and quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion and use those data to determine the value of an unknown. ● 3.B.3.4: Construct a qualitative and/or quantitative explanation of oscillatory behavior given evidence of a restoring force.	● Elongation ● Displacement from Equilibrium ● Hooke's Law ● Spring Constant ● Restoring Force ● Simple Harmonic Motion ● Amplitude ● Cycle ● Oscillation ● Elastic Potential Energy ● Simple Pendulum

UNIT 6 Simple Harmonic Motion

Unit Phenomenon:
Storyline: Having finished our basic survey of fundamental mechanics principles, our attention turns to the application of those principles.

Unit Essential Questions:
- What new terms describe harmonic motion?
- What is a simple harmonic oscillator?
- What is the link between simple harmonic motion and waves?
- How do springs store energy?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Springs	• I can graph the elongation of a spring to the applied force. • I can experimentally determine a spring's spring constant from the graph. • I can determine a spring's elastic limit from a graph.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** / **DCI** / **CCC** • 3.B.3.1: Predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.	Spring constant calculations ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
(2) Simple Harmonic Motion	• I can define and calculate the period of a mass on a spring. • I can apply the relationship between period and frequency. • I can experimentally determine that period is independent of amplitude.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** / **DCI** / **CCC** • 3.B.3.1: Predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. • 3.B.3.2: Design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.	Simple oscillation lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
(3) Spring potential energy	• I can appreciate that objects store energy due to their deformation. • I can calculate the energy stored in a deformed spring. • I can solve problems involving the transfer of spring energy into other forms.	[ ] Selected Response [x] Constructed Response [x] Performance	**SEP** / **DCI** / **CCC** • 3.B.3.2: Design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force. • 3.B.3.4: Construct a qualitative and/or quantitative explanation of oscillatory behavior given evidence of a restoring force.	Elastic potential energy lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3

		Observation		Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
(4) Pendulums	• I can experimentally determine what factors affect the period of a pendulum. • I can calculate the period of a pendulum of a given length.	Selected Response Constructed Response Performance Observation	**SEP** / **DCI** / **CCC** • 3.B.3.2: Design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force. • 3.B.3.3: Analyze data to identify qualitative and quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion and use those data to determine the value of an unknown.	Pendulum lab Simple harmonic motion quiz ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

UNIT 7: Gravitation

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.</td><td>SEP</td><td>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.</td><td rowspan="9">● Gravity
● Inverse Square
● Action at a Distance
● Field
● Gravitational Field Strength
● Kepler's Laws
● Elliptical
● Focus
● Orbital Motion
● Synchronous Orbit
● Satelite</td></tr>
<tr><td>DCI</td><td>PS2.A: Forces and Motion
● Newton's second law accurately predicts changes in the motion of macroscopic objects.</td></tr>
<tr><td>CCC</td><td>Cause and Effect
● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td rowspan="3">HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
● Use mathematical representations of phenomena to describe explanations.</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>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.</td></tr>
<tr><td rowspan="3">HS-ESS1-4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.</td><td>SEP</td><td>Using Mathematical and Computational Thinking
● Use mathematical or computational representations of phenomena to describe explanations.</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>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).</td></tr>
</table>

UNIT 7 Gravitation

Unit Narrative: All forces are different manifestations of a small number of fundamental forces. The same force that holds us to the Earth also holds the moon in its orbit.

Unit Essential Questions:
- How does a change in mass or distance impact gravitational force?
- What is a field theory and why is it important to the study of physics?
- What is a gravitational field? How is a gravitational field calculated?
- What are Kepler's laws?
- What is the relationship between a body in orbit and the gravitational force?

