[Earth and Space Systems](#ESS)

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| **Earth and Space Systems** |
| **Topic** | **High School NGSS (2015) Performance Expectations (PE)** | **Associated PhET Simulation** | **Portions of PE Addressed by Simulation (Note: Most simulations will apply to only a part of a lesson designed around an NGSS PE)** |
| **Space Systems** | [HS-ESS1-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=167) | Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy in the form of radiation. | [Isotopes and Atomic Mass](http://phet.colorado.edu/en/simulation/legacy/isotopes-and-atomic-mass) | Understand the nucleus and natural abundance of isotopes in the sun. |
| **Space Systems** | [HS-ESS1-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=169) | Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. | [Blackbody Spectrum](http://phet.colorado.edu/en/simulation/blackbody-spectrum) | Color vs. temperature of stars. |
| [Wave Interference](http://phet.colorado.edu/en/simulation/wave-interference) | Understand light interference patterns for interpreting what is seen through a diffraction grating. |
| **Space Systems** | [HS-ESS1-4](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=173) | Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. | [My Solar System](http://phet.colorado.edu/en/simulation/legacy/my-solar-system) | How do masses and initial velocities affect orbital radius? (Extension: How does this relate to dark matter?) |
| [Gravity and Orbits](http://phet.colorado.edu/en/simulation/gravity-and-orbits) | Use qualitative observations to determine the relationships between mass, velocity, and orbital motion. |
| **History of Earth** | [HS-ESS1-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=174) | Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. | [Plate Tectonics](http://phet.colorado.edu/en/simulation/legacy/plate-tectonics) | Explore features at plate boundaries and plate movements that cause them. Compare with global maps of Earth features. |
| **History of Earth** | [HS-ESS1-6](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=175) | Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history. | [Radioactive Dating Game](http://phet.colorado.edu/en/simulation/legacy/radioactive-dating-game) | Explore and measure decay rates, radiometric dating, fossil layers. |
| **History of Earth** | [HS-ESS2-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=183) | Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. | [Glaciers](http://phet.colorado.edu/en/simulation/glaciers) | Observe glacier properties and movements with resulting changes to land formations. |
| **Earth’s Systems** | [HS-ESS2-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=185) | Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. | [The Greenhouse Effect](http://phet.colorado.edu/en/simulation/greenhouse) | Take simulated data to examine how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures. |
| [Fluid Pressure and Flow](http://phet.colorado.edu/en/simulation/fluid-pressure-and-flow) | Apply observations and measurements of fluid flow rates and pressure at flow restrictions to how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion. |
| **Earth’s Systems** | [HS-ESS2-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=188) | Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. | [Salts and Solubility](http://phet.colorado.edu/en/simulation/legacy/soluble-salts) | Investigate solubility and concentration to enhance investigation of chemical weathering. |
| [Friction (HTML5)](http://phet.colorado.edu/en/simulation/friction) | Investigate friction as a mechanism of mechanical weathering. |
| **Earth’s Systems** | [HS-ESS2-7](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=190) | Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth. | [Natural Selection](http://phet.colorado.edu/en/simulation/legacy/natural-selection) | Activity "Is Natural Selection Fur-real?" examines evolution in different environments (arctic vs. equator). |
| **Weather and Climate** | [HS-ESS2-4](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=187) | Use a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate. | [The Greenhouse Effect](http://phet.colorado.edu/en/simulation/greenhouse) | Use PhET greenhouse model to examine the effects of atmospheric changes on climate. |
| **Weather and Climate** | [HS-ESS3-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=195) | Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. | [The Greenhouse Effect](http://phet.colorado.edu/en/simulation/greenhouse) | Use the simulation along with geoscience data to make predictions. |

