Physical Science – Physics

HS-PSP-1 – Motion and Stability: Forces and Interactions

<u>**HS-PSP-1.1**</u> Students who demonstrate understanding can:
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.

Supporting Content PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PSP-1.1)

Further Explanation: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Assessment Limit: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.

<u>**HS-PSP-1.2**</u> Students who demonstrate understanding can:
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.

Supporting Content PS2.A: Forces and Motion

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PSP-1.2)
- 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. (HS-PSP-1.2, HS-PSP-1.3)

Further Explanation: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle (Newton's first law).

Assessment Limit: Assessment is limited to systems of two macroscopic bodies moving in one dimension.

<u>HS-PSP-1.3</u> Students who demonstrate understanding can:
Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Supporting Content PS2.A: Forces and Motion

- 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. (HS-PSP-1.2, HS-PSP-1.3)

Supporting Content 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. (HS-PSP-1.3)

Supporting Content ETS1.C: Optimizing the Design Solution

- 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. (HS-PSP-1.3)

Further Explanation: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.

Assessment Limit: Assessment is limited to qualitative evaluations and/or algebraic manipulations.

<u>HS-PSP-1.4</u> Students who demonstrate understanding can:
Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Supporting Content PS2.B: Types of Interactions

- 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. (HS-PSP-1.4)
- 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. (HS-PSP-1.4, HS-PSP-1.5)

Further Explanation: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.

Assessment Limit: Assessment is limited to systems with two objects. Base equations will be provided.

<u>HS-PSP-1.5</u> Students who demonstrate understanding can:
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.

Supporting Content PS2.B: Types of Interactions

- 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. (HS-PSP-1.4, HS-PSP-1.5)

Supporting Content PS3.A: Definitions of Energy

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (HS-PSP-1.5)

Assessment Limit: Assessment is limited to designing and conducting investigations with provided materials and tools.

<u>HS-PSP-1.6</u> Students who demonstrate understanding can:
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Supporting Content PS1.A: Structure and Properties of Matter

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PSP-1.6)

Supporting Content PS2.B: Types of Interactions

- 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. (HS-PSP-1.6, *HS-PSC-1.3, HS-PSC-1.5*)

Further Explanation: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.

Assessment Limit: Assessment is limited to provided molecular structures of specific designed materials.

HS-PSP-2 – Energy

HS-PSP-2.1 Students who demonstrate understanding can:
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.

Supporting Content 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. (HS-PSP-2.1, HS-PSP-2.2)

Supporting Content 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-PSP-2.1)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PSP-2.1, HS-PSP-2.4)
- 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. (HS-PSP-2.1)
- The availability of energy limits what can occur in any system. (HS-PSP-2.1)

Further Explanation: Emphasis is on explaining the meaning of mathematical expressions used in the model.

Assessment Limit: 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-PSP-2.2 Students who demonstrate understanding can:
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).

Supporting Content 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. (HS-PSP-2.1, HS-PSP-2.2)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PSP-2.2, HS-PSP-2.3)
- 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. (HS-PSP-2.2)

Further Explanation: 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.

<u>HS-PSP-2.3</u> Students who demonstrate understanding can:
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Supporting Content PS3.A: Definitions of Energy

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PSP-2.2, HS-PSP-2.3)

Supporting Content 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. (HS-PSP-2.3, HS-PSP-2.4)

Supporting Content 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. (HS-PSP-2.3)

Further Explanation: 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 multiple energy forms and evaluations of efficiency.

Assessment Limit: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to examples of devices provided to students.

<u>HS-PSP-2.4</u> Students who demonstrate understanding can:
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).

Supporting Content PS3.B: Conservation of Energy and Energy Transfer

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PSP-2.1, HS-PSP-2.4)
- Uncontrolled systems always evolve toward more stable states—that is, toward a more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PSP-2.4)

Supporting Content 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. (HS-PSP-2.3, HS-PSP-2.4)

Further Explanation: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.

Assessment Limit: Assessment is limited to examples of closed system investigations.

HS-PSP-2.5 Students who demonstrate understanding can:
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.

Supporting Content 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-PSP-2.5)

Further Explanation: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.

Assessment Limit: Assessment is limited to systems containing two objects.

HS-PSP-3 – Waves

HS-PSP-3.1 Students who demonstrate understanding can:
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Supporting Content PS4.A: Wave Properties

- 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. (HS-PSP-3.1)

Further Explanation: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.

Assessment Limit: Assessment is limited to algebraic relationships and describing those relationships qualitatively.

HS-PSP-3.2 Students who demonstrate understanding can:
Evaluate questions about the advantages of using digital transmission and storage of information.

Supporting Content PS4.A: Wave Properties

- 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. (HS-PSP-3.2, HS-PSP-3.5)

Further Explanation: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.

HS-PSP-3.3 Students who demonstrate understanding can:
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.

Supporting Content PS4.A: Wave Properties

- 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.) (HS-PSP-3.3)

Supporting Content PS4.B: Electromagnetic Radiation

- 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. (HS-PSP-3.3)

Further Explanation: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.

Assessment Limit: Assessment does not include using quantum theory.

<u>HS-PSP-3.4</u> Students who demonstrate understanding can:
Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

Supporting Content PS4.B: Electromagnetic Radiation

- 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. (HS-PSP-3.4)

Further Explanation: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.

Assessment Limit: Assessment is limited to qualitative descriptions.

<u>HS-PSP-3.5</u> Students who demonstrate understanding can:
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.

Supporting Content PS3.D: Energy in Chemical Processes

- Solar cells are human-made devices that likewise capture the Sun's energy and produce electrical energy. (HS-PSP-3.5)

Supporting Content PS4.A: Wave Properties

- 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. (HS-PSP-3.2, HS-PSP-3.5)

Supporting Content PS4.B: Electromagnetic Radiation

- Photoelectric materials emit electrons when they absorb light of a high enough frequency. (HS-PSP-3.5)

Supporting Content PS4.C: Information Technologies and Instrumentation

- 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. (HS-PSP-3.5)

Further Explanation: Examples could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.

Assessment Limit: Assessments are limited to qualitative information. Assessments do not include band theory.