**NCHS Science Pacing Guide**

**Time Frame: August – December Physics**

**Unit 1: Motion, Force, and Interactions**

| **Science & Engineering Practices** | **Crosscutting Concepts** | **Literacy Standards** | **Mathematics Standards** |
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| [**Planning and Carrying Out Investigations**](http://www.nap.edu/openbook.php?record_id=13165&page=59)Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.* 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. (HS-PS2-5)

**Analyzing and Interpreting Data**Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (HS-PS2-1)

**Using Mathematics and Computational Thinking**Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.* Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4)

**Constructing Explanations and Designing Solutions**Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.* Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

**Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena*** Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4)
* Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4)
 | **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. (HS-PS2-4)**Cause and Effect*** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5)
* Systems can be designed to cause a desired effect. (HS-PS2-3)

**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) |

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**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS2-1)***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*. (HS-PS2-1)***WHST.11-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS2-3),(HS-PS2-5)***WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. *(HS-PS2-5)***WHST.11-12.9** Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS2-1),(HS-PS2-5)* |

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**MP.2** Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)**MP.4** Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)**HSN.Q.A.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. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),*(HS-PS2-5)***HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5)***HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),*(HS-PS2-5)***HSA.SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)**HSA.SSE.B.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1),(HS-PS2-4)**HSA.CED.A.1** Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)**HSA.CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-1),(HS-PS2-2)***HSA.CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-1),(HS-PS2-2)***HSF-IF.C.7** Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. *(HS-PS2-1)***HSS-IS.A.1** Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)* |

| **Next Generation Science Standards** | **Disciplinary Core Ideas** | **Essential Questions** | **Assessments** | **Vocabulary** | **Resources** |
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| Students who demonstrate understanding can: **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.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]**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.] [*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]**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-PS2-4** Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.[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-PS2-5** 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.[*Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*] | **PS2.A: Forces and Motion**Newton’s second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)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. (HS-PS2-2),(HS-PS2-3)**PS2.B: Types of Interactions**Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)**PS3.A: Definitions of Energy**“Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.*(secondary to HS-PS2-5)***ETS1.A: Defining and Delimiting an Engineering Problem**Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS2-3)***ETS1.C: Optimizing the Design Solution**Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary to HS-PS2-3)* | How can one explain and predict interactions between objects and within systems of objects?Why do physicists work in SI units?What is the role of uncertainty in physical measurement?What is the difference between speed and velocity?How can you determine velocity from a position-time graph?How can you determine acceleration from a velocity-time graph?How can a velocity-time graph be created from a position-time graph?How does force affect the motion of an object and how can the same magnitude of force cause a great change in motion?How do Newton’s laws explain the horizontal acceleration of a projectile?How do Newton’s laws explain the vertical acceleration of a projectile?Why is an object in uniform circular motion experiencing centripetal acceleration?Why does centrifugal force not actually exist?On what variables does the value of *g* depend? What factors do not affect it?How can a person’s weight change depending on their location?How can you find net force using vector resolution?How does the angle of inclination change an object’s normal force, friction force, and net force?Explain using an example how Newton’s third law relates to conservation of momentum in collisions. How can a bullet have the same momentum as a truck?What conditions are necessary for an object to stay in orbit around the Earth?What is the relationship between work and energy? | **Before**: **HS-PS2-1**Pretest over the Newton’s laws, velocity, acceleration, and data and graph analysisDiscussions with the students.KWL**During**: **HS-PS2-1**Collecting data for objects in motion can be very simple so this is a great unit to begin with because students get introduced to data collection and analysis while also being introduced to velocity and acceleration. * Depending on the difficulty of the lab you may want to give the lab before or after the material is lectured. Quick assessments should be used after lectures, e.g. response cards, daily assignments, think/pair/share, or quick writes.
* Conduct an experiment that collects data of an object with a constant velocity.
* Conduct an experiment that collects data of an object with a constant acceleration.
* Conduct an experiment that collects data of an object with a constant force and mass as the independent variable and acceleration as the dependent variable.

