Physics

Curriculum/Content Area: Science	Course Length: 2 Terms
Course Title: Physics	**Date last reviewed:** September 2017
Prerequisites: None	**Board approval date:** December 5, 2017
Primary Resource:	

Desired Results

Course description and purpose: Physics is structured around the major areas of physics, which encompass core scientific principles, theories, and processes of the discipline. The course encourages students to make connections from the classroom to their daily lives. These connections should not simply be content connections, but also science practices used in the laboratory which will translate to the way students problems solve, analyze evidence, and form conclusions in their daily lives.

Physics is the study of the relationship between matter and energy and is conceptual in nature. The course is concerned with the fundamental laws and principles of the physical world and their practical applications. Topics of study are selected from the following: mechanics, wave motion, light, sound, and electricity. Course activities involve laboratory work with comprehensive reports, student presentations, regular problem solving and periodic classroom demonstrations.

Enduring Understandings:	**Essential Questions**:
1. **Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. 2. **Cause and Effect:** Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. 3. **Scale, Proportion, and Quantity:** In	1. How can Newton's Laws of Motion be used to provide evidence for the motion of an object? 2. How do net force and fields affect the motion and energy of an object? 3. How do different graphical representations affect how we describe motion? 4. How can the net force (impulse) we apply affect the energy and momentum of a system?

considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. 4. **Systems and System Models:** A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. 5. **Energy and Matter:** Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. 6. **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions. 7. **Stability and Change:** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.	5. How do work and motion affect the energy flow in out of a system? 6. How do the properties (mass, friction, charge, conductivity, elasticity) of an object impact how it behaves? 7. How do the energy, momentum, and forces of a system change over time?

Forces & Motion
Essential Questions: 1. How can Newton's Laws of Motion be used to provide evidence for the motion of an object? 2. How do net force and fields affect the motion and energy of an object? 3. How do different graphical representations affect how we describe motion? 4. How do the properties (mass, friction, charge, conductivity) of an object impact how it behaves?

Standards:

Cross-Cutting Concepts

1. **Patterns -** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
2. **Cause and Effect -** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Systems can be designed to cause a desired effect.
3. **Systems and System Models -** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)
4. **Structure and Function -** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Science and Engineering Practices

1. **Analyzing and Interpreting Data:** Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
2. **Using Mathematics and Computational Thinking:** Use mathematical representations of phenomena to describe explanations.

Disciplinary Core Ideas

1. **PS2.A: Forces and Motion**
    a. Newton's second law accurately predicts changes in the motion of macroscopic objects.
2. **PS2.B: Types of Interactions**
    a. Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
    b. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
3. **ESS1.B: Earth and the Solar System**
    a. Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

WI Standards for Literacy in All Subjects:

1. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
2. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in

diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
3. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
4. **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.

Learning Targets:

1. I can 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. (PS2.A, Analyzing Data, Cause and Effect)
2. I can use mathematical representations of Newton's Law of Gravitation to describe and predict the gravitational and electrostatic forces between objects. (PS2.B, Mathematical and Computational Thinking, Patterns)
3. I can use mathematical or computational representations to predict the motion of orbiting objects in the solar system. (ESS1.B, Mathematical Thinking, Scale Proportion Quantity)

Assessment Evidence:

Performance Assessment Options
May include, but are not limited to the following:

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

2. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.] (HS-PS2-2)

Other assessment options
May include, but are not limited to the following:

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3. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's laws of orbital motions should not deal with more than two bodies, nor involve calculus.]	

Digital Tools & Supplementary Resources: Tools and resources that can augment the learning experience for students
Simulations: Gravity and Orbits Force and Motion Basics The Moving Man Balancing Act Friction Projectile Motion Lunar Lander Maze Game Forces in 1D Gravity Force Lab Ramp Forces and Motion

Momentum
Essential Questions: 1. How can Newton's Laws of Motion be used to provide evidence for the motion of an object? 2. How do net force and fields affect the motion and energy of an object? 3. How can the net force (impulse) we apply affect the energy and momentum of a system? 4. How do the energy, momentum, and forces of a system change over time?
Standards:
Cross-Cutting Concepts 1. **Patterns** - Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. 2. **Cause and Effect -** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Systems can be designed to cause a desired effect.

