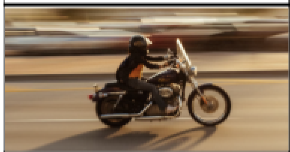
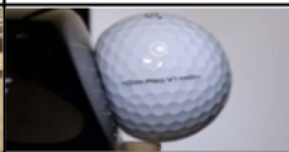
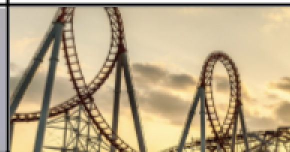
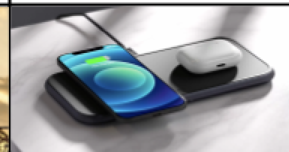
West Windsor-Plainsboro Regional School District
Course Title: Physics
Grade: 10-12

The Mission of the West Windsor-Plainsboro Science Department

Our mission is to cultivate science learners who have the foundational knowledge to make ethical, scientifically literate decisions and the ability to apply scientific practices in order to contribute to the needs of society and a changing world.

- **Vision**
  We envision a K-12 science experience that supports and challenges every student in their science learning journey. We will:
  - *Capitalize on diversity by reaching and exciting students at all levels and interests by differentiating learning within classrooms and by offering a robust program of studies.*
  - *Emphasize authentic science and engineering practices and leverage the interdisciplinary nature of science with arts, technology, math, reading, and writing.*
  - *Integrate scientific knowledge and 21st century competencies to prepare students to make informed decisions and take action to address real world problems.*
  - *Cultivate an inclusive and diverse community where all learners are welcomed, valued, respected, and celebrated.*

Curriculum Storyboard

Physics Curriculum	Essential Question(s):	How can interactions between objects and systems of objects be explained? What are some of the mechanisms used to describe the interactions of submicroscopic particles and how they explain how technology works?		
Unit 0: Motion: Defining what we observe around us in the world.	**Unit 1:** Forces: How interactions affect the motion of objects.	**Unit 2:** Energy and Momentum: Looking at interactions through a different lens.	**Unit 3:** Electricity and Magnetism: Interactions at a submicroscopic level.	**Unit 4:** Waves: Application of interactions at a technological level.
				
Focus of the story	**Focus of the story**	**Focus of the story**	**Focus of the story**	**Focus of the story**
Motion is observed everyday in life, but how can we come to an agreement on how it can be defined? Students will learn how to describe and measure the motion of objects within a defined frame of reference. They will investigate the many different ways in which objects can move while practicing important science skills. For example: modeling, question formation, experimental design, and analysis of data.	What causes motion in the first place? Now that motion has been defined, students will investigate the interactions that are the cause of an object's motion. Students will experiment and analyze data to determine the relationship between forces and motion. They will then study the mechanisms behind specific forces such as friction and gravity.	Are external forces the only way to describe motion? What happens inside a system of objects? Students will explore how interactions affect energy and momentum of objects within a system. They will apply key conservation concepts to real world phenomena like rollercoasters and collisions in order to model transformations and transfers of energy and momentum.	Are the interactions we see the only ones that can be explained? What interactions occur at the smallest scales? Students will investigate the electric and magnetic behavior of materials. They will apply concepts previously learned to explore how charges interact with electric and magnetic fields. The concepts will be applied to relevant technology such as wireless charging devices.	How does technology use complex interactions to function? How is information shared at great distances? Students investigate waves and their use in modern technology. Students will study how different types of waves interact and transmit energy as well as information. The ideas students explore in this unit are fundamental to understanding how communication technology works and develops in our modern day.
Learning Targets	**Learning Targets**	**Learning Targets**	**Learning Targets**	**Learning Targets**
I can design and conduct experiments to observe and describe real world motion. I can analyze and interpret data from an experiment and make a conclusive statement regarding what the data represents. I can model real world motion using measurements, equations, diagrams and graphs.	I can model the cause-effect relationship between forces and motion using diagrams and equations. I can use vector algebra to model multiple forces acting on an object or system of objects. I can model the interactions between objects in contact as well as objects at a distance using diagrams and equations.	I can model the conservation of energy or momentum in a system using diagrams and equations. I can define a system of interacting objects that is advantageous for solving a problem. I can distinguish between a system in which quantities are conserved and a system in which quantities aren't.	I can use models to describe and predict the effects of electrostatic forces between distant objects. I can model how the field created by charged particles affect the space around them. I can explain how electricity and magnetism are related and give specific examples for how moving charges and magnets interact.	I can describe the different types of waves, their properties and how they transmit energy and information. I can recognize when to use the wave model or particle model to describe electromagnetic radiation. I can identify the advantages and disadvantages of different transmission and storage technologies.

Unit 0: Kinematics	
Content Area: Science	
Course & Grade Level: Physics, 10-12	
Summary and Rationale	
In this unit students explore the patterns and relationships of fundamental kinematics, concentrating on developing understanding of speed, velocity and acceleration. They will also begin to develop a baseline understanding of vector measurements. Examples of Phenomena	
Recommended Pacing	
15 days	
New Jersey Student Learning Standards for Science (NGSS)	
Standard: NGSS	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. (Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.)
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Standard: English Language Arts/Literacy	
CPI #	**Cumulative Progress Indicator (CPI)**
NJSLSA.R3	Analyze how and why individuals, events, and ideas develop and interact over the course of a text.
NJSLSA.R4	Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.
NJSLSA.R7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
NJSLSA.R10	Read and comprehend complex literary and informational texts independently and proficiently with scaffolding as needed.
RST.11-12.1	Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.
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.
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.
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.
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.
RST.11-12.10	By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

NJSLSA.W1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
NJSLSA.W6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.CI.1	Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12 prof.CR3a).
9.4.12.CT.2	Explain the potential benefits of collaborating to enhance critical thinking and problem solving (e.g., 1.3E.12profCR3.a).
9.4.12.IML.7	Develop an argument to support a claim regarding a current workplace or societal/ethical issue such as climate change (e.g., NJSLSA.W1, 7.1.AL.PRSNT.4).
9.4.12.TL.1:	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).
9.4.12.TL.2	Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.
New Jersey Student Learning Standards for Computer Science and Design Thinking	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.2.DA.3	Identify and describe patterns in data visualizations.
8.1.2.DA.4	Make predictions based on data using charts or graphs.
8.1.5.DA.1	Collect, organize, and display data in order to highlight relationships or support a claim.
8.1.5.DA.5	Propose cause and effect relationships, predict outcomes, or communicate ideas using data.
8.1.12.DA.5	Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6	Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.2.5.ED.2	Collaborate with peers to collect information, brainstorm to solve a problem, and evaluate all possible solutions to provide the best results with supporting sketches or models.
Interdisciplinary Standards (Math and Social Studies)	
Standards: Mathematics	
CPI #	**Cumulative Progress Indicator (CPI)**
N-Q	**Reason quantitatively and use units to solve problems.** 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. 2. Define appropriate quantities for the purpose of descriptive modeling. 3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
A-CED	**Create equations that describe numbers or relationships** 1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. 2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.
F-IF	**Analyze functions using different representations** 7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. 9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