**After**: **HS-PS2-1** The final test for this standard should include concepts and calculations for velocity, acceleration, forces, and Newton’s laws. If possible, it is a good idea to add data analysis questions similar to questions found on the ACT or MME. **Before**: **HS-PS2-2**Pretest over concepts related to momentum.Discussions with the students.KWL**During**: **HS-PS2-2**Quick assessments should be used after lectures, e.g. response cards, daily assignments, think/pair/share, or quick writes. Practice problems involving impulse and change in momentum and the conservation of momentum. **After**: **HS-PS2-2**The final test for this standard should include concepts on momentum and calculations for momentum, impulse, change in momentum, and conservation of momentum. If possible, it is a good idea to add data analysis questions similar to questions found on the ACT or MME.**Before**: **HS-PS2-3**Have a class discussion to gage student interest level for different project ideas. You may want to offer multiple ideas for students to choose from if the recourses are available.**During**: **HS-PS2-3****S**tudents must complete a project that uses engineering practices to design or redesign an object that reduces the force experienced by the object during a collision. E.g. design an egg dropping apparatus, draw a diagram and explain the redesign of specific products such as football helmets or parachutes.**After**: **HS-PS2-3**Have students write a report about their project and why they used certain design features or have students answer a list of follow-up questions.**Before**: **HS-PS2-4**Pretest over concepts related to gravitational force and electrical force.Discussions with the students.KWL**During**: HS**-PS2-4**Quick assessments should be used after lectures, e.g. response cards, daily assignments, think/pair/share, or quick writes. Practice problems involving Newton’s Universal Law of Gravitation and Coulomb’s Law.**After**: **HS-PS2-4**The final test for this standard should include concepts on gravity and electrostatic forces and calculations using Coulomb’s Law and Newton’s Law of Gravitation. If possible, it is a good idea to add data analysis questions similar to questions found on the ACT or MME.**Before**: **HS-PS2-5**Discussions with the students.KWL**During**: **HS-PS2-5**Have students predict the outcome of demonstrations and analyze the results. E.g. Electric generator, electric motor.**After**: **HS-PS2-5**Have students design their own investigation that shows the relationship between electric current and magnetic force. E.g. place a compass around a current carrying wire or test what variables will increase the magnetic force of an electromagnet. | Acceleration due to gravityAccuracyAgent Apparent weight Average accelerationAverage speedAverage velocityCentripetal accelerationCentripetal forceClosed systemCoefficient of kinetic frictionCoefficient of static frictionComponentContact force Coordinate systemDependent variableDimensional analysisDisplacementDistanceDrag force EquilibrantEquilibrium External forceField force Force Free fallFree-body diagram Gravitational force Gravitational massGravityHypothesisImpulseImpulse-momentum theoremIndependent variableInertia Inertial massInstantaneousInstantaneous accelerationInstantaneous velocityInteraction pair Internal forceInverse relationshipIsolated systemKepler’s second lawKinetic frictionLaw of conservation of momentumLine of best fitLinear relationshipMagnitudeMeasurementMomentum Motion diagramNet force Newton’s first law Newton’s law of universal gravitationNewton’s second lawNewton’s third lawNormal forceOriginParticle modelPhysicsPositionPositionPosition-time graphPrecisionProjectileQuadratic relationshipResultantScalarScientific lawScientific methodScientific theorySignificant digitsStatic frictionSystemTensionTerminal velocityTime intervalTrajectoryUniform circular motionVectorVector resolution Velocity-time graphWeightlessness | Overview and suggestions for Project-Based Learning <http://www.cotf.edu/ete/teacher/teacherout.html> Physics videos and lessons<http://www.fearofphysics.com/>Science articles and videos on current science topics<http://science.howstuffworks.com/> Great for 2 dimensional motion. <http://www.physicsclassroom.com/mmedia/vectors/mzi.html>Interactive animations for multiple Science concepts. <http://whyfiles.org/interactives/>Lessons, labs, and questions for all topics in physics. <http://www.physicsclassroom.com/class>Great website that uses graphs and animations to show multiple concepts. <http://www.launc.tased.edu.au/online/sciences/PhysSci/ScPhy.html>Great engineering contest that could be a class project. <http://rubegoldberg.com/>Web-based projects created by students for other students. <http://thinkquest.org/pls/html/f?p=52300:30:1124949128675338::::P30_CATEGORY_ID:CPJ_PHYSICAL_SCIENCE>Summarizes many concepts from physics and is a collection of other resources. <http://www.studyphysics.ca/index.html>Another collection of animations and summaries of physical concepts. <http://zonalandeducation.com/mstm/physics/physics.html>Awesome website with interactive animations. <http://phet.colorado.edu/en/simulations/category/physics> |