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| **Physical Science** |
| **Topic** | **High School NGSS (2015) Performance Expectations (PE)** | **Associated PhET Simulation** | **Portions of PE Addressed by Simulation (Note: Most simulations will apply to only a part of a lesson designed around an NGSS PE)** |
| **Structure and Properties of Matter** | [HS-PS1-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=85) | Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. | [Build an Atom (HTML5)](http://phet.colorado.edu/en/simulation/build-an-atom) | Investigate the relationship between numbers of particles, element, atomic mass and atomic number, net charge, and number of valence electrons. |
| [Build a Molecule (Java)](http://phet.colorado.edu/en/simulation/build-a-molecule) | Could be used in conjunction with Build an Atom to investigate the relationship between valence electrons and how atoms combine to form actual elements. |
| **Structure and Properties of Matter** | [HS-PS1-8](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=92) | Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. | [Alpha Decay (Java)](http://phet.colorado.edu/en/simulation/alpha-decay) | Investigate alpha decay, activation energy, half-life, and energy transformations. |
| [Beta Decay (Java)](http://phet.colorado.edu/en/simulation/beta-decay) | Investigate beta decay, and half-life. |
| [Nuclear Fission (Java)](http://phet.colorado.edu/sims/nuclear-physics/nuclear-fission_en.jnlp) | Investigate nuclear fission and how a nuclear power plant operates |
| **Chemical Reactions** | [HS-PS1-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=89) | Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. | [Reactions & Rates (Java)](http://phet.colorado.edu/en/simulation/reactions-and-rates) | Provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. |
| **Chemical Reactions** | [HS-PS1-6](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=90) | Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. | [Reactions & Rates (Java)](http://phet.colorado.edu/en/simulation/reactions-and-rates) | Change concentrations, energy of reactions, temperatures, types of reactions and see changing concentrations |
| **Chemical Reactions** | [HS-PS1-7](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=91) | Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. | [Balancing Chemical Equations (HTML5)](http://phet.colorado.edu/en/simulation/balancing-chemical-equations) | Use mathematics and visual representations to balance chemical equations. |
| [Reactions & Rates (Java)](http://phet.colorado.edu/en/simulation/reactions-and-rates) | See that atoms are conserved in an equilibrium situation where there are unreacted particles. |
| **Forces and Interactions** | [HS-PS2-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=95) | 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. | [Forces and Motion Basics (HTML5)](http://phet.colorado.edu/en/simulation/forces-and-motion-basics) | Can use to meet all parts of the PE. Investigate meaning of net force, observe effects of non-zero net force, make measurements of variables to determine or verify the relationship F(net) = ma. |
| [Force and Motion (Java)](http://phet.colorado.edu/en/simulation/forces-and-motion) |
| [Ramp: Force and Motion](http://phet.colorado.edu/sims/motion-series/ramp-forces-and-motion_en.jnlp) |
| **Forces and Interactions** | [HS-PS2-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=96) | 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. | [Collision Lab (Flash)](http://phet.colorado.edu/en/simulation/legacy/collision-lab) | Can use to meet all parts of the PE. Qualitative and quantitative analysis of conservation of momentum. |
| **Forces and Interactions** | [HS-PS2-4](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=98) | Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects. | [Gravity Force Lab (HTML5)](http://phet.colorado.edu/en/simulation/gravity-force-lab) | Quantitative representation of gravitational force between two masses at variable distances. |
| [Balloons and Static Electricity (HTML5)](http://phet.colorado.edu/en/simulation/balloons-and-static-electricity) | Qualitative introduction to Coulomb forces. |
| [Electric Field Hockey](http://phet.colorado.edu/en/simulation/legacy/electric-hockey) |
| [Charges and Fields](http://phet.colorado.edu/en/simulation/legacy/charges-and-fields) | Quantitative representation of electrostatic force and fields around charged bodies. |