Standards: Social Studies	
CPI #	**Cumulative Progress Indicator (CPI)**
Standard 6.1 U.S. History	America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History	Global Studies: All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century

Instructional Focus

Unit Enduring Understandings

- A reference frame consists of an object of reference, a point of reference on that object, a coordinate system whose origin is at the point of reference, and a clock.
- Displacement is a vector drawn from the initial position of an object to its final position. The x-component of the displacement is the change in position of the object along the x-axis.
- Distance (a scalar quantity) is the magnitude of a linear displacement and is always positive.
- Distance in 2-dimensions is a measurement of path length.
- Velocity (a vector quantity) is the displacement of an object during a time interval divided by that time interval. The velocity is *instantaneous* if the time interval is very small and *average* if the time interval is longer. Can be defined as a rate of change in position.
- Speed (a scalar quantity) is the magnitude of velocity for linear motion, but in general is distance divided by time.
- Acceleration (a vector quantity) is the change in an object's velocity during a time interval divided by the time interval. The acceleration is *instantaneous* if the time interval is very small and *average* if the time interval is longer.
- Motion with constant velocity or constant acceleration can be represented with words, a sketch, a motion diagram, kinematics graphs, and mathematically.

Unit Essential Questions

- How can we represent an object's motion?
- How do we use mathematical equations to represent physics concepts?
- How do we define a problem to be solved (including establishing boundary conditions for that problem)?
- How many different ways can an object move?
- What does it mean for a rate of change to change?

Objectives

Students will know:

- Motion measurements are relative to a given frame of reference.
- Difference between position, distance, displacement.
- Difference between speed and velocity.
- Difference between motion and change in motion.
- How to interpret velocity and acceleration units.
- How to interpret the kinematic equations.

Students will be able to:

- Students will 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. Students organize data that represent the net force on a macroscopic object, its mass (which is held constant), and its acceleration (e.g., via tables, graphs, charts, vector drawings).

- Students use tools, technologies, and/or models to analyze the data and identify relationships within the datasets.
- Describe motion which includes combinations of velocities and accelerations in various directions within a frame of reference ('+'/'-') *(limited to linear, 1-dimensional motion)*
- Interpret motion graphs
- Apply kinematics equations to describe real life phenomena

Sample Performance Tasks - Specific for Unit 0:

- Students will be able to conduct graphical and mathematical analysis through comparison of kinematics and dynamics-related physical quantities (Newton's Second Law) to represent causality (HS-PS2-1, CC2).
- Students will be able to select and evaluate the structure and function of possible solutions to a real traffic-related engineering design problem using mathematical representations (HS-ETS1-3, CC6).

Evidence of Learning

☑ **Formative Assessment**

- Progress and understanding will be assessed through student-presented ideas and class discussion.
- Students will self assess their understanding by solving problems and checking their solutions with classmates and posted solutions.
- Students will take a short quiz at the beginning or end of a class period to assess their understanding of concepts through their ability to solve problems similar to the problems in the relevant lessons.
- Students will self assess their understanding by designing and conducting an experiment, collecting data, and observing the outcome.
- Students will identify a testable scientific question or problem, make a claim, and predict the results of an experiment.
- Students will support a claim with evidence from experimental data.

☑ **Summative Assessment**

- Students will demonstrate their understanding at the end of the unit to assess their ability to solve problems and apply concepts similar to the problems and concepts within this unit and previous units where applicable.
- Students will show evidence of learning through well thought out lab reports creating appropriate diagrams to represent physical situations as well as determining relationships by creating graphs that show a functional relationship between two variables.
- Students will communicate learned concepts and the application of those concepts through the creation and/or presentation of research and evidence through the lens of relevant phenomena; including the appropriate citation and evaluation of sources.

☑ **Alternative Assessment**

- Students may provide graphical, diagrammatic, anecdotal or mathematical evidence of learning. For example: students use a graph to address the learning expectation in place of mathematically solving a problem.
- Students will be provided choice within the structure of a required assessment. For example: student are assigned a choice of project topics, phenomena and/or modalities

☑ **Benchmark**

- Students use tools, technologies, and/or models to collect and represent data as empirical evidence to distinguish between the variable relationships linking position, time, velocity, and acceleration.
- Students use and analyze data as evidence to describe that the relationship between the observed quantities is accurately modeled across the range of data by the use of kinematic equations.

Assessment Statement for Science Curriculum

The assessment plan includes teacher-designed formative and summative assessments, including common assessments, self-assessments, and performance tasks aligned with the NJSLS-S and the NJSLS-S

for Climate Change. During each common, formative, and summative assessment, teachers will provide alternative assessment opportunities that adhere to 504 and IEP requirements. Alternative assessments are individualized for the needs of all students. Accommodations
Resources
Core Text: SAVAS - Experience Physics ISBN-13 978-1-4183-3396-6 **Suggested Resources:** https://www.google.com/url?q=https://pubs.aip.org/physicstoday/article/76/3/22/2868068/Community-heightens-attention-to-accessibility-for&sa=D&source=docs&ust=1690552232692069&usg=AOvVaw3P6vi8F3fMXA_wPFhQJhFq http://www.nap.edu/catalog.php?record_id=13165 http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS%20PS2%20Evidence%20Statements%20June%202015%20asterisks.pdf http://www.nextgenscience.org https://www.aapt.org/K12/upload/Physics-in-the-NGSS.pdf https://docs.google.com/a/wwprsd.org/spreadsheets/d/16bw9s5xIOztwW3REnCrR33dytzFZSOKxhRVWXg4pkNg/edit?usp=sharing http://phet.colorado.edu http://physicsclassroom.com http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html http://ecommerce-prod.mheducation.com.s3.amazonaws.com/unitas/school/explore/ngss/correlations/ngss_correlation_physics_dci.pdf https://climatescienceteaching.org/ https://docs.google.com/document/d/1DLUvy9OltSo2574aDXDVaajL_oNHQ2iDWsHVt8IeTVQ/edit?usp=sharing CASEL Framework for SEL: https://casel.org/wp-content/uploads/2020/12/CASEL-SEL-Framework-11.2020.pdf

Unit 1: Dynamics	
Content Area: Science	
Course & Grade Level: Physics, 10-12	
Summary and Rationale	
In this unit students will build on their understanding of motion and acceleration in order to correlate those patterns with Newton's Second Law and how it applies in specific situations such as surfaces with friction and the Universal Law of Gravitation. Examples of Phenomena	
Recommended Pacing	
25 days	
New Jersey Student Learning Standards for Science	
Standard: NGSS	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. (Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.)
HS-PS2-4	Use the mathematical representation of Newton's Law of Gravitation to describe and predict gravitational forces between objects. (Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational fields.)
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Standards: English Language Arts/Literacy	
CPI #	**Cumulative Progress Indicator (CPI)**
NJSLSA.R3	Analyze how and why individuals, events, and ideas develop and interact over the course of a text.
NJSLSA.R4	Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.
NJSLSA.R7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
NJSLSA.R10	Read and comprehend complex literary and informational texts independently and proficiently with scaffolding as needed.
RST.11-12.1	Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.
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.
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.
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.
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.