**NCHS Science Pacing Guide**

**Time Frame: January – March Physics**

**Unit 2: Energy**

| **Science & Engineering Practices** | **Crosscutting Concepts** | **Literacy Standards** | **Mathematics Standards** |
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| **Developing and Using Models**Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.* Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5)

**Planning and Carrying Out Investigations**Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.* 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. (HS-PS3-4)

**Using Mathematics and Computational Thinking**Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.* Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)

**Constructing Explanations and Designing Solutions**Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.* 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. (HS-PS3-3)
 | **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. (HS-PS3-5)**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. (HS-PS3-4)
* 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. (HS-PS3-1)

**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. (HS-PS3-3)
* Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2)

**Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering and Technology on Society and the Natural World**Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)**Connections to Nature of Science****Scientific Knowledge Assumes an Order and Consistency in Natural Systems**Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1) | **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS3-4)***WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS3-3)*,(HS-PS3-4),*(HS-PS3-5)***WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. *(HS-PS3-4),(HS-PS3-5)***WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS3-4),(HS-PS3-5)***SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-1),(HS-PS3-2),(HS-PS3-5)* | **MP.2** Reason abstractly and quantitatively. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5)**MP.4** Model with mathematics. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),*(HS-PS3-4)*,(HS-PS3-5)**HSN.Q.A.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. (HS-PS3-1),(HS-PS3-3)**HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3)**HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-3) |

| **Next Generation Science Standards** | **Disciplinary Core Ideas** | **Essential Questions** | **Assessments** | **Vocabulary** | **Resources** |
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| Students who demonstrate understanding can: **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.] [*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-PS3-2** 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 could include diagrams, drawings, descriptions, and computer simulations.]**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-PS3-4** 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-PS3-5** 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.*] | **PS3.A: Definitions of Energy**Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1),(HS-PS3-2)At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3)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. (HS-PS3-2)**PS3.B: Conservation of Energy and Energy Transfer**Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4)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. (HS-PS3-1)The availability of energy limits what can occur in any system. (HS-PS3-1)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). (HS-PS3-4)**PS3.C: Relationship Between Energy and Forces**When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5)**PS3.D: Energy in Chemical Processes**Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3),(HS-PS3-4)**ETS1.A: Defining and Delimiting an Engineering Problem**Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS3-3)* | What is the relationship between work, power and energy?What are different ways in which mechanical energy can be transferred and stored?How can the conservation of energy be maximized.What is the relationship between momentum and kinetic energy?When is momentum conserved and not kinetic energy?How does wave speed relate to wavelength and period?What is the relationship between the amplitude of a wave and the rate of energy transfer?What is the relationship between the amplitude of a wave and the rate of energy transfer?What is the difference between constructive and destructive interference?  | **Before**: **HS-PS3-1**Pretest over energy transformation and conservation.**During**: **HS-PS3-1**Complete a lab that will show the conservation of mechanical energy. E.g. inelastic collisions lab or a rollercoaster lab**After**: **HS-PS3-1**Have students create their own equations for energy conservation based on the results from the lab. Have students use their energy equation to calculate changes in energy. **Before**: **HS-PS3-2**Have students brainstorm a list of different types of energy.Make a rubric for the diagram, drawing, or animation that will model the energy chosen by the students**During**: **HS-PS3-2**Depending on your resources, have students complete a project described in the standard to the left.**After**: **HS-PS3-2**Have students share their projects.**Before**: **HS-PS3-3**Have students brainstorm project ideas that will demonstrate transforming of energy (Many ideas are listed in the standard).Have students choose an appropriate project.**During**: **HS-PS3-3**A big project like this should have check points for the students such as a materials list, a blue print, updates during construction, and the final project.**After**: **HS-PS3-3**Projects may be shared.If data can be collected from projects then students may use them to test variables and produce graphs.**Before**: **HS-PS3-4**Have students brainstorm ideas for conducting an experiment similar to the one described in the standard.**During**: **HS-PS3-4**The lab completed by students will depend on available materials.Have advanced students design their own data tables and graphs.**After**: **HS-PS3-4**Grade lab reports, share data and graphs.**Before**: **HS-PS3-5**Brainstorm project ideas (diagram, drawing, animation, etc.), that will represent one of the different forms of energy interaction listed in the standard.**During**: **HS-PS3-5**Check points should be set for the project.**After**: **HS-PS3-5**Share the projects with presentations. | AmplitudeAmplitudeAntinodeAntinodeCrestEfficiencyEffort forceElastic collisionElastic potential energyEnergyFrequencyFrequencyGravitational potential energyIdeal mechanical advantageInelastic collisionInterferenceInterferenceJouleKinetic energyKinetic energyLaw of conservation of energyLongitudinal waveLongitudinal waveMachineMechanical advantageMechanical energyNodeNodePeriodPeriodPeriodic motionPeriodic motionPowerReference levelRefractionRefractionResistance forceRotational kinetic energyThermal energyTransverse waveTransverse waveTroughTroughWattWaveWaveWavelength Machine WorkWork-energy theorem | Webquest with activities that relates the inventions of Leonardo Divinci to the simple machines.<http://legacy.mos.org/sln/Leonardo/InventorsWorkshop.html> Relates Energy conservation to rollercoaster design. <http://www.learner.org/interactives/parkphysics/coaster.html>Overview and suggestions for Project-Based Learning <http://www.cotf.edu/ete/teacher/teacherout.html> Physics videos and lessons<http://www.fearofphysics.com/>Science articles and videos on current science topics<http://science.howstuffworks.com/> Interactive animations for multiple Science concepts. <http://whyfiles.org/interactives/>Lessons, labs, and questions for all topics in physics. <http://www.physicsclassroom.com/class>Great website that uses graphs and animations to show multiple concepts. <http://www.launc.tased.edu.au/online/sciences/PhysSci/ScPhy.html>Great engineering contest that could be a class project. <http://rubegoldberg.com/>Web-based projects created by students for other students. <http://thinkquest.org/pls/html/f?p=52300:30:1124949128675338::::P30_CATEGORY_ID:CPJ_PHYSICAL_SCIENCE>Summarizes many concepts from physics and is a collection of other resources. <http://www.studyphysics.ca/index.html>Another collection of animations and summaries of physical concepts. <http://zonalandeducation.com/mstm/physics/physics.html>Awesome website with interactive animations. <http://phet.colorado.edu/en/simulations/category/physics> |

