HS.PS-FM Forces and Motion

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Students who demonstrate understanding can:

- **a. Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion.** [Assessment Boundary: Restricted to one- and two-dimensional motion and does not include rotational motion. Does not apply in the case of subatomic scales or for speeds close to the speed of light. Calculations restricted to macroscopic objects moving at non-relativistic speeds.]
- **b. Generate and analyze data to support the claim that the total momentum of a closed system of objects before an interaction is the same as the total momentum of the system of objects after an interaction.** [Clarification Statement: Conservation of momentum is the focus.]
- **c. Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known.** [Assessment Boundary: Restricted to macroscopic interactions and only two objects moving in one or two dimensions.]
- **d. Design and evaluate devices that minimize the force on a macroscopic object during a collision.**
- **e. Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system.** [Assessment Boundary: Restricted to macroscopic interactions.]
- **f. Communicate arguments to support claims that Newton's laws of motion apply to macroscopic objects but not to objects at the subatomic scales or speeds close to the speed of light.** [Assessment Boundary: No details of quantum physics or relativity are included.]

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

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

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.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims. (b)

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 expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (c)

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 knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (e),(f)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. (a),(e),(f)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (b)
- In any system, total momentum is always conserved. (b),(c)
- 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. (c),(d),(e)

PS2.C: Stability and Instability in Physical Systems

- Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from outside, helps predict its behavior under a variety of conditions. (d),(e)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(c),(d)

Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (b),(e)

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Connections to Engineering, Technology, and Applications of Science

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

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (d)

HS.PS-FM **Forces and Motion** ***(continued)***
Connections to other DCIs in this grade-level: **HS.ETS-ED, HS.ESS-SS, HS.ESS-ES**
Articulation to DCIs across grade-levels: **MS.PS-FM, MS.PS-WER**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RST.6-8.3** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks **RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **WHST.9** Draw evidence from informational texts to support analysis, reflection, and research. *Mathematics –* **MP.2** Reason abstractly and quantitatively **MP.4** Model with Mathematics **MP.5** Use appropriate tools strategically **8.F** Define, evaluate, and compare functions. **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **F.BF** Build a function that models a relationship between two quantities **N-Q** Reason quantitatively and use units to solve problems