RST.11-12.10	By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
NJSLSA.W1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
NJSLSA.W6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3). (Students will need to engage in relationship management and goal-setting practices as part of these collaborations, which aligns with the CASEL framework.)
9.4.12.TL.2	Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.
9.4.12.IML.3	Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions (e.g., S-ID.B.6a., 8.1.12.DA.5, 7.1.IH.IPRET.8)
New Jersey Student Learning Standards for Computer Science and Design Thinking	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.2.DA.3	Identify and describe patterns in data visualizations.
8.1.2.DA.4	Make predictions based on data using charts or graphs.
8.1.5.DA.1	Collect, organize, and display data in order to highlight relationships or support a claim.
8.1.5.DA.5	Propose cause and effect relationships, predict outcomes, or communicate ideas using data.
8.1.12.DA.5	Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6	Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.2.5.ED.2	Collaborate with peers to collect information, brainstorm to solve a problem, and evaluate all possible solutions to provide the best results with supporting sketches or models.
Interdisciplinary Standards (Math and Social Studies)	
Standard: Math	
CPI #	**Cumulative Progress Indicator (CPI)**
N-Q	**Reason quantitatively and use units to solve problems.** 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. 2. Define appropriate quantities for the purpose of descriptive modeling. 3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
N-VM	**Represent and model with vector quantities.** 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. 3. Solve problems involving velocity and other quantities that can be represented by vectors.
A-CED	**Create equations that describe numbers or relationships** 1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. 2. Create equations in two or more variables to represent relationships between quantities;

	graph equations on coordinate axes with labels and scales. 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.
A-REI	3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. 10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).
F-IF	**Analyze functions using different representations** 7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. 9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

Standard: Social Studies

CPI #	Cumulative Progress Indicator (CPI)
Standard 6.1 U.S. History: America in the World	America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century. (This interdisciplinary focus aligns with District Goal 4, accepting learners from all backgrounds in conversations and scientific practices through a cross-curricular lens.)

Instructional Focus

Unit Enduring Understandings

- Newton's second law accurately predicts changes in the motion of macroscopic objects not moving near the speed of light.
- A system may be a single object or include two or more interacting objects. Interactions between objects within the system cannot externally influence that system.
- Some influences, while real, can be quantifiably negligible, and so can be discounted in models of a system.
- Newton's law of universal gravitation provides the mathematical model to describe and predict the effects of gravitational forces between any two objects, but is most useful for distant objects.
- Understanding transformations within a system and interactions between systems can enable predictions to be made about the behavior of a system.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Unit Essential Questions

- How do we define a system? How do we choose what object(s) to include in our system?
- How does one determine what influences to account for, or will have a negligible impact on a system?
- How can we explain interactions between systems?
- How can we use explanations of interactions to predict how a system or systems will evolve?

Objectives

Students will know:

- When the system of interest experiences a net force as a result of interactions with other objects or systems, the system of interest will experience a change of motion.
- The relationship $a = \frac{\Sigma F}{m}$ (Newton's Second Law) is written to show cause and effect, namely that a net force on an object causes the object to accelerate.

- A more massive object experiencing the same net force as a less massive object experiences a smaller acceleration.
- Within small displacements (e.g., near the surface of the Earth), the effect of gravitation on macroscopic objects is approximately constant, as evidenced by the fact that the ratio of net force to mass remains constant.
- Newton's Law of Gravitation describes the gravitational force between two objects according to their mass and the distance between them. The mathematical representation of the force the gravitational field exerts on a system is $F_G = -\frac{Gm_1m_2}{d^2}$
    - The mathematical result of this representation is always positive because mass is always positive. The negative sign is meant to represent an attraction between the two masses, not the direction that the force points in a particular reference frame.

Students will be able to:

- Clearly define the system of the interacting objects that is mathematically represented.
- Students use vector math to analyze forces and changes in linear motion. *(2-dimensional analysis is limited to examples where the forces only lie on the x and y-axes and the sum of the forces on one or both of those axes is zero. For example: a sliding object that experiences friction on the x-axis as well as normal force and weight on the y-axis.)*
- identify the type of friction acting on an object and the factors that affect the amount of friction. *(limited to examples of kinetic and static friction.)*
- Organize data into models (e.g. diagrams, tables, graphs, etc.) in order to structure analysis of observed phenomena, provide evidence of scientific claims, and support problem-solving applications.
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical, etc.) in order to: make valid and reliable scientific claims, determine an optimal design solution; and/or identify relationships within datasets. (e.g., use tables and graphs to develop Newton's 2nd Law)
- Predict the behavior of a system through the use of mathematical models (e.g., predict the gravitational force between objects).
- Use data as empirical evidence to distinguish between mathematical expressions that define physical quantities and those that represent causal relationships between quantities. (e.g. $a = \frac{\Delta v}{\Delta t}$ is the definition of acceleration while $a = \frac{\Sigma F}{m}$ is a cause-and-effect relationship.)
- Evaluate discrepancies between experimental data and theoretical predictions and discuss the possible causes. (e.g. unaccounted losses due to friction, etc.)

Sample Performance Tasks:

- Students will use patterns to develop Newton's Second Law by collection and analysis of real world data (HS-PS2-1, CC1).
- Students will use system and system models and force diagrams to make mathematical predictions and explanations of apparent weight changes in an elevator applying Newton's Second Law (HS-PS2-1, CC4).
- Students will be able to use data to determine different gravitational force constants based on scale and proportion of different planets' mass or locations far from Earth's surface (HS-PS2-4, CC3).
- Students will be able to select and evaluate the structure and function of possible solutions to a real traffic-related engineering design problem (HS-ETS1-3, CC6).

Evidence of Learning

☑ **Formative Assessment**

- Progress and understanding will be assessed through student-presented ideas and class discussion.
- Students will self assess their understanding by solving problems and checking their solutions with classmates and posted solutions.
- Students will take a short quiz at the beginning or end of a class period to assess their understanding of concepts through their ability to solve problems similar to the problems in the relevant lessons.

- Students will self assess their understanding by designing and conducting an experiment, collecting data, and observing the outcome.
- Students will identify a testable scientific question or problem, make a claim, and predict the results of an experiment.
- Students will support a claim with evidence from experimental data.

☑ **Summative Assessment**

- Students will demonstrate their understanding at the end of the unit to assess their ability to solve problems and apply concepts similar to the problems and concepts within this unit and previous units where applicable.
- Students will show evidence of learning through well thought out lab reports creating appropriate diagrams to represent physical situations as well as determining relationships by creating graphs that show a functional relationship between two variables.
- Students will communicate learned concepts and the application of those concepts through the creation and/or presentation of research and evidence through the lens of relevant phenomena; including the appropriate citation and evaluation of sources.