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| **Forces and Interactions** | [HS-PS2-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=100) | 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. | [Faraday's Law (HTML5)](http://phet.colorado.edu/en/simulation/faradays-law) | Qualitative introduction with evidence that a changing magnetic field can produce an electric current. Could be used by students to get ideas for their own investigation with real parts. |
| [Faraday's Electromagnetic Lab (Java)](http://phet.colorado.edu/en/simulation/faraday) | Tabs "Electromagnet" and "Transformer" provide a qualitative or quantitative platform for evidence that an electric current can produce a magnetic field. Could be used by students to get ideas for their own investigation with real parts. |
| [Generator (Java)](https://phet.colorado.edu/en/simulation/generator) | Qualitative introduction with evidence that a changing magnetic field can produce an electric current. Could be used by students to get ideas for their own investigation with real parts. |
| **Energy** | [HS-PS3-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=105) | 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. | [Energy Skate Park Basics (HTML5)](http://phet.colorado.edu/en/simulation/energy-skate-park-basics) | Qualitative introduction to energy changes, with bar graphs, pie chart, relative masses, and relative speeds. |
| [Energy Skate Park (Java)](http://phet.colorado.edu/en/simulation/energy-skate-park) | Can use to meet all parts of the PE. Similar to the above, but includes quantitative graphs. |
| [Pendulum Lab](http://phet.colorado.edu/en/simulation/pendulum-lab) | Qualitative introduction to energy changes, with bar graphs, relative masses, and relative speeds. Also can provide data for quantitative computation |
| [Masses & Springs](http://phet.colorado.edu/en/simulation/legacy/mass-spring-lab) | Qualitative introduction to energy changes, with bar graphs, relative masses, and relative speeds. |

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| **Energy** | [HS-PS3-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=106) | 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. | [Energy Skate Park Basics (HTML5)](http://phet.colorado.edu/en/simulation/energy-skate-park-basics)  | Can use to meet all parts of the PE. Observe total energy and compare to kinetic and gravitational potential as skater moves to different positions.. |
| [Pendulum Lab](http://phet.colorado.edu/en/simulation/pendulum-lab) |
| [Masses & Springs](http://phet.colorado.edu/en/simulation/legacy/mass-spring-lab) |
| **Energy** | [HS-PS3-3](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=107) | Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. | [Energy Forms and Changes (Java)](http://phet.colorado.edu/en/simulation/energy-forms-and-changes) | Student designs and builds an energy transformation system. A wide variety of energy inputs and outputs are available. Thermal energy investigation with various specific heat examples also available. Meets the PE except for "refine". |
| **Energy** | [HS-PS3-4](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=108) | 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). | [Energy Forms and Changes (Java)](http://phet.colorado.edu/en/simulation/energy-forms-and-changes) | Can use to meet all parts of the PE. Thermal energy investigation: Place objects of various specific heats in contact, then add or remove heat. Measure temperature. (Try iron bock on top of brick, thermometer on each, heat the brick from below!) |
| **Waves and Electromagnetic Radiation** | [HS-PS4-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=116) | Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. | [Wave on a String (HTML5)](http://phet.colorado.edu/en/simulation/wave-on-a-string) | Can use to meet all parts of the PE. Measure period, wavelength, vary tension (media). Can be used to develop or verify mathematical representations. |
| [Sound (Java)](http://phet.colorado.edu/en/simulation/sound) | Can use to meet all parts of the PE. Measure period, wavelength, vary density of air. Can be used to develop or verify mathematical representations. |