**NCHS Science Pacing Guide**

**Time Frame: March – May Physics**

**Unit 3: Waves, Electricity and Magnetism**

| **Science & Engineering Practices** | **Crosscutting Concepts** | **Literacy Standards** | **Mathematics Standards** |
| --- | --- | --- | --- |
| **Asking Questions and Defining Problems** Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. * Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2)

**Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. * Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)

**Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science. * Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3)

**Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. * Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)
* 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). (HS-PS4-5)

**Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)  | **Cause and Effect** * Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)
* 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. (HS-PS4-4)
* Systems can be designed to cause a desired effect. (HS-PS4-5)

**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. (HS-PS4-3) **Stability and Change** Systems can be designed for greater or lesser stability. (HS-PS4-2) **Connections to Engineering, Technology, and Applications of Science****Interdependence of Science, Engineering, and Technology** Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5) **Influence of Engineering, Technology, and Science on Society and the Natural World** * Modern civilization depends on major technological systems. (HS-PS4-2),(HS-PS4-5)
* Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS4-2)
 | **RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) **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. (HS-PS4-1),(HS-PS4-4) **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. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS4-5) **WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)  | **MP.2** Reason abstractly and quantitatively. (HS-PS4-1),(HS-PS4-3) **MP.4** Model with mathematics. (HS-PS4-1) **HSA-SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1),(HS-PS4-3) **HSA-SSE.B.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1),(HS-PS4-3) **HSA.CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1),(HS-PS4-3)  |