☑ **Alternative Assessment**

- Students may provide graphical, diagrammatic, anecdotal or mathematical evidence of learning. For example: students use a graph to address the learning expectation in place of mathematically solving a problem.
- Students will be provided choice within the structure of a required assessment. For example: student are assigned a choice of project topics, phenomena and/or modalities

☑ **Benchmark**

- Students use tools, technologies, and/or models to analyze data and identify relationships between variables including:
    - A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration
    - The result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant.
- Students will distinguish between causal and correlational relationships, analyzing and interpreting data as empirical evidence to link force, mass, and acceleration.
- Using the given mathematical representations, students identify and describe the gravitational attraction between two objects as the product of their masses divided by the separation distance squared where a negative force is understood to be attractive.
- Students evaluate their investigation, including an evaluation of:
    - The limitations of the investigation such as assumptions.
    - The ability of the data to provide the evidence required.

<u>Assessment Statement for Science Curriculum</u>

The assessment plan includes teacher-designed formative and summative assessments, including common assessments, self-assessments, and performance tasks aligned with the NJSLS-S and the NJSLS-S for Climate Change. During each common, formative, and summative assessment, teachers will provide alternative assessment opportunities that adhere to 504 and IEP requirements. Alternative assessments are individualized for the needs of all students. [Accommodations]

Resources

<u>Core Text:</u>

SAVAS - Experience Physics
ISBN-13 978-1-4183-3396-6

<u>Suggested Resources:</u>

http://www.nap.edu/catalog.php?record_id=13165

https://www.google.com/url?q=https://pubs.aip.org/physicstoday/article/76/3/22/2868068/Community-heightens-attention-to-accessibility-for&sa=D&source=docs&ust=1690552232692069&usg=AOvVaw3P6vi8F3fMXA_wPFhQJhFq
http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS%20PS2%20Evidence%20Statements%20June%202015%20asterisks.pdf
http://www.nextgenscience.org
https://www.aapt.org/K12/upload/Physics-in-the-NGSS.pdf
https://docs.google.com/a/wwprsd.org/spreadsheets/d/16bw9s5xIOztwW3REnCrR33dytzFZSOKxhRVWXg4pkNg/edit?usp=sharing
http://phet.colorado.edu
http://physicsclassroom.com
http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
http://ecommerce-prod.mheducation.com.s3.amazonaws.com/unitas/school/explore/ngss/correlations/ngss_correlation_physics_dci.pdf
https://climatescienceteaching.org/
https://docs.google.com/document/d/1DLUvy9OltSo2574aDXDVaajL_oNHQ2iDWsHVt8IeTVQ/edit?usp=sharing
CASEL Framework for SEL: https://casel.org/wp-content/uploads/2020/12/CASEL-SEL-Framework-11.2020.pdf

Unit 2: Conserved Quantities	
Content Area: Science	
Course & Grade Level: Physics, 10-12	
Summary and Rationale	
In this unit, students apply concepts previously learned as well as principles of conservation of energy and momentum to investigate relationships between and within systems. Relationships may include work, power, and the transfer and/or transformation of energy or momentum. Examples of Phenomena	
Recommended Pacing	
30 days	
New Jersey Student Learning Standards for	
Standard: NGSS	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-PS2-2	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. (Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.)
HS-PS2-3	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]
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. (Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.)
HS-PS3-2	Develop and use models to illustrate that energy can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). (Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.)
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (Students will need to exercise social awareness as part of the design process for a complex task, which aligns with the CASEL framework.)
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Standard: English Language Arts/Literacy	
CPI #	**Cumulative Progress Indicator (CPI)**
NJSLSA.R3	Analyze how and why individuals, events, and ideas develop and interact over the course of a text.
NJSLSA.R4	Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.
NJSLSA.R7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
NJSLSA.R10	Read and comprehend complex literary and informational texts independently and proficiently with scaffolding as needed.

RST.11-12.1	Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.
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.
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.
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.
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.
RST.11-12.10	By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
NJSLSA.W1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
NJSLSA.W6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).
9.4.12.TL.2	Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.
9.4.12.IML.3	Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions (e.g., S-ID.B.6a., 8.1.12.DA.5, 7.1.IH.IPRET.8)
New Jersey Student Learning Standards for Computer Science and Design Thinking	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.2.DA.3	Identify and describe patterns in data visualizations.
8.1.2.DA.4	Make predictions based on data using charts or graphs.
8.1.5.DA.1	Collect, organize, and display data in order to highlight relationships or support a claim.
8.1.5.DA.5	Propose cause and effect relationships, predict outcomes, or communicate ideas using data.
8.1.12.DA.5	Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6	Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.2.5.ED.2	Collaborate with peers to collect information, brainstorm to solve a problem, and evaluate all possible solutions to provide the best results with supporting sketches or models.
Interdisciplinary Standards (Math and Social Studies)	
Standard: Math	
CPI #	**Cumulative Progress Indicator (CPI)**
N-Q	**Reason quantitatively and use units to solve problems.** 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. 2. Define appropriate quantities for the purpose of descriptive modeling.

	3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
N-VM	**Represent and model with vector quantities.** 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. 3. Solve problems involving velocity and other quantities that can be represented by vectors.
A-CED	**Create equations that describe numbers or relationships** 1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. 2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.
A-REI	3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. 10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).
F-IF	**Analyze functions using different representations** 7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. 9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

Standard: Social Studies

CPI #	Cumulative Progress Indicator (CPI)
Standard 6.1 U.S. History: America in the World	America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century. (This interdisciplinary focus aligns with District Goal 4, accepting learners from all backgrounds in conversations and scientific practices through a cross-curricular lens.)

Instructional Focus

Unit Enduring Understandings

- Momentum is defined for a particular frame of reference; it is the product of a system's mass and velocity. In any system subject to no net force, the momentum of that system will remain constant.
- 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.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter within that system. Energy is continually transferred from one system to another, and is converted between its various possible forms.
- Work is defined as the change in energy of a system. When energy is transferred from one system to another, the work done on one system will have the opposite sign for the work done on the other.
- Energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to a combination of potential energy and macroscopic kinetic energy, not thermal energy, sound, or light.

- Conservation of energy means when no work is done on a system by its surroundings, the total energy of that system remains constant. Mathematical expressions, which quantify how the energy in a system is distributed, depend on the configuration of a system (e.g. relative positions of charged particles, compression of a spring) and the motion of that system. The concept of conservation of energy can be used to describe and predict system behavior, including limitations of a system (e.g. a pendulum released from rest cannot swing higher than its initial height).
- 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.
- In some conditions, it is advantageous to choose one conservation principle over another in conducting analysis.

Unit Essential Questions

- How do we choose what object(s) to include in our system? How does our choice change the analysis of the interaction/process?
- How can we represent the change in momentum or energy that a given system undergoes?
- Under what conditions can the conservation principles be applied?
- What are the limitations of the conservation principles given the models of interactions discussed so far? (e.g. the formulas, analysis techniques, and measuring equipment we typically use may not be able to account for air resistance, changes in thermal energy, etc; what are the implications for mathematical models in experiments?)
- What factors affect the outcome of a collision?

