HIGH SCHOOL PHYSICS: ENERGY

Standards Bundle

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon the potential for related phenomena that can be used throughout a unit.

HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of the energy associated with the motion and relative position of particles (objects). (SEP: 2; DCI: PS3.A; CCC: Energy/Matter) [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to the 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. (SEP: 6; DCI: PS3.A, PS3.D, ETS1.C; CCC: Energy/Matter) Alignment may include HS-ETS1-2 [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 the 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.]*

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

The energy of a macroscale system depends on the motion or position of the system, as well as the interactions that occur within the system. Energy is always changing from one kind to another, but the total energy of the system is always the same. Energy can take many forms such as motion, sound, light, and heat. The amount of energy available is mathematically calculable and determines what the system can do. Energy can be seen in multiple ways and be used to accomplish goals by building machines that capture and use the energy. These machines will transfer one type of energy to another type of energy until a balance is reached.

Phenomena

Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- Mixing two volumes of water with different temperatures
- Burn a peanut, walnut, or chip (beware of peanut allergies in the classroom)
- A picture of a South Dakota hydroelectric dam along the Missouri River
- Video of a pendulum in motion
- A child on playground swings or slides
- Observe the function of a wind-up car.

- Watch a movie clip showing Rube Goldberg machines in action (i.e., Goonies, Robots, Toy Story, etc.).
- Tsunami picture or video.
- Watch roller coasters and observe for common features.
- Christmas tea light spinners.
- Thermochromic pigments (aka heat-sensitive dyes that change color when heated).
- Collisions and Newton's cradle.
- A nail surrounded by coils of wire hooked up to a battery attracts a piece of iron.

Storyline

This section aims to decode not only the DCI connections but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. **Constructing Explanations and Designing Solutions** ● Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence,	**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. ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. ● These relationships are better understood at the microscopic scale, at which all 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. ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.	**Energy and Matter** ● Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems. ● 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.

prioritized criteria, and tradeoff considerations.	**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. **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.	

Energy is a concept that crosses all disciplines within science. It is a quantitative property that encompasses the motion and interactions of matter and radiation within a system. Energy can be transferred and stored in a variety of forms (light, motion, sounds, electrical and magnetic fields, and thermal energy). Students calculate the change in the energy of one component when they change the energy of the other component(s) in the system. Students plan and conduct an investigation to determine the relationship between kinetic and thermal energy in a closed system. Students also investigate the relationship between the amounts of thermal energy transferred between different components in a closed system. Students predict an accurate change in temperature based on the amount of heat or heated material they add to the system. An understanding of the components in the model leads students to use the model to predict the behavior of a different system of energy at the macroscopic scale.

Energy can be accounted for as either the motion of particles or energy stored in fields. This is an opportunity for students to highlight that energy cannot be created or destroyed, it only moves from one place to another, between objects and/or fields, or between systems. An example of this could include, shining a light (incandescent) on a system and seeing a change in temperature or the ability of the system to do work. Models could include diagrams, drawings, descriptions, and computer simulations. These models can be used to support explanations, predict phenomena, analyze systems, and/or solve problems around the concepts of energy at the microscopic scale.

Energy is present in many different forms at the macroscopic scale, such as motion, sound, light, and thermal energy. Thermal energy provides an opportunity to model how overall energy is conserved throughout a system. If there is a difference in the amount of thermal energy, it will try to distribute that energy throughout the system. Students will plan and conduct an investigation to provide evidence that the transfer of thermal energy happens within a closed system. This will allow them to see a very basic picture of the second law of thermodynamics. Part of this process will involve students selecting appropriate tools to collect, record, analyze, and evaluate data. They will use this data to support explanations for the phenomena and they will evaluate the design of the investigation to ensure that variables are controlled.

