SC DEPARTMENT OF EDUCATION

Bundling Guide for Physics

Office of Assessment and Standards

Purpose and Use

This document is intended to be a guide to provide examples of ways Performance Expectations (PEs) could be bundled. For this purpose, a bundle as defined by Pruit (2014), is, "a set of PEs that provide students with coherent connections among concepts within and across disciplines." This document is not intended to be read from cover to cover, but to be used, when needed, to support teacher professional learning and curriculum decisions. This is not intended for student use, and thus is not written in student-friendly language. This is not a curriculum or a means to limit instruction in the classroom. The bundles presented in this guide are not ordered for instruction. Although each PE states a dedicated Science and Engineering Practice (SEP) and Crosscutting Concept (CCC), students will need to use the whole range of SEPs and CCCs to achieve success by the end of instruction.

The bundles in this document do not represent the only way the PEs can be bundled. PEs bundled together may change depending upon the selected anchoring phenomenon that students are working to explain. The bundles presented in this guide were developed using an iterative process informed by the work of Krajick and colleagues (2014). This process is summarized in the steps below:

1. Review bundles that already exist.
2. Build bundles around an anchoring phenomenon.
   a. The "Example anchoring phenomena to support 3D instruction" provided in this resource is just that, an example. There are myriad phenomena to support 3D instruction, and different phenomena may be more appropriate for different learning contexts.
3. Explore and look for unexpected relationships among the PEs, including bundling across disciplines (Earth and Space Science, Life Science, Physical Science) when appropriate. This can include identification of PEs that are only partially met in the bundle.
   a. PEs within a bundle marked with an asterisk (*) share an authentic connection with the bundle but may not fully met.
   b. PEs from additional high school content areas with a close connection to the bundle are listed. This is not intended to add to the instructional demand, but instead to provide teachers with additional content to build upon and/or support student sensemaking.
4. Make sure each PE in the grade/course is found in at least one bundle.

Forces & Motion

Newton's second law predicts changes in the motion of macroscopic objects ($F_{net}=ma$). Momentum is the product of the mass and velocity of an object for a particular frame of reference ($p=mv$). 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.

PEs aligned to this bundle:

- P-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.
- P-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.
- P-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the effect of a force on a macroscopic object during a collision.
- P-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the following are known: 1) the change in energy of the other component(s) and 2) the energy flowing in and out of the system.*
- P-PS3-2. Develop and use models to illustrate that energy can be explained by the combination of motion and position of objects at the macroscopic scale and the motion and position of particles at the microscopic scale.*

Connected PEs from additional content areas:

- C-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- C-PS1-5. 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.
- E-ESS3-2. Evaluate competing design solutions that address the impacts of developing, managing, and using Earth's energy and mineral resources.

Example anchoring phenomena to support 3D instruction:

- Regenerative braking
- Anti-shoplifting devices
- Multistage rockets

Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. Energy is transferred and conserved in a system and between 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, because 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. 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.

PEs aligned to this bundle:

- P-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the following are known: 1) the change in energy of the other component(s) and 2) the energy flowing in and out of the system.
- P-PS3-2. Develop and use models to illustrate that energy can be explained by the combination of motion and position of objects at the macroscopic scale and the motion and position of particles at the microscopic scale.
- P-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- P-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.*
- P-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.*

Connected PEs from additional content areas:

- B-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
- B-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.
- C-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- C-PS1-8. 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.
- E-ESS3-2. Evaluate competing design solutions that address the impacts of developing, managing, and using Earth's energy and mineral resources.
- E-ESS1-5. 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.
- E-ESS2-3. Develop a model based on evidence of Earth's interior that describes cycling of matter through convection processes.

Example anchoring phenomena to support 3D instruction:

- Aerogels
- Drinking Bird
- Crook's radiometer

Fields

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. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Electric current flow (flow of electrons), like a magnet, generates magnetic fields. Similarly, electric charges or changing magnetic fields can generate electric current. When two objects interacting through a field change relative position, the energy stored in the field is changed.

PEs aligned to this bundle:

- P-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.
- P-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.
- P-PS3-5. Develop and use a model to illustrate the forces between two objects and the changes in energy of the objects due to their interaction through electric or magnetic fields.
- P-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

Connected PEs from additional content areas:

- C-PS2-6. Communicate scientific and technical information about why the molecular structure determines the functioning of designed materials.
- E-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the universe due to gravity.

Example anchoring phenomena to support 3D instruction:

- Static cling
- Induction cooktops
- Metal detector

Electromagnetic Radiation

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. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the bases of wave properties. Electromagnetic radiation (for example 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. 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. Photoelectric materials emit electrons when they absorb light of a high-enough frequency. Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (for example 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. Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Waves can add or cancel one another as they cross, depending on their relative phase (limited to relative position of peaks and troughs of the waves), but they emerge unaffected by each other. Information can be digitized (for example a picture stored as the values of an array of pixels). In this stable form, information can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PEs aligned to this bundle:

- P-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- P-PS4-2. Design, evaluate, and refine a solution for improving how digital devices store and transmit information.
- P-PS4-3. Evaluate the claims, evidence, and reasoning about how electromagnetic radiation can be described either by a wave model or a particle model, and in some situations one model is more useful than the other.
- P-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.
- P-PS-4-5. 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.
- P-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.*

- P-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

Connected PEs from additional content areas:

- C-PS2-6. Communicate scientific and technical information about why the molecular structure determines the functioning of designed materials.
- C-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.
- C-PS4-5. Communicate technical information about how some technological devices use the principles of the electromagnetic spectrum to cause matter to transmit and capture information and energy
- E-ESS1-1. Develop a model based on evidence to illustrate that energy generated by nuclear fusion within the sun (and other stars) radiates to and influences orbiting planets.

Example anchoring phenomena to support 3D instruction:

- Fiberoptics
- Tanning bed

References

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