Objectives

Students will know:

- Interactions between objects within a system cannot externally influence the system; however they can result in a transfer of the momentum or energy of objects within the system.
- A system may experience a change in momentum or energy by interacting with another system. Any change in one system will be accounted for by an opposite change in the interacting system.
- In the absence of external influences or interactions between systems, conserved quantities (i.e. mass, momentum, energy) will remain constant.
- A frame of reference must be defined to calculate changes in energy and momentum over the course of a physical process. It can be advantageous to choose a frame of reference in which the initial or final state (momentum or energy) is zero.
- Momentum for each object in a system is defined as the product of its mass and its velocity (
- $p = mv$). The total momentum of the system is equal to the vector sum of the momenta of all objects within the system. *(limited to analysis in 1-dimension)*
- For a system's momentum to change, an external net force must be exerted onto the system over an interval of time. ($\Delta p = \Sigma F \Delta t$) For a given change in momentum, a greater net force exerted on the system would be exerted over a smaller period of time.
- Kinetic energy for each object in a system is defined as $K = \frac{1}{2}mv^2$. The total kinetic energy of the system is equal to the sum of the kinetic energies of all objects within the system.
- Potential energy can be quantified by a system's configuration or composition (i.e. two objects with mass in a system have an associated gravitational potential energy).
- The total energy of a system is equal to the sum of the kinetic and potential energies within the system at a given time. Any change in the total energy of a system is the result of work, which is determined by external interactions. ($W = Fd$, when force and displacement are collinear.)
- Collisions can be classified as two types: elastic and inelastic, where in elastic collisions kinetic energy remains constant before and after the collision. In inelastic collisions a portion of kinetic energy is transformed into other types of energy.

Students will be able to:

- Clearly define the system to be analyzed and mathematically represent the distribution of the conserved quantities among objects within the system.
- Use mathematical representations to model and describe the physical interaction between systems and determine changes in conserved quantities.
- Identify multiple methods of analysis when problem solving and choose among them a method that is advantageous.
- Visualize data relevant to conserved quantities in multiple forms such as sketches, graphs, bar charts, diagrams, etc.
- Use data from experiments to support or refute claims about conserved quantities (e.g momentum and energy)
- Evaluate discrepancies between experimental data and theoretical predictions and discuss the possible causes. (e.g energy lost to sound, heat, or light, etc.)

Sample Performance Tasks

- Students will be able to design a structure or plan for a roller coaster by applying previously learned concepts and concepts of work, power and transformation and conservation of energy (cycle and flow) within a system (HS-ETS1-2, CC5, CC6, CC7).
- Students will be able to represent conserved quantities and account for system changes by using diagrams and mathematical representations (HS-PS3-1, CC4).
- Students will be able to apply energy and momentum conservation principles and mathematical representations to real world applications and systems (HS-PS3-2, CC5).
- Students will be able to design a structure or plan in order to minimize impact during collisions, evaluating their structure by applying mathematical relationships, and considering cause and effect relationships between relevant physical quantities (HS-PS2-2, CC6, CC7).

Evidence of Learning

☑ **Formative Assessment**

- Progress and understanding will be assessed through student-presented ideas and class discussion.
- Students will self assess their understanding by solving problems and checking their solutions with classmates and posted solutions.
- Students will take a short quiz at the beginning or end of a class period to assess their understanding of concepts through their ability to solve problems similar to the problems in the relevant lessons.
- Students will self assess their understanding by designing and conducting an experiment, collecting data, and observing the outcome.
- Students will identify a testable scientific question or problem, make a claim, and predict the results of an experiment.
- Students will support a claim with evidence from experimental data.

☑ **Summative Assessment**

- Students will demonstrate their understanding at the end of the unit to assess their ability to solve problems and apply concepts similar to the problems and concepts within this unit and previous units where applicable.
- Students will show evidence of learning through well thought out lab reports creating appropriate diagrams to represent physical situations as well as determining relationships by creating graphs that show a functional relationship between two variables.
- Students will communicate learned concepts and the application of those concepts through the creation and/or presentation of research and evidence through the lens of relevant phenomena; including the appropriate citation and evaluation of sources.

☑ **Alternative Assessment**

- Students may provide graphical, diagrammatic, anecdotal or mathematical evidence of learning. For example: students use a graph to address the learning expectation in place of mathematically solving a problem.

- Students will be provided choice within the structure of a required assessment. For example: student are assigned a choice of project topics, phenomena and/or modalities

☑ **Benchmark**

- Students clearly define the system of the two interacting objects that is represented mathematically, including boundaries and initial conditions.
- Students identify and describe the components to be computationally modeled, including:
    - The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero)
    - The initial energies of the system's components including a quantification in an algebraic description to calculate the total initial energy of the system
    - The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive or flow out of the system being defined as negative.
    - The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system.
- Students indicate that the total energy of a system of two interacting objects is constant if there is no net force on the system.
- Students identify and describe the momentum of each object in the system as the product of its mass and its velocity, $p = mv$ (p and v are restricted to one-dimensional vectors), using the mathematical representations.
- Students indicate that the total momentum of a system of two interacting objects is constant if there is no net force on the system.
- Students evaluate a device or design that minimizes the force on a macroscopic object during a collision. In the design, students incorporate the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision ($F\Delta t = m\Delta v$)

Assessment Statement for Science Curriculum

The assessment plan includes teacher-designed formative and summative assessments, including common assessments, self-assessments, and performance tasks aligned with the NJSLS-S and the NJSLS-S for Climate Change. During each common, formative, and summative assessment, teachers will provide alternative assessment opportunities that adhere to 504 and IEP requirements. Alternative assessments are individualized for the needs of all students. Accommodations

Resources

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http://www.nap.edu/catalog.php?record_id=13165
https://www.google.com/url?q=https://pubs.aip.org/physicstoday/article/76/3/22/2868068/Community-heightens-attention-to-accessibility-for&sa=D&source=docs&ust=1690552232692069&usg=AOvVaw3P6vi8F3fMXA_wPFhQJhFq
http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS%20PS2%20Evidence%20Statements%20June%202015%20asterisks.pdf
http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS%20PS3%20Evidence%20Statements%20June%202015%20asterisks.pdf
http://www.nextgenscience.org
https://www.aapt.org/K12/upload/Physics-in-the-NGSS.pdf
https://docs.google.com/a/wwprsd.org/spreadsheets/d/16bw9s5xIOztwW3REnCrR33dytzFZSOKxhRVWXg4pkNg/edit?usp=sharing
http://phet.colorado.edu

http://physicsclassroom.com http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html http://ecommerce-prod.mheducation.com.s3.amazonaws.com/unitas/school/explore/ngss/correlations/ngss_correlation_physics_dci.pdf https://climatescienceteaching.org/ https://docs.google.com/document/d/1DLUvy9OltSo2574aDXDVaajL_oNHQ2iDWsHVt8IeTVQ/edit?usp=sharing CASEL Framework for SEL: https://casel.org/wp-content/uploads/2020/12/CASEL-SEL-Framework-11.2020.pdf

