Unit #7 Linear Momentum & Collisions

Impulse, Conservation of Momentum & Collisions

Big Idea: Momentum is conserved in all collisions, as long as external forces do not act on the system.

Essential Questions:

- What is the direction of momentum?
- What happens to momentum & energy during and after a collision?
- What is the difference between impact and impulse?
- What determines the direction of an impulse?
- How is impulse related to momentum?
- How do internal and external forces affect a system's momentum?

Vocabulary:

momentum	impulse	elastic collision
inelastic collision	internal force	external force

Next Generation Priority Standards:

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.**[Clarification Statement: 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 Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

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.**[Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]

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.***[Clarification Statement: 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 Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.**[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

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.**[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: 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-PS3-3 **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.***[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 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.*]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence

Disciplinary Core Ideas

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-PS3-1),
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.(HS-PS3-3)
- 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

Crosscutting Concepts

Energy and Matter

- 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. (HS-PS3-3)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1)
- Systems can be designed to cause a desired effect. (HS-PS2-3)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) consistent with scientific ideas, principles, and theories.

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena to describe explanations. (HS-PS2-2))

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

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-PS3-1)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4)
- 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-PS3-1)
- The availability of energy limits what can occur in any system. (HS-PS3-1)

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-PS3-3),

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. *(secondary to HS-PS3-3)*

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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. *(secondary to HS-PS2-3)*

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Connections to Engineering, Technology,

and Applications of Science

Influence of Science, Engineering and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)

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Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

	• 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. *(secondary to HS-PS1-1),(secondary to HS-PS1-3)* **PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) • 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-PS2-2),(HS-PS2-3)	

Connections to other DCIs in this grade-band:

HS.PS1.A (HS-PS3-2); **HS.PS1.B** (HS-PS3-1),(HS-PS3-2); **HS.PS2.B** (HS-PS3-2),(HS-PS3-5); **HS.LS2.B** (HS-PS3-1); **HS.ESS1.A** (HS-PS3-1),(HS-PS3-4) ; **HS.ESS2.A** (HS-PS3-1),(HS-PS3-2),(HS-PS3-4); **HS.ESS2.D** (HS-PS3-4); **HS.ESS3.A** (HS-PS3-3)

Articulation of DCIs across grade-bands:

MS.PS1.A (HS-PS3-2); **MS.PS2.B** (HS-PS3-2),(HS-PS3-5); **MS.PS3.A** (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); **MS.PS3.B** (HS-PS3-1),(HS-PS3-3),(HS-PS3-4); **MS.PS3.C** (HS-PS3-2),(HS-PS3-5); **MS.ESS2.A** (HS-PS3-1),(HS-PS3-3)

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS3-3)*
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-1),(HS-PS3-2),*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2)
MP.4	Model with mathematics. (HS-PS2-1),(HS-PS2-2)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1),(HS-PS2-2)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1)
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-1),(HS-*

	PS2-2)
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-1),(HS-PS2-2)*
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. *(HS-PS2-1)*
HSS-IS.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)*
MP.2	Reason abstractly and quantitatively. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3)
MP.4	Model with mathematics. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1),(HS-PS3-3)
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