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| **Waves and Electromagnetic Radiation** | [HS-PS4-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=117) | Evaluate questions about the advantages of using a digital transmission and storage of information. | [Radio Waves & Electromagnetic Fields (Java)](http://phet.colorado.edu/en/simulation/radio-waves) | Introduction to analog signals prior to study of digital signals. Examine the production, transmission, and reception of radio waves. |
| **Waves and Electromagnetic Radiation** | [HS-PS4-3](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=118) | 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. | [Wave Interference (Java)](http://phet.colorado.edu/en/simulation/wave-interference) | Investigate interference patterns produced by water waves, sound waves, and light waves (evidence for the wave model). |
| [Photoelectric Effect (Java)](http://phet.colorado.edu/en/simulation/photoelectric) | Investigate the particle nature of light energy through the photoelectric effect (evidence for the particle model). |
| **Waves and Electromagnetic Radiation** | [HS-PS4-4](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=120) | Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. | [Photoelectric Effect (Java)](http://phet.colorado.edu/en/simulation/photoelectric) | Investigate photoelectric effect: e.g. how changing the intensity of light will affect the current and the energy of electrons, how changing the wavelength of light will affect the current and the energy of electrons, how changing the voltage of light will affect the current and the energy of electrons, how changing the material of the target will affect the current and the energy of electrons |
| **Waves and Electromagnetic Radiation** | [HS-PS4-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=122) | 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. | [Microwaves (Java)](http://phet.colorado.edu/en/simulation/microwaves) | Interaction of microwaves (and other frequencies) with water molecules. |
| [Radio Waves & Electromagnetic Fields (Java)](http://phet.colorado.edu/en/simulation/radio-waves) | Production (at the antenna), transmission, and reception (at the antenna) of radio waves. |

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| **Life Science** |
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| **Inheritance and Variation of Traits** | [HS-LS3-1](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=153) | Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. | [Gene Expression - The Basics (Java)](http://phet.colorado.edu/en/simulation/legacy/gene-expression-basics) | Clarifies the role of DNA and chromosomes in coding for traits. |
| **Inheritance and Variation of Traits** | [HS-LS3-3](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=155) | Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. | [Plinko Probability (Flash)](http://phet.colorado.edu/en/simulation/legacy/plinko-probability) | Examine the principles of probability. |
| [Curve Fitting (Flash)](http://phet.colorado.edu/en/simulation/legacy/curve-fitting) | Investigate automatic and manual curve fitting for data. Linear and polynomial. |
| [Least-Squares Regression (HTML5)](http://phet.colorado.edu/en/simulation/least-squares-regression) | Investigate the meaning of the r^2 value obtained from a least-squares regression. |
| **Interdependent Relationships in Ecosystems** | [HS-LS2-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=141) | Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. | [Natural Selection (Java)](http://phet.colorado.edu/en/simulation/natural-selection) | Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity. |
| **Interdependent Relationships in Ecosystems** | [HS-LS2-7](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=146) | Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. | [Natural Selection (Java)](http://phet.colorado.edu/en/simulation/natural-selection) | Could use as an introduction to the impacts of predators and food supplies (in general) on species. |
| **Natural Selection and Evolution** | [HS-LS4-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=157) | Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. | [Natural Selection (Java)](http://phet.colorado.edu/en/simulation/natural-selection) | Investigate the effect of limited resources on a species. |
| **Natural Selection and Evolution** | [HS-LS4-3](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=159) | Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. | [Plinko Probability (Flash)](http://phet.colorado.edu/en/simulation/legacy/plinko-probability) | Investigate probability. |
| **Natural Selection and Evolution** | [HS-LS4-5](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=163) | Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. | [Natural Selection (Java)](http://phet.colorado.edu/en/simulation/natural-selection) | Investigate how changing environmental conditions affect a species. |

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| **Engineering Design** |
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| **Engineering Design** | [HS-ETS1-2](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=203) | Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. | [The Greenhouse Effect (Java)](http://phet.colorado.edu/en/simulation/legacy/greenhouse) | Investigate and isolate individual causes of the greenhouse effect. |
| **Engineering Design** |  [HS-ETS1-4](http://standards.nsta.org/DisplayStandard.aspx?view=pe&id=205) | Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. | [The Greenhouse Effect (Java)](http://phet.colorado.edu/en/simulation/legacy/greenhouse) | Investigate the greenhouse effect prior to developing solutions, then investigate preliminary solutions. |