Unit 3: Electricity and Magnetism	
Content Area: Science	
Course & Grade Level: Physics, 10-12	
Summary and Rationale	
In this unit students apply the concepts previously learned to investigate the electric and magnetic behavior of materials and the conceptual framework of fields. Students will also explore the relationships between electric and magnetic fields. Examples of Phenomena	
Recommended Pacing	
35 days	
New Jersey Student Learning Standards for	
Standard: NGSS	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-PS2-4	Use the mathematical representation of Coulomb's Law to describe and predict the electrostatic forces between objects. (Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of electric fields.)
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.
HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]
HS-PS3-5	Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. (Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.)
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Standard: Climate Change	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on climate change and other natural systems.
HS-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and climate change have influenced human activity.
HS-ESS3-6	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity (i.e., climate change)
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Standard: English Language Arts/Literacy	
CPI #	**Cumulative Progress Indicator (CPI)**
NJSLSA.R3	Analyze how and why individuals, events, and ideas develop and interact over the course of a text.
NJSLSA.R4	Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.

NJSLSA.R7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
NJSLSA.R10	Read and comprehend complex literary and informational texts independently and proficiently with scaffolding as needed.
RST.11-12.1	Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.
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.
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.
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.
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.
RST.11-12.10	By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
NJSLSA.W1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
NJSLSA.W6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
NJSLSA.W7	Conduct short as well as more sustained research projects, utilizing an inquiry based research process, based on focused questions, demonstrating understanding of the subject under investigation.
NJSLSA.W8	Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
NJSLSA.W9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).
9.4.12.TL.2	Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.
9.4.12.IML.3	Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions (e.g., S-ID.B.6a., 8.1.12.DA.5, 7.1.IH.IPRET.8)
New Jersey Student Learning Standards for Computer Science and Design Thinking	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.2.DA.3	Identify and describe patterns in data visualizations.
8.1.2.DA.4	Make predictions based on data using charts or graphs.
8.1.5.DA.1	Collect, organize, and display data in order to highlight relationships or support a claim.
8.1.5.DA.5	Propose cause and effect relationships, predict outcomes, or communicate ideas using data.
8.1.12.DA.5	Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.

8.1.12.DA.6	Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.2.5.ED.2	Collaborate with peers to collect information, brainstorm to solve a problem, and evaluate all possible solutions to provide the best results with supporting sketches or models.
8.2.12.ETW.3	Identify a complex, global environmental or climate change issue, develop a systemic plan of investigation, and propose an innovative sustainable solution.
Interdisciplinary Standards (Math and Social Studies)	
Standard: Math	
CPI #	**Cumulative Progress Indicator (CPI)**
N-Q	**Reason quantitatively and use units to solve problems.** 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. 2. Define appropriate quantities for the purpose of descriptive modeling. 3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
N-VM	**Represent and model with vector quantities.** 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. 3. Solve problems involving velocity and other quantities that can be represented by vectors.
A-CED	**Create equations that describe numbers or relationships** 1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. 2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law $V = IR$ to highlight resistance R.
A-REI	3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. 10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).
F-IF	**Analyze functions using different representations** 7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. 9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
Standard: Social Studies	
CPI #	**Cumulative Progress Indicator (CPI)**
Standard 6.1 U.S. History: America in the World	America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies	All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century. (This interdisciplinary focus aligns with District Goal 4, accepting learners from all backgrounds in conversations and scientific practices through a cross-curricular lens.)

Instructional Focus
Unit Enduring Understandings
● Coulomb's law provides the mathematical model to describe and predict the effects of electrostatic forces between distant objects. ● Forces at a distance are modeled through a framework of fields which permeate space and can transfer energy through space. ● Electric charges or changing magnetic fields cause electric fields, while the motion of charge (i.e. a changing electric field) causes magnetic fields. ● 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. ● Certain phenomena at the macroscopic scale are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). ● Electric and magnetic fields contain energy and can transmit energy across space from one object to another. When two objects interacting through a field change relative position, the energy stored in the field is changed.
Unit Essential Questions
● What causes an electric field, or electric current? ● What factors affect the electrical current in a simple circuit? ● What causes a magnetic field? ● How do electric and magnetic fields interact? Is there a relationship between electric and magnetic fields? ● How do Earth's magnetic properties affect our lives? ● How can the relationship between E-fields and B-fields be applied in order to engineer solutions to technological challenges? ● With a push to move beyond fossil fuels, what are the benefits and limitations of alternative energy sources?
Objectives
Students will know: ● The electrostatic force between two objects has a magnitude given by $F_{E\ on\ Ion} = \frac{kq_1q_2}{d^2}$, which is the product of a constant and their individual charges divided by the separation distance squared, and independent of the mass of those objects. This force can be attractive or repulsive; the direction the force points in space is determined by the position of charges in and around the system of interest. ● Electrostatic forces on the atomic and molecular scale result in interactions with more commonly named contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale. ● Conductivity is a property defined by the ease with which a conductor transmits electric charge. Good conductors (e.g. metals) have high conductivity, while insulators (a.k.a. dielectricts) have low conductivity. ● All materials can be made to conduct electricity, even insulators, if subject to a strong enough electric field. ● The movement of charge is regulated by the materials through which they are moving (a conducting path) and the difference in the energy between two positions. This statement is summarized by Ohm's Law: $I = \Delta V/R$ ● Electromagnetic interactions are best described by fields; different representations of these fields (e.g. vector field vs. field lines) have strengths and weaknesses in what they portray, like any analogy or model. The field model in general describes that forces are exerted between objects even without being physically in contact, and also describes the manner in which the strength of these interactions vary in all of space. ● Magnetic fields exert forces on moving charges or currents. This force is perpendicular to both the velocity of the charged particles and the direction of the B-field. ● Moving charges cause magnetic fields, and a change in the magnetic field will cause an electric field (induce an electric current). **Students will be able to:**

- Correctly apply mathematical formulas and reasoning to solve for a variable (e.g. electrostatic force, magnetic force, etc).
- Define and delineate quantities being tested in a scientific experiment (e.g. measuring electrical current or voltage differences across elements; describing the motion of wires or magnets in an experiment to test the relationship between electricity and magnetism; etc).
- Design and refine an experiment that controls variables, and analyze data from such an experiment to determine causal effects (e.g. controlling for and varying the motion of wires or magnets in an experiment to test the relationship between electricity and magnetism).
- Delineate between correlational and causal effects when analyzing experimental data. (e.g, the electric force exerted between two objects is dependent on the objects' charges, a constant, and the distance between the objects.)
- Derive mathematical models of natural phenomenon from measured data (e.g. voltage, current, and resistance measurements in simple circuits).
- Measure scientific quantities accurately through the use of equipment and measuring tools (e.g. voltmeters, ammeters, etc).
- Evaluate discrepancies between experimental data and theoretical predictions and discuss the possible causes. (e.g. ideal predictions from Ohm's Law do not account for the internal resistance of a wire, etc.)