Students are going to take the role of an engineer and apply scientific knowledge, specifically about energy on the macroscopic scale (motion, sound, light, and thermal energy), and design, build, and refine a device that converts one form of energy into another form of energy. The changes of energy and matter in system can be described in terms of energy that flows into, out of, and within that system. Since energy cannot be created or destroyed, the total energy within the system will remain the same.

Formative Assessment

Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given bundle, standard, or lesson-level performance expectation.

SEP Constructing Explanations and Designing Solutions

- Perform a calorimetry experiment to determine the energy content of a sample of food and explain the energy transformations.
- Investigate the relationship between spring compression and gravitational potential energy using motion detectors.
- Use ramps and motion detectors to explain and quantify energy conversions within the cart system and to explain and quantify external work done on the system by friction.

SEP Developing and Using Models

- Use a motion simulation as a model to observe and describe the relationship between potential, kinetic, thermal, and total energy under different situations such as varying objects, object masses, and planets or gravitational constants.
- Diagram the energy conversions that take place between a power plant (i.e., hydroelectric dam, a nuclear plant) and the end user (i.e., home).

CCC Energy and Matter

- Using two hand generators describe the conversion of mechanical energy to electrical energy and back; and how the type of energy conversion determines the classification as a motor or a generator.
- Using a given system, describe in terms of energy and matter that flows into, out of, and within the system.
- Using the given system, describe where losses of energy may occur.

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Develop a model** to identify and describe how a colorimeter works while showing the *components of the system and its surroundings,* as well as *energy flows between the system and its surroundings.*
- **Identify in a model** the relationship between energy on a macroscale as motion, sound, light, thermal energy, potential energy, or energy in fields related to molecular/atomic forms of energy such as motions (kinetic energy) of particles (e.g., nuclei and electrons), the relative positions of particles in fields (potential energy), and energy in fields.
- **Identify in a model** of a roller coaster the relationship between the energy of position (potential energy) and the energy of motion (kinetic energy) as well as the *conversion of each to the other* throughout the roller coaster's path.

- **Describe the relationships between components in the models,** including how changes in the relative position of objects in gravitational, magnetic, or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy).
- **Describe the** relationship between the thermal energy of a *system* and the kinetic and potential energy of the particles.
- **Use a model to show the** total energy of the *system* and surroundings is conserved at a *macroscopic and molecular/atomic level.*
- Use a model to show as one form of energy increases, others must decrease by the same amount as *energy is transferred among and between objects and fields.*
- **Use a model to show** that in *closed systems the energy is conserved on both the macroscopic and molecular/atomic scales* so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the *system.*
- **Use a model 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 on both the *macroscopic and microscopic scales*.
- **Design a device that** *converts one form of energy into another form of energy.*
- **Develop a plan for a device to** identify what scientific principles provide the basis for the energy conversion design, identify the forms of energy that will be converted from one form to another in the designed system, and identify losses of energy by the design system to the surrounding environment.
- **Describe the scientific rationale for choices of materials and structure of the** device *designed to convert one form of energy to another*, **including how student-generated evidence influenced the design.**
- **Describe how a device that** converts one form of energy into another **(e.g. solar cell, battery, heat exchanger, wind turbine) is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing** *costs and risk***.**
- **Describe and quantify prioritized criteria and constraints such as cost and** *efficiency* **of** energy conversion, **for the design of the device, along with the tradeoffs implicit in these design solutions.**
- **Use the results of the tests to improve the device performance** by increasing the efficiency of energy conversion, **keeping in mind the criteria and constraints, and noting any modifications in tradeoffs.**
- **Evaluate two different devices designed** to convert solar energy to thermal energy based on *efficiency*, cost, and environmental impact.
- **Evaluate** the *efficiency* of a device to keep a beverage cold (or warm) using student-derived evidence according to a set of constraints such as cost, availability, and environmental impact of materials.
- **Create a model** to show how thermal energy is *transferred from a hot liquid to the surrounding environment* to include the molecular motion of all of the components of the *system*.