3. **Systems and System Models -** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)
4. Structure and Function. Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Science and Engineering Practices

1. **Using Mathematics and Computational Thinking**: Use mathematical representations of phenomena to describe explanations.
2. **Constructing Explanations and Designing Solutions:**Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

Disciplinary Core Ideas

1. **PS2.A: Forces and Motion**
    a. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved.
    b. 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.
2. **ETS1.A: Defining and Delimiting an Engineering Problem**
    a. Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)
3. **ETS1.C: Optimizing the Design Solution**
    a. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary)

WI Standards for Literacy in All Subjects:

1. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
2. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
3. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
4. **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.

Learning Targets:	
1. I can 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. (PS2.A, Mathematics and Computational Thinking, Systems and Models) 2. I can apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. (PS2.A, Constructing Explanations and Designing Solutions, Cause and Effect)	
Assessment Evidence:	
Performance Assessment Options May include, but are not limited to the following: 1. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.] (HS-PS2-2) 2. 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-PS2-3)	**Other assessment options** May include, but are not limited to the following: •
Digital Tools & Supplementary Resources:	
Simulations: Collision Lab	

Energy
Essential Questions: 1. How do net force and fields affect the motion and energy of an object?

2. How can the net force we apply affect the energy and momentum of a system?
3. How do work and motion affect the energy flow in out of a system?
4. How do the properties (mass, friction, charge, conductivity, elasticity) of an object impact how it behaves?
5. How do the energy, momentum, and forces of a system change over time?

Standards:

Cross-Cutting Concepts

1. **Cause and Effect -** Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
2. **Systems and System Models -** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.
3. **Energy and Matter -** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Science and Engineering Practices

1. **Using Mathematics and Computational Thinking:** Create a computational model or simulation of a phenomenon, designed device, process, or system.
2. **Developing and Using Models:** Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
3. **Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
4. **Planning and Carrying Out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
5. **Developing and Using Models:** Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas:

1. **PS3.A: Definitions of Energy**
    a. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is

conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

   b. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

2. **PS3.B: Conservation of Energy and Energy Transfer**
   a. Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
   b. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
   c. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
   d. The availability of energy limits what can occur in any system.
   e. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
3. **PS3.C: Relationship Between Energy and Forces**
   a. When two objects interacting through a field change relative position, the energy stored in the field is changed.
4. **PS3.D: Energy in Chemical Processes and Everyday Life**
   a. Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

<u>WI Standards for Literacy in All Subjects:</u>

1. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
2. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
3. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
4. **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.

Learning Targets:
1. I can 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. (PS3.A, PS3.B, Mathematical and Computational Thinking, Systems and System Models) 2. I can develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). (PS3.A, Developing and Using Models, Energy and Matter) 3. I can design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (PS3.A, PS3.D, Constructing Explanations and Defining Solutions, Energy and Matter) 4. I can plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). (PS3.B, PS3.D, Planning and Carrying Out Investigations, Systems and Models) 5. I can 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. (PS3.C, Developing and Using Models, Cause and Effect)

Assessment Evidence:	
Performance Assessment Options May include, but are not limited to the following: 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.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.] (HS-PS3-1) 2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). [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	**Other assessment options** May include, but are not limited to the following: •

could include diagrams, drawings, descriptions, and computer simulations.] (HS-PS3-2) 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-PS3-3) 4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.] (HS-PS3-4) 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.] [Assessment Boundary: Assessment is limited to systems containing two objects.] (HS-PS3-5)	
Digital Tools & Supplementary Resources:	
Simulations: [Hooke's Law] [Energy Skate Park] [Mass and Spring]	

Waves
Essential Questions: 1. How do different graphical representations affect how we describe motion? 2. How do work and motion affect the energy flow in out of a system? 3. How do the properties (mass, friction, charge, conductivity, elasticity) of an object impact how it behaves?
Standards:
<u>**Cross-Cutting Concepts**</u> 1. **Cause and Effect -** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. 2. **Systems and System Models -** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 3. **Stability and Change -** Systems can be designed for greater or lesser stability. <u>**Science and Engineering Practices**</u> 1. **Using Mathematics and Computational Thinking:** Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. 2. **Asking Questions and Defining:** Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design. 3. **Engaging in Argument from Evidence:** Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. 4. **Obtaining, Evaluating, and Communicating Information:** Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. 5. **Obtaining, Evaluating, and Communicating Information:** Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). 6. **Constructing Explanations and Designing Solutions:** Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Disciplinary Core Ideas:

1. **PS4.A: Wave Properties**
    a. 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.
    b. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
    c. [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)
2. **PS4.B: Electromagnetic Radiation**
    a. Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
    b. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
    c. Photoelectric materials emit electrons when they absorb light of a high-enough frequency.
3. **PS4.C: Information Technologies and Instrumentation**
    a. Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research.They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
4. **ESS1.A: The Universe and Its Stars**
    a. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
    b. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

WI Standards for Literacy in All Subjects:

1. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
2. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging

conclusions with other sources of information.