Sample Performance Tasks

- Students will use patterns from qualitative observations to discover how to create a simple circuit consisting of a battery, light bulb, and a single wire (HS-PS3-5, CC1).
- Students will develop a pattern for electrostatic interactions through a series of observational experiments and using their data as evidence (HS-PS2-4, CC1).
- Students will compare and contrast representationally the quantities associated with electrical, magnetic and gravitational fields, the behavior of objects in these fields, and look for causal explanations in these comparisons (HS-PS2-4, HS-PS3-5, CC1, CC2).
- Students will compare and contrast representationally sources of electrical energy for human use and explain the mechanism of how energy is transformed in each case (HS-PS2-5, HS-ETS1-2, CC2, CC5, CC6).
- Students will predict or engineer the behavior of ions in electric and/or magnetic fields by considering energy principles, the mechanism of such behavior change, and the defined system (HS-PS3-5, HS-ETS1-2, CC6, CC7).
- Students will be able to use concepts of electromagnetic induction to evaluate a technological solution for how alternative energy solutions function (e.g. wind, hydro, nuclear) (HS-ESS3-4).
- Students work in teams to describe and model transfer of energies within the conservation of energy theory as seen in alternative energy processes (HS-ESS3-4).

Evidence of Learning

☑ **Formative Assessment**

- Progress and understanding will be assessed through student-presented ideas and class discussion.
- Students will self assess their understanding by solving problems and checking their solutions with classmates and posted solutions.
- Students will take a short quiz at the beginning or end of a class period to assess their understanding of concepts through their ability to solve problems similar to the problems in the relevant lessons.
- Students will self assess their understanding by designing and conducting an experiment, collecting data, and observing the outcome.
- Students will identify a testable scientific question or problem, make a claim, and predict the results of an experiment.
- Students will support a claim with evidence from experimental data.

☑ **Summative Assessment**

- Students will demonstrate their understanding at the end of the unit to assess their ability to solve problems and apply concepts similar to the problems and concepts within this unit and previous units where applicable.

- Students will show evidence of learning through well thought out lab reports creating appropriate diagrams to represent physical situations as well as determining relationships by creating graphs that show a functional relationship between two variables.
- Students will communicate learned concepts and the application of those concepts through the creation and/or presentation of research and evidence through the lens of relevant phenomena; including the appropriate citation and evaluation of sources.

☑ **Alternative Assessment**

- Students may provide graphical, diagrammatic, anecdotal or mathematical evidence of learning. For example: students use a graph to address the learning expectation in place of mathematically solving a problem.
- Students will be provided choice within the structure of a required assessment. For example: student are assigned a choice of project topics, phenomena and/or modalities

☑ **Benchmark**

- Using the given mathematical representations, students identify and describe the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared, where a negative force is understood to be attractive.
- Students describe that the mathematical representation of the electric field predicts both attraction and repulsion due to the convention that electric charge can be either positive or negative
- Students use the given formulas for the electrostatic force as evidence to describe that the change in the energy of objects interacting through electric force depends on the distance between the objects.
- Students develop a model in which they identify and describe a field as a quantity that has a magnitude and direction at all points in space and which contains energy.
- Students develop and apply models to identify and describe the relevant components that affect forces and changes in energy within systems of electrostatic and magnetic objects including:
  - The nature of the interaction (electric or magnetic) between the two objects.
  - The relative magnitude and the direction of the relevant vector measurements involved in the interaction (example: force, field, and velocity).
  - The cause and effect relationships on a qualitative level between forces produced by electric or magnetic fields and the change of energy of the objects in the system.
- Students describe the idea that an electric current produces a magnetic field and that a changing magnetic field produces an electric current.
- Students predict an observable effect of a magnetic field that is uniquely related to the presence of an electric current in the circuit, and an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the circuit.
- Students design a device that converts one form of energy into another form of energy.
  - Identify the forms of energy involved and what scientific principles provide the basis for the energy conversion
  - Identify losses of energy by the design system to the surrounding environment.

Assessment Statement for Science Curriculum

The assessment plan includes teacher-designed formative and summative assessments, including common assessments, self-assessments, and performance tasks aligned with the NJSLS-S and the NJSLS-S for Climate Change. During each common, formative, and summative assessment, teachers will provide alternative assessment opportunities that adhere to 504 and IEP requirements. Alternative assessments are individualized for the needs of all students. Accommodations

Resources

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SAVAS - Experience Physics

ISBN-13 978-1-4183-3396-6

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https://www.google.com/url?q=https://pubs.aip.org/physicstoday/article/76/3/22/2868068/Community-heightens-attention-to-accessibility-for&sa=D&source=docs&ust=1690552232692069&usg=AOvVaw3P6vi8F3fMXA_wPFhQJhFq
http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS%20PS2%20Evidence%20Statements%20June%202015%20asterisks.pdf
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https://www.aapt.org/K12/upload/Physics-in-the-NGSS.pdf
https://docs.google.com/a/wwprsd.org/spreadsheets/d/16bw9s5xIOztwW3REnCrR33dytzFZSOKxhRVWXg4pkNg/edit?usp=sharing
https://www.youtube.com/watch?v=NJUTUFAWfEY
http://phet.colorado.edu
http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
http://ecommerce-prod.mheducation.com.s3.amazonaws.com/unitas/school/explore/ngss/correlations/ngss_correlation_physics_dci.pdf
https://climatescienceteaching.org/
https://docs.google.com/document/d/1DLUvy9OltSo2574aDXDVaajL_oNHQ2iDWsHVt8IeTVQ/edit?usp=sharing
Pivot Interactives - Force at a distance
CASEL Framework for SEL: https://casel.org/wp-content/uploads/2020/12/CASEL-SEL-Framework-11.2020.pdf

Unit 4: Waves	
Content Area: Science	
Course & Grade Level: Physics, 10-12	
Summary and Rationale	
In this unit students will learn that most of the energy in the Universe travels through waves. Wave mechanics is crucial to understanding the transmission and transformation of energy. Students will investigate the behavior of waves and understand that light exhibits properties of both particles and waves. [Examples of Phenomena]	
Recommended Pacing	
27 days	
New Jersey Student Learning Standards for	
Standard: NGSS	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.)
HS-PS4-2	Evaluate questions about the advantages of using a digital transmission and storage of information. (Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.)
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. (Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.)
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. (Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.)
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
Standard: Climate Change	
CPI #	**Cumulative Progress Indicator (CPI)**
HS-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on climate change and other natural systems.
New Jersey Student Learning Standards for English Language Arts Companion Standards	
Standard: English Language Arts/Literacy	
CPI #	**Cumulative Progress Indicator (CPI)**
NJSLSA.R3	Analyze how and why individuals, events, and ideas develop and interact over the course of a text.
NJSLSA.R4	Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.
NJSLSA.R7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.