Learning Sequence	**Objective(s):** The students will be able to:	**Summative Assessment Strategy**	**Priority NGSS Dimensions**	**Common Learning Experiences**
(1) Gravitation	• I can understand and explain the relationship between gravity and mass. • I can calculate the force between two given masses separated by a given distance using Newton's Universal Law of gravity. • I can use the inverse square law to predict how force changes with separation.	Selected Response x Constructed Response x Performance Observation	**SEP** / **DCI** / **CCC** • Use mathematical or computational representations of phenomena to describe explanations. • 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 • 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).	Newton's Universal Law of Gravitation calculations/practice ELA/Math Connection: CCSS.ELA-LITERACY.WHST.11-12.1.B Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.
(2) Gravitation Fields	• I can use the value of a field theory to explain forces acting at a distance. • I can calculate the gravitational field strength/acceleration of gravity at a given distance from a given body.	Selected Response x Constructed Response x Performance Observation	**SEP** / **DCI** / **CCC** • Use mathematical or computational representations of phenomena to describe explanations. • 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. • 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).	Gravitational field calculations Acceleration of gravity calculations ELA/Math Connection: CCSS.MATH.CONTENT.HSA.REI.A.1 Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

(3) Kepler's Laws	• I can state Kepler's Laws. • I can use Kepler's laws to describe a body in orbit.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • Use mathematical or computational representations of phenomena to describe explanations. • 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. • 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).	Kepler's laws calculations Body in Orbit Model-Kepler's Laws ELA/Math Connection: CCSS.ELA-LITERACY.WHST.11-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
(4) Orbital Motion	• I can explain how orbital motion is achieved. • I can identify gravity as the centripetal force acting on an orbiting body. • I can determine the speed and period of a body in orbital motion. • I can explain the advantages of a satellite in a synchronous orbit.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • Use mathematical or computational representations of phenomena to describe explanations. • 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. • 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).	Body in Orbit Model (continued) Quiz on gravitation ELA/Math Connection: CCSS.ELA-LITERACY.WHST.11-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

UNIT 8: Heat

UNWRAPPED STANDARDS

Standard	Dimensions of the NGSS Standard		Concepts and Disciplinary-Specific Vocabulary
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*	**SEP**	**Obtaining, Evaluating, and Communicating Information** ● Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	● Temperature ● Specific Heat ● Heat ● Calorimetry ● Transfer ● Linear Expansion
	DCI	**PS2.B: Types of Interactions** ● Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	
	CCC	**Structure and Function** ● Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.	
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 motion of particles (objects) and energy associated with the relative positions of particles (objects).	**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.	
	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.	
	CCC	**Energy and Matter** ● Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.	

UNIT 8 Heat

Unit narrative: The concept of energy is expanded to include heat.

Unit Essential Questions:

- What is heat?
- How is heat exchanged?
- How does heat exchange relate to the Law of Conservation of Energy?
- How can heat exchange be used to identify unknown substances?
- What is the relationship between mechanical energy and heat energy?
- How are the dimensions of substances impacted by a change in temperature?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Heat	• I can identify heat as a form of energy. • I can explain the relationship between the heat of a substance and the kinetic energy of the energy possessed by the particles of the substance. • I can explain how heat is exchanged from one object to another. • I can associate specific heat as an energy "tank".	Selected Response x Constructed Response x Performance Observation	SEP | DCI | CCC • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal 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.	Specific heat calculations ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
(2) Calorimetry	• I can investigate and explain heat exchange through the lens of energy conservation. • I can use data to identify a substance by the amount of heat it has exchanged.	Selected Response x Constructed Response x Performance Observation	SEP | DCI | CCC • 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. • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.	Calorimetry calculations Calorimetry lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
(3) Mechanical Equivalent of	• I can explain the relationship between mechanical and heat energy.		SEP | DCI | CCC	The mechanical equivalent of heat lab

Heat	• I can solve problems involving the conversion of energy to different forms	Selected Response x Constructed Response x Performance Observation	• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
(4) Thermal Expansion	• I can explain why matter changes physical dimension due to a change in temperature. • I can quantify the change in physical dimension.	Selected Response x Constructed Response x Performance Observation	**SEP** **DCI** **CCC** • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	Thermal activity-Change in dimesion ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