3. **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.

Learning Targets:

1. I can use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (PS4.A, Mathematical and Computational Thinking, Cause and Effect)
2. I can evaluate questions about the advantages of using a digital transmission and storage of information. (PS4.A, Asking Questions and Defining Problems, Stability and Change)
3. I can 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. (PS4.A, PS4.B, Engaging in Argument from Evidence, Systems and Models)
4. I can evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. (PS4.B, Obtaining Evaluating Communicating Information, Cause and Effect)
5. I can 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. (PS4.A, PS4.B, PS4.C, Obtaining Evaluating Communicating Information, Cause and Effect)

Assessment Evidence:

Performance Assessment Options May include, but are not limited to the following: 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.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.] (HS-PS4-1) 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-PS4-2)	**Other assessment options** May include, but are not limited to the following: •

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.] [Assessment Boundary: Assessment does not include using quantum theory.] (HS-PS4-3) 4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.] (HS-PS4-4) 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.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.] (HS-PS4-5)	

Digital Tools & Supplementary Resources:

Simulations:
[Resonance]
[Pendulum Lab]
[Bending Light]
[Color Vision]
[Geometric Optics]
[Wave Interference]
[Waves on a String]
[Sound]

Electricity and Magnetism
Essential Questions: 1. How do net force and fields affect the motion and energy of an object? 2. How do work and motion affect the energy flow in out of a system? 3. How do the properties (mass, friction, charge, conductivity, elasticity) of an object impact how it behaves? 4. How do the energy, momentum, and forces of a system change over time?
Standards:
Cross-Cutting Concepts 1. **Patterns -** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. 2. **Cause and Effect -** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Systems can be designed to cause a desired effect. 3. **Systems and System Models -** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. 4. **Structure and Function -** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. **Science and Engineering Practices** 1. **Using Mathematics and Computational Thinking:** Use mathematical representations of phenomena to describe explanations. 2. **Planning and Carrying Out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. 3. **Obtaining, Evaluating, and Communicating Information**: Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including oral, graphical, textual and mathematical). **Disciplinary Core Ideas:** 1. **PS3.A: Definitions of Energy** a. “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. 2. **PS2.B: Types of Interactions** a. Newton’s law of universal gravitation and Coulomb’s law provide the

mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
   b. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
   c. 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.
3. **PS3.C: Relationship Between Energy and Forces**
   a. When two objects interacting through a field change relative position, the energy stored in the field is changed.
4. **PS3.D: Energy in Chemical Processes and Everyday Life**
   a. Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

WI Standards for Literacy in All Subjects:

1. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
2. **RST.11-12.** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
3. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
4. **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.

Learning Targets:

1. I can use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. (PS2.B, Mathematical and Computational Thinking, Patterns)
2. I can 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. (PS2.B, PS3.A, Planning and Carrying Out Investigations, Cause and Effect)
3. I can communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. (PS2.B, Obtaining Evaluating Communicating Information, Structure and Function)
4. I can 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. (PS3.C, Developing and Using Models, Cause and Effect)

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<tr><td colspan="2">Assessment Evidence:</td></tr>
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Performance Assessment Options
May include, but are not limited to the following:

1. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.] (HS-PS2-4)
2. 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. [Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.] (HS-PS2-5)
3. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] (HS-PS2-6)
4. 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.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

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Other assessment options
May include, but are not limited to the following:

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<tr><td colspan="2">Digital Tools & Supplementary Resources:</td></tr>
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Simulations
Charges and Fields
Balloons and Static Electricity

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[Circuit Construction Kit] [Magnet and Compass] [Generator] [Electric Field Hockey] [John Travoltage] [Ohm's Law] [Battery Voltage] [Resistance in a Wire] [Battery Resistor Circuit]