NJSLSA.R10	Read and comprehend complex literary and informational texts independently and proficiently with scaffolding as needed.
RST.11-12.1	Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.
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.
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.
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.
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.
RST.11-12.10	By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
NJSLSA.W1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
NJSLSA.W6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
NJSLSA.W9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
New Jersey Student Learning Standards for Career Readiness, Life Literacies and Key Skills	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.GCA.1	Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).
New Jersey Student Learning Standards for Computer Science and Design Thinking	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.2.DA.1	Collect and present data, including climate change data, in various visual formats.
8.1.2.DA.3	Identify and describe patterns in data visualizations.
8.1.2.DA.4	Make predictions based on data using charts or graphs.
8.1.5.DA.1	Collect, organize, and display data in order to highlight relationships or support a claim.
8.1.5.DA.4	Organize and present climate change data visually to highlight relationships or support a claim.
8.1.5.DA.5	Propose cause and effect relationships, predict outcomes, or communicate ideas using data.
8.1.12.DA.5	Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6	Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.2.5.ED.2	Collaborate with peers to collect information, brainstorm to solve a problem, and evaluate all possible solutions to provide the best results with supporting sketches or models.
Interdisciplinary Standards (Math and Social Studies)	
Standard: Math	
CPI #	**Cumulative Progress Indicator (CPI)**
N-Q	**Reason quantitatively and use units to solve problems.** 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

	2. Define appropriate quantities for the purpose of descriptive modeling.
A-CED	**Create equations that describe numbers or relationships** 2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.
A-REI	3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. 10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).
F-IF	**Analyze functions using different representations** 7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
Standard: Social Studies	
CPI #	**Cumulative Progress Indicator (CPI)**
Standard 6.1 U.S. History: America in the World	America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
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Instructional Focus

Unit Enduring Understandings

- A wave is a model of energy transport. Waves can be formed by a change in energy of a system, and can transfer energy to a system. The properties of a wave (e.g. amplitude, wavelength, frequency) are dependent on the nature of the energy change in the system which caused the wave to form.
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- Similar wave types obey the superposition principle. The resulting patterns can be used as evidence for the wave model of light.
- Electromagnetic radiation (e.g. radio, microwaves, light) can be modeled as either a wave of changing electric and magnetic fields or as particles called photons.
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium.
- Waves transmit energy and information across a distance.
- Multiple technologies based on the understanding of waves and their interactions with matter are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
- The photoelectric effect is the emission of electrons when electromagnetic radiation, such as light, hits a material.

Unit Essential Questions

- How are different models of waves useful in understanding the behavior of waves?
- How can waves as a transmission of energy and information be applied in order to engineer solutions to technological challenges?
- What are the benefits of wireless communication and how will it evolve?

Objectives
Students will know: ● The product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and is defined as the speed of that wave in the medium through which it is traveling: $v = f\lambda$ ● The difference between mechanical and EM waves. ● The difference between mechanical and EM waves. ● Electromagnetic radiation exhibits properties associated with both particles and waves depending on the experiment being done. As a result, electromagnetic radiation can be conceptualized through either a particle or wave model of behavior. Each of these models have limitations and abstractions, but both are useful for describing the results of experiments and making predictions, and neither necessarily contradicts the other. ● Mathematical models describe interactions in science, and applying those models in engineering and invention can have real-world applications, such as in the case of the photoelectric effect and solar panels. **Students will be able to:** ● Predict the relative change in the wavelength of a wave when it moves from one medium to another. Students express the relative change in terms of cause (different media) and effect (different wavelengths but same frequency). ● Describe how different types of waves transmit information within technological processes. ● Describe the application of scientific models in ordinary phenomena, and assess the benefits and drawbacks of particular applications (e.g. advantages and disadvantages of digital storage or wireless transmission of information). ● Evaluate the degree to which models accurately describe natural phenomena when conducting experiments (e.g. collecting data or other evidence to determine: how models of the photoelectric effect support the particle model of electromagnetic radiation; or how interference patterns support the wave model of electromagnetic radiation; etc).
Sample Performance Tasks ● Students will be able to research at least two devices that communicate technical information and ideas and the physical principles upon which the devices depend, thus investigating interdependence of science, engineering and technology and the influence of these on society. (HS-PS4-2, HS-PS4-5, HS-ETS1-1, CC2, 4, 7). ● Students will be able to investigate and qualitatively evaluate the properties of waves such as mechanical, light and sound and evaluate the cause and effect relationships among these properties. (HS-PS4-1, CC2, CC4, CC7). ● Students will be able to qualitatively evaluate observations and experimental data regarding properties of light as evidence for a wave or particle model as a system (HS-PS4-3, CC2, CC4, CC7). ● Students will be able to research and qualitatively describe electromagnetic waves of varying wavelengths and their cause and effects on living organisms (HS-PS4-4, CC2, CC4, CC7). ● Students will be able to compare and contrast how the absorption of outgoing radiation is affected by the chemical composition in the atmosphere. (HS-PS4-1, HS-PS4-4, HS-ESS3-6)
Evidence of Learning
☑ **Formative Assessment** ● Progress and understanding will be assessed through student-presented ideas and class discussion. ● Students will self assess their understanding by solving problems and checking their solutions with classmates and posted solutions. ● Students will take a short quiz at the beginning or end of a class period to assess their understanding of concepts through their ability to solve problems similar to the problems in the relevant lessons. ● Students will self assess their understanding by designing and conducting an experiment, collecting data, and observing the outcome. ● Students will identify a testable scientific question or problem, make a claim, and predict the results of an experiment.

- Students will support a claim with evidence from experimental data.

☑ **Summative Assessment**

- Students will demonstrate their understanding at the end of the unit to assess their ability to solve problems and apply concepts similar to the problems and concepts within this unit and previous units where applicable.
- Students will show evidence of learning through well thought out lab reports creating appropriate diagrams to represent physical situations as well as determining relationships by creating graphs that show a functional relationship between two variables.
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- Students will be provided choice within the structure of a required assessment. For example: student are assigned a choice of project topics, phenomena and/or modalities

☑ **Benchmark**

- Students use tools, technologies, and/or models to analyze data and identify the mathematical relationship between frequency, wavelength, and speed of a wave.
- Students describe how information is stored and transmitted through various technologies and discuss the advantages/disadvantages of each.
- Students evaluate the evidence that supports the claim that electromagnetic radiation can be described by the wave model in some contexts and by the particle model in others.
    - Students evaluate (conceptually) the phenomenon of the photoelectric effect to determine how it supports the particle model.
    - Students evaluate (conceptually) the phenomenon of interference in a double slit experiment to determine how it supports the wave model.

Assessment Statement for Science Curriculum

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http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS%20PS4%20Evidence%20Statements%20June%202015%20asterisks.pdf
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