UNIT 9: Electrostatics

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*</td><td>SEP</td><td>Obtaining, Evaluating, and Communicating Information
Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td rowspan="8">Electrostatics
Charge
Conductor
Insulator
Charging by Contact
Induced
Ground
Charging by Induction
Polarization
Elementary Charge
Coulomb
Coulomb’s Law
Electric Field Strength
Lines of force
Test Charge
Point Charge
Electric Potential
Electric Potential difference
Voltage
Electric Potential Energy</td></tr>
<tr><td>DCI</td><td>PS2.B: Types of Interactions
Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.</td></tr>
<tr><td>CCC</td><td>Structure and Function
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.</td></tr>
<tr><td rowspan="3">HS-PS2-4 Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
Use mathematical representations of phenomena to describe explanations.</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>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.</td></tr>
<tr><td rowspan="2">HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.</td><td>SEP</td><td>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.</td></tr>
<tr><td>DCI</td><td>PS1.A: Structure and Properties of Matter
PS1.A: Structure and Properties of Matter
The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
PS2.B: Types of Interactions</td></tr>
</table>

		• Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (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.	

UNIT 9 Electrostatics

Unit Narrative: The production and distribution of electricity is indispensable for modern life. Here we begin our study of electricity beginning with the charges of matter and their static effects.

Unit Essential Questions:
- What is the charged nature of particles?
- How do charged particles behave in proximity with one another?
- What is Coulomb's law?
- What is the relationship between an electric field and the force acting on a charged body?
- What is voltage?
- How are gravitational and electric potential similar? Different?

Learning Sequence	Objective(s): The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Electrical properties of matter	• I can identify two distinct forms of charge, and their sources. • I can contrast conductors and insulators. • I can explain charge transfer.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.	Quiz on electrostatics ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
(2) Coulomb's Law	• I can construct a model to describe that pairs of charges exert repulsive or attractive forces on each other. • I can calculate the force between two given charges separated by a given distance using Coulomb's Law. • I can use the inverse square law to predict how force changes with separation.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Use mathematical representations of phenomena to describe explanations. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • 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. •	Model-Attractive and Repulsive forces ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

(3) Electric fields	• I can associate a field with an action-at-a-distance force. • I can explain that an electric field can exert a force on a charge. • I can calculate the force on a charge in an E-field	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material 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. • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.	CER-Electric field and force ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
(4) Electric Potential	• I can relate the gravitational potential energy to electric potential energy. • I can associate voltage with the presence of an electric field.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). • 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. • 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.	CER-Gravitational potential vs. Electric potential ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

<table>
<tr><th colspan="4">UNIT 10: Electric Circuits</th></tr>
<tr><th colspan="4">UNWRAPPED STANDARDS</th></tr>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">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.</td><td>SEP</td><td>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.</td><td rowspan="3">• Circuit
• Schematic symbol
• Resistor
• Current
• Resistance
• Amp
• Ohm
• Series
• Parallel</td></tr>
<tr><td>DCI</td><td>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. (HS-PS2-4)
• 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.
PS3.A: Definitions of Energy
• “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary)</td></tr>
<tr><td>CCC</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
</table>

UNIT 10 Electric Circuits

Unit Narrative: Charges are now allowed to move through wires and have practical applications.

Unit Essential Questions:

- What is an electric current?
- How are electric currents measured?
- What is the relationship between current, resistance and voltage?
- What are the different types of circuits? How do they compare?
- How do you map and construct a circuit?
- How do resistors convert energy?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Simple Circuits	• I can define electric current • I can define resistance • I can model an electric circuit using schematic symbols. • I can experimentally relate current, resistance, and voltage. • I can calculate the rate at which a resistance transfers energy.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • 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. • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)	The electrical equivalent of heat Model-Electric Circuit ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
(2) Complex circuits	• I can solve series circuits • I can solve parallel circuits • I can differentiate between series and parallel arrangements • I can experimentally construct series and parallel circuits, and perform measurements of current and voltage.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • 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. • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)	Laboratory-Circuit building ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

UNIT 11: Magnetism

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
● Use mathematical representations of phenomena to describe explanations.</td><td rowspan="7">● Pole
● Dipole
● Monopole
● Electromagnetic induction
● Flux</td></tr>
<tr><td>DCI</td><td>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.</td></tr>
<tr><td>CCC</td><td>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.</td></tr>
<tr><td rowspan="3">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.</td><td>SEP</td><td>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.</td></tr>
<tr><td>DCI</td><td>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. (HS-PS2-4)
● 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.
PS3.A: Definitions of Energy
● "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary)</td></tr>
<tr><td>CCC</td><td>Cause and Effect
● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*</td><td>SEP</td><td>Obtaining, Evaluating, and Communicating Information
● Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td></tr>
</table>

	DCI	**PS2.B: Types of Interactions** ● Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	
	CCC	**Structure and Function** ● Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.	

