# HS.PS-IF Interactions of Forces

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Students who demonstrate understanding can:

**a. Use mathematical expressions to determine the relationship between the variables in Newton's Law of Gravitation and Coulomb's Law, and use these to predict the electrostatic and gravitational forces between objects.** [Assessment Boundary: Only situations with two objects are predicted.]

**b. Use models to demonstrate that electric forces at the atomic scale affect and determine the structure, properties (including contact forces), and transformations of matter.** [Clarification statement: Models can include graphical and computer models. Examples of properties and transformations of matter can include intermolecular forces, chemical bonding, and enzyme substrate interaction.] [Assessment Boundary: Only a qualitative understanding is expected.]

**c. Plan and carry out investigations to demonstrate the claim that magnets, electric currents, or changing electric fields cause magnetic fields and electric charges or changing magnetic fields cause electric fields.** [Assessment Boundary: Qualitative observations only.]

**d. Obtain, evaluate, and communicate information to show that strong and weak nuclear interactions inside atomic nuclei determine which nuclear isotopes are stable, and that the pattern of decay of an unstable nucleus can often be predicted.** [Clarification Statement: Types of decay in unstable nuclei can include alpha or beta radiation.] [Assessment Boundary: Only a qualitative understanding of nuclear interactions is expected.]

**e. Obtain, evaluate, and communicate information to show how scientists and engineers take advantage of the effects of electrical and magnetic forces in materials to design new devices and materials through a process of research and development.** [Clarification Statement: Designed devices can include magnetic strips on credit cards, laser printers, and photo copiers.]

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

**Developing and Using Models**

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (b)

**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 the investigation's design has controlled for them. (c)

**Using Mathematical 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. (a)

**Obtaining, Evaluating, and Communicating Information**

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods and designs that appear in scientific and technical texts or media reports. (d),(e)

### Disciplinary Core Ideas

**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. (a)
- Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (c)
- 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. (b),(e)
- The strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones. (d)

### 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),(b),(c),(d)

***Connections to Engineering, Technology, and Applications of Science***

**Interdependence of Science, Engineering, and Technology**

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (e)

*Connections to other DCIs in this grade-level:* **HS.ETS-ETSS, HS.ESS-SS, HS.ESS-ES**

*Articulation to DCIs across grade-levels:* **MS.PS-IF, MS.PS-FM**

*Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]*

*ELA –*

**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

**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