K-12 Conceptual Vertical Articulation of PS3 – Energy

PS3.A: Definitions of Energy

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
4	• The faster a given object is moving, the more energy it possesses. (4-PS3-1) • Energy can be moved [transferred] from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2) (4-PS3-3)
6	• The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary) The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. (secondary) Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary) (6-PS1-4) • The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and energy transfers by convection, conduction, and radiation (particularly infrared and light). (6-PS3-3) • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (6-PS3-4)
7	• Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed [sic]. (7-PS3-1) • A system of objects may also contain stored (potential) energy, depending on their relative positions. (7-PS3-2)

K-12 Conceptual Vertical Articulation of PS3 – Energy

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
Physics	• "Electrical Energy" may mean energy stored in battery or energy transmitted by electric current. (P-PS2-5) • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. A system's total energy is 1) conserved as energy is transferred within the system from one object to another and between its various possible forms and 2) always equal to the energy transferred into or out of the system. (P-PS3-1) • 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. Energy at the macroscopic level can be better understood, 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. (P-PS3-2) • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (P-PS3-3)

PS3.B: Conservation of Energy and Energy Transfer

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
K	• Sunlight warms Earth's surface. (K-PS3-1) (K-PS3-2)
4	• Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated, and sound is produced. Light also transfers energy from place to place. Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. (4-PS3-2) • Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated, and sound is produced. (4-PS3-3) • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-4)
6	• The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is spontaneously transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. (6-PS3-3) • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (6-PS3-4)
7	• When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (7-PS3-5)

K-12 Conceptual Vertical Articulation of PS3 – Energy

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
Chemistry	• Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. 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). (C-PS3-4)
Physics	• 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. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions allow the concept of conservation of energy to be used to predict and describe system behavior. Mathematical expressions quantify how the stored energy in a system depends on its configurations (such as relative positions of charged particles or compression of a spring) and how kinetic energy depends on mass and speed. The availability of energy limits what can occur in any system. (P-PS3-1)

K-12 Conceptual Vertical Articulation of PS3 – Energy

PS3.C: Relationship between Energy and Forces

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
K	• A bigger push or pull makes things speed up or slow down more quickly. (K-PS2-1)
4	• When objects collide, the contact forces transfer energy so as to change the objects' motions. (4-PS3-3)
7	• When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (7-PS3-2)
Physics	• When two objects interacting through a field change relative position, the energy stored in the field is changed. Each force between the two interacting objects acts in the direction such that the motion in that direction would reduce the energy in the force field between the objects. (P-PS3-5)

K-12 Conceptual Vertical Articulation of PS3 – Energy

PS3.D: Energy in Chemical Processes and Everyday Life

Grade Band	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
4	• The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use (4-PS3-4)
5	• The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (5-PS3-1)
7	• The chemical reaction by which plants produce complex food molecules (sugars) required an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary) (7-LS1-6) • Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary) (7-LS1-7)
Biology	• The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary) (B-LS2-5)
Chemistry	• Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (C-PS3-4)
Physics	• Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (P-PS3-3)
Earth and Space Science	• Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (E-ESS1-1)

Adapted from *The Framework for K-12 Science Education* and the *Next Generation Science Standards.*

References:

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States (Appendix E: Disciplinary Core Idea Progression)*. Retrieved from https://www.nextgenscience.org/