UNIT 11 Magnetism

Unit Narrative: Flowing charges create magnetic fields. Magnetic fields exert forces on moving charges.

Unit Essential Questions:

- What are the properties of magnets?
- What are the similarities and differences between magnetic forces and electric forces?
- How do magnetic fields impact a current-carrying wire?
- What is a magnetic flux?
- How can a magnetic flux create induced current?

Learning Sequence	Objective(s): The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Magnetic fields	• I can identify that magnets have poles, and magnets exert attractive and repulsive forces on other magnets. • I can model the similarities and differences between magnetic and electric forces. • I can identify the magnetic force as an action-at-a-distance force, so there is a magnetic field. • I can model the 3-d nature of magnetism.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** / **DCI** / **CCC** • 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.	Model-Electric vs magnetic forces Model-3D nature of magnetism ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
(2) Forces due to magnetic fields	• I can calculate the force on a moving charge in a magnetic field, magnitude and direction. • I can calculate the force on a current-carrying wire in a magnetic field, magnitude and direction.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** / **DCI** / **CCC** • 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.	Calculations-Magnetic fields ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
(3) Electromagnetic Induction	• I can model a magnetic flux with a flow of magnetic lines of force through an area. • I can calculate the induced voltage due to a change in magnetic flux. • I can determine the direction of the induced current. • I can calculate the motional voltage on a	[ ] Selected Response [x] Constructed Response	**SEP** / **DCI** / **CCC** • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary) • Attraction and repulsion between electric charges at the atomic scale explain the	CER-induced current flow

	wire moving in a magnetic field.	x Performance Observation	structure, properties, and transformations of matter, as well as the contact forces between material objects.	ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

UNIT 12: Waves

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</td><td>SEP</td><td>Using Mathematics and Computational Thinking
● Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.</td><td rowspan="6">● Pulse
● Periodic wave
● Medium
● Crest
● Trough
● Equilibrium line
● Wavelength
● Interference
● Superposition
● Interface
● Incident ray
● Reflected ray
● Refracted ray
● Normal line
● Angle of incidence
● Angle of reflection
● Angle of refraction
● Index of refraction
● Total internal reflection
● Critical angle
● Reflection
● Refraction
● Dispersion
● Convex
● Concave
● Converging
● Diverging
● Real focus
● Virtual focus
● Focal length
● Radius of curvature
● Real image
● Virtual image
● Magnification
● Aberration
● Diffraction</td></tr>
<tr><td>DCI</td><td>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 pass</td></tr>
<tr><td>CCC</td><td>Cause and Effect
● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td rowspan="3">HS-PS4-3 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.</td><td>SEP</td><td>Engaging in Argument from Evidence
● Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</td></tr>
<tr><td>DCI</td><td>PS4.A: Wave Properties
● [From the 3–5 grade band endpoints] 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.)
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.</td></tr>
<tr><td>CCC</td><td>Systems and System Models
● Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.</td></tr>
</table>

UNIT 12 Waves

Unit Narrative: Waves transfer energy without transfer of matter.

