High School Domains Model Course II - Physics

Narrative and Rationale: This Physics model course map is the second in a three-year course sequence that uses a customized version of the Modified High School Domains Model from NGSS Appendix K as the instructional year end goals. This course model assumes that students are grounded in the basics of chemistry and have previously spent one year in high school developing their proficiency in the NGSS Science and Engineering Practices and crosscutting concepts.

The first bundle in this course continues the study of structure and properties of matter that began in chemistry the previous year, and extends to a focus on how forces arise from the interactions between fields. The second bundle continues a focus on forces, but shifts to a study of collisions at the macroscopic scale. The third bundle focuses on forces and energy transfer when objects interact, and the fourth bundle ends the course by focusing on harnessing energy transfer for communication purposes. Throughout the course, relevant Earth and Space Sciences and Engineering Design PEs are integrated.

The bundles in this domains model guide students through the use of the SEPs, CCCs, and DCIs to answer the essential questions for each unit listed in the bundles below. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Why Don't We Fall Through the Floor? **~6 weeks**	**Bundle 2:** How Do We Protect Ourselves From Collisions? **~6 weeks**	**Bundle 3:** What Happens When Energy Moves From One Place to Another? **~8 weeks**	**Bundle 4:** How Do We Use Energy to Communicate With Each Other? **~4 weeks**
HS-PS1-1. 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.[1] **HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. **HS-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. **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* **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 positions of particles (objects). **HS-PS3-5.** Develop and use a model of two objects interacting through electric or	**HS-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. **HS-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. **HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* **HS-ESS1-2.** 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. **HS-ESS1-4.** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.[1] **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints,	**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. **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.* **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). **HS-ESS2-1**. 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. **HS-ESS2-2**. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS2-3.** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	**HS-PS4-1.** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. **HS-PS4-2.** Evaluate questions about the advantages of using a digital transmission and storage of information. **HS-PS4-3.** 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. **HS-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. **HS-PS4-5**. 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.*

Bundle 1: Why Don't We Fall Through the Floor? **~6 weeks**	**Bundle 2:** How Do We Protect Ourselves From Collisions? **~6 weeks**	**Bundle 3:** What Happens When Energy Moves From One Place to Another? **~8 weeks**	**Bundle 4:** How Do We Use Energy to Communicate With Each Other? **~4 weeks**
magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.[1]	**HS-ESS2-4.** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Domains Model Course II (Physics) Flowchart

Bundle 1

PS1.A as found in HS-PS1-1
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

To PS4.B in Bundle 4

PS1.A as found in HS-PS1-3
- The structure and interactions of matter at the bulk scale are determined by the electrical forces within and between atoms.

PS2.B as found in HS-PS2-4
- 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. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS2.B as found in HS-PS2-6
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

PS3.A as found in HS-PS3-2
- 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 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.

PS3.C as found in HS-PS3-5
- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Bundle 2

PS2.A as found in HS-PS2-1
- Newton's second law accurately predicts changes in the motion of macroscopic objects.

PS2.A as found in HS-PS2-2
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.

PS2.A as found in HS-PS2-2 and HS-PS2-3
- 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.

PS4.B as found in HS-ESS1-2
- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.

ESS1.A as found in HS-ESS1-2
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

To ESS2.D in Bundle 3 and PS3.D in Bundle 4

ESS1.B as found in HS-ESS1-4
- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

ETS1.A as found in HS-PS2-3 and HS-ETS1-1
- 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.

ETS1.A as found in HS-ETS1-1
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-ETS1-3
- When evaluating solution, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Bundle 3

PS3.A as found in HS-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.

PS3.A as found in HS-PS3-3
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.B as found in HS-PS3-1
- 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, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

PS3.B as found in HS-PS3-4
- 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).

PS3.D as found in HS-PS3-3 and HS-PS3-4
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ESS1.B as found in HS-ESS2-4
- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

ESS2.A as found in HS-ESS2-1 and HS-ESS2-2
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.A as found in HS-ESS2-3
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

ESS2.A as found in HS-ESS2-4
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Bundle 4

PS3.D as found in HS-PS4-5
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

PS4.A as found in HS-PS4-1
- 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.

PS4.A as found in HS-PS4-2 and HS-PS4-5
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PS4.A as found in HS-PS4-3
- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

PS4.B as found in HS-PS4-3
- Electromagnetic radiation (e.g., 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.

PS4.B as found in HS-PS4-4
- 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.

PS4.B as found in HS-PS4-5
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

PS4.C as found in HS-PS4-5
- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., 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.

ETS1.C as found in HS-PS2-3
•Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

ESS2.B as found in HS-ESS2-1
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.

ESS2.B as found in HS-ESS2-3
• The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

ESS2.C as found in HS-ESS2-5
• The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

ESS2.D as found in HS-ESS2-2 and HS-ESS2-4
• The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

To PS4.B in Bundle 4

ETS1.A as found in HS-PS3-3
•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.

ETS1.C as found in HS-ETS1-2
•Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.