**HS-PS3 Energy**

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 position 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 qualitatively and conceptually. Examples of evidence 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 diagrams, drawings, 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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**Science and Engineering Practices**

**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, 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 problem. (HS-PS3-4)

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**Disciplinary Core Ideas**

**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 when interactions or energy transfers occur. (HS-PS3-1)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2)
- 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 one form is converted to energy associated with another form. (HS-PS3-3)

**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-PS3-3)
- The availability of energy limits what can occur in any system. (HS-PS3-3)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surroundings 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)
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the process of a chemical reaction. (HS-PS3-5)

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**Crosscutting Concepts**

- **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 its 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, between objects and/or fields, or between systems. (HS-PS3-2)

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**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)

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**Connections to Nature of Science**

- **Scientific Knowledge Assumes an Order and Consistency in Natural Systems**

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*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.
### ETS1.A: Defining and Delimiting Engineering Problems

- 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)

### Science Assumptions

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

### Connections to Other DCIs

#### In this grade band:
- **HS.PS1.A** (HS-PS3-2), **HS.PS1.B** (HS-PS3-1), (HS-PS3-2); **HS.PS2.B** (HS-PS3-2), (HS-PS3-3); **HS.PS2.D** (HS-PS3-4); **HS.ESS1.A** (HS-PS3-1), (HS-PS3-3), (HS-PS3-4); **HS.ESS2.A** (HS-PS3-1), (HS-PS3-2), (HS-PS3-4); **HS.ESS2.D** (HS-PS3-4); **HS.ESS3.A** (HS-PS3-3)

#### Across grade bands:
- **MS.PS1.A** (HS-PS3-2); **MS.PS2.B** (HS-PS3-2), (HS-PS3-5); **MS.PS3.A** (HS-PS3-1), (HS-PS3-2), (HS-PS3-3); **MS.PS3.B** (HS-PS3-1), (HS-PS3-3), (HS-PS3-4); **MS.PS3.C** (HS-PS3-2), (HS-PS3-5); **MS.ESS2.A** (HS-PS3-1), (HS-PS3-3), (HS-PS3-4)

### Articulation to Content Standards

#### ELA/Literacy
- **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (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)

#### Mathematics
- **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)

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