| **Next Generation Science Standards** | **Disciplinary Core Ideas** | **Essential Questions** | **Assessments** | **Vocabulary** | **Resources** |
| --- | --- | --- | --- | --- | --- |
| Students who demonstrate understanding can: **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.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.] **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.] [Assessment Boundary: Assessment does not include using quantum theory.] **HS-PS4-4** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [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-PS4-5** 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.]  | **PS3.D: Energy in Chemical Processes** Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (secondary to HS-PS4-5) **PS4.A: Wave Properties** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1) 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. (HS-PS4-2),(HS-PS4-5) [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.) (HS-PS4-3) **PS4.B: Electromagnetic Radiation** Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) 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. (HS-PS4-4) Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5) **PS4.C: Information Technologies and Instrumentation** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)  | What factors does the amount of current produced in a magnetic field depend on?How does a cathode ray tube work?Describe the orientation of the electric field, magnetic field, and direction of travel in an electromagnetic wave.How does a capacitor work?What are four factors that affect the resistance properties of a piece of metal wire?Why do wires heat up when a current flows in them?What does an ammeter measure? What does a voltmeter measure? How would you insert each in a circuit? | **Before**: **HS-PS4-1**KWL wavesPretest**During**: **HS-PS4-1**Use equations to solve for the speed, period, frequency, and wavelength for a variety of different waves traveling through various media.**After**: **HS-PS4-1**Posttest for wave calculations.**Before**: **HS-PS4-2**Discuss advantages and disadvantages of digital transmission of information.**During**: **HS-PS4-2**Research a current issue, positive or negative, with digital information.**After**: **HS-PS4-2**Share research reports with the class. **Before**: **HS-PS4-3**KWL Pretest**During**: **HS-PS4-3**Demonstrate or show many properties of mechanical waves that are shared by electromagnetic waves (diffraction, interference, Doppler effect, etc.). Discuss characteristics of electromagnetic waves that are similar to particles.Discuss how the idea of photons brings the two theories together.**After**: **HS-PS4-3**Posttest**Before**: **HS-PS4-4**Brainstorm ideas for research projects related to the standard.Create a rubric for how students should evaluate the published material.Evaluate the validity of an article with the class as an example.**During**: **HS-PS4-4**Have check points for the students’ research paper.**After**: **HS-PS4-4**Share research papers with the class and have discussions.**Before**: **HS-PS4-5**Brainstorm research ideas**During**: **HS-PS4-5**Students should complete research and a report on different uses for electromagnetic waves.**After**: **HS-PS4-5**Students shouldshare their research with the class. The class should take notes or complete worksheets on the different uses of electromagnetic waves. | AmmeterAmpereAntennaAtomic mass unitAverage powerBatteryCapacitanceCapacitorCharging by conductionCharging by inductionCircuit breakerConductorCoulombCoulomb’s lawDielectricsElectric circuitElectric currentElectric fieldElectric field linesElectric potential differenceElectromagnetic inductionElectromagnetic radiationElectromagnetic spectrumElectromagnetic waveElectromotive forceElectrostaticsElementary chargeEquipotentialEquivalent resistanceFuseGround-fault interrupterGroundingInsulatorsIsotopeKilowatt-hourMass spectrometerNeutralParallel circuitParallel connectionPrimary coilReceiverResistanceResistorSeries circuitSeries connectionShort circuitStep-down transformerStep-up transformerSuperconductorVoltVoltmeter | Animations of wave types. <http://www.acs.psu.edu/drussell/demos/waves/wavemotion>.Relates different sound waves to nature. <http://www.dosits.org/>Videos and text about light. <http://www.learner.org/teacherslab/science/light/index.html> Explanations and pictures of many modern technologies that involve electromagnetic waves.<http://www.colorado.edu/physics/2000/index.pl?Type=TOC> Simple Overview and suggestions for Project-Based Learning <http://www.cotf.edu/ete/teacher/teacherout.html> Physics videos and lessons<http://www.fearofphysics.com/>Science articles and videos on current science topics<http://science.howstuffworks.com/> Interactive animations for multiple Science concepts. <http://whyfiles.org/interactives/>Lessons, labs, and questions for all topics in physics. <http://www.physicsclassroom.com/class>Great website that uses graphs and animations to show multiple concepts. <http://www.launc.tased.edu.au/online/sciences/PhysSci/ScPhy.html>Great engineering contest that could be a class project. <http://rubegoldberg.com/>Web-based projects created by students for other students. <http://thinkquest.org/pls/html/f?p=52300:30:1124949128675338::::P30_CATEGORY_ID:CPJ_PHYSICAL_SCIENCE>Summarizes many concepts from physics and is a collection of other resources. <http://www.studyphysics.ca/index.html>Another collection of animations and summaries of physical concepts. <http://zonalandeducation.com/mstm/physics/physics.html>Awesome website with interactive animations. <http://phet.colorado.edu/en/simulations/category/physics> |