Unit Essential Questions:

- What are the parts and properties of periodic waves?
- What are the different types of waves?
- What is wave interference?
- What is the difference between reflection and refraction?
- How are refracted light rays predictable?
- What is the nature of light?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) Wave motion	• I can model a wave with a disturbance in a medium. • I can name parts and properties of periodic waves. • I can explain the relationship between wavelength, frequency and the speed of a wave. • I can explain the relationship between the period and frequency of a wave • I can identify a transverse and longitudinal wave and state examples of each. • I can model and explain wave interference by superposition.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | • 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 pass • [From the 3–5 grade band endpoints] 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.)	Model-Wave and Wave disturbance ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
(2) Sound	• I can explain how wave frequency impacts pitch or tone • I can explain the relationship between wave amplitude and loudness. • I can experimentally determine the speed of sound	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	**SEP** | **DCI** | **CCC** • 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 pass • 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.	Speed of sound lab ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
(3) Light	• I can associate light as part of the electromagnetic spectrum • I can draw a ray diagram	[ ] Selected Response	**SEP** | **DCI** | **CCC** • [From the 3–5 grade band endpoints] Waves	Calculations-Speed of Light Activity-Refraction

	• I can predict of the path of a reflecting ray • I can calculate the speed of light in a given medium • I can use Snell's Law to predict the path of a refracting ray • I can determine whether a ray will reflect or refract at an interface • I can state practical applications of total internal reflection • I can recognize that index of refraction is wavelength independent	x Constructed Response x Performance Observation	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.) • 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.	 ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
(4) Geometric Optics	• I can understand that light can be focused and create images by reflection and refraction • I can use ray tracing to locate images and determine their properties • I can use analytical methods to locate images and determine their properties • I can use experimental methods to locate images and determine their properties	Selected Response x Constructed Response x Performance Observation	**SEP** | **DCI** | **CCC** • [From the 3–5 grade band endpoints] 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.)	Intro to lenses lab Lens quiz ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
(5) Physical Optics	• I can define diffraction • I can explain Young's Experiment by means of wave interference • I can model inferences about nature of light from interference experiments	Selected Response x Constructed Response x Performance Observation	**SEP** | **DCI** | **CCC** • [From the 3–5 grade band endpoints] 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.)	Model-Nature of Light ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

UNIT 13: The Particle Nature of Light

UNWRAPPED STANDARDS

<table>
<tr><th>Standard</th><th colspan="2">Dimensions of the NGSS Standard</th><th>Concepts and Disciplinary-Specific Vocabulary</th></tr>
<tr><td rowspan="3">HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.</td><td>SEP</td><td>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.</td><td rowspan="6">● Quantum
● Photon
● Work function
● KE max
● Photoelectron
● Intensity
● Threshold frequency
● Nucleus
● Energy level
● Ionization
● Absorption
● Emission
● Spectral line
● Bohr Model of the atom</td></tr>
<tr><td>DCI</td><td>PS4.B: Electromagnetic Radiation
● 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.</td></tr>
<tr><td>CCC</td><td>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.</td></tr>
<tr><td rowspan="3">HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*</td><td>SEP</td><td>Obtaining, Evaluating, and Communicating Information
● 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).</td></tr>
<tr><td>DCI</td><td>PS3.D: Energy in Chemical Processes
● Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (secondary)
PS4.A: Wave Properties
● 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.
PS4.B: Electromagnetic Radiation
● Photoelectric materials emit electrons when they absorb light of a high-enough frequency.
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.</td></tr>
<tr><td>CCC</td><td>Cause and Effect
● Systems can be designed to cause a desired effect.</td></tr>
</table>

UNIT 13 The Particle Model of Light

Unit Narrative: A wave model of light can not explain all that light can do.

Unit Essential Questions:
- What are situations in which the wave model of light is insufficient?
- How does the wave particle model of light explain the photoelectric effect?

Learning Sequence	**Objective(s):** The students will be able to:	Summative Assessment Strategy	Priority NGSS Dimensions	Common Learning Experiences
(1) The photoelectric effect	• I can explain why a wave model of light fails to predict how light interacts with matter. • I can solve problems involving work function, maximum kinetic energy and frequency. • I can analyze the relationships between the above quantities on a graph.	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. • 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).	CER-Wave model of Light ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
(2) Atomic models	• I can explain the limitations of the Rutherford model of the atom and why it needed to be updated • I can state the assumptions of the Bohr model of the hydrogen atom • I can predict the wavelength of an emitted or absorbed photon during an electron transition	[ ] Selected Response [x] Constructed Response [x] Performance [ ] Observation	SEP / DCI / CCC • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.	CER-Limitations of the Rutherford Model ELA/Math Connection: CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.