

HS-PS2-4

Students who demonstrate understanding can:

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. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

The performance expectation above was developed using the following elements from *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.

- Use mathematical representations of phenomena to describe explanations.

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Theories and laws provide explanations in science.
- Laws are statements or descriptions of the relationships among observable phenomena.

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.
- 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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Observable features of the student performance by the end of the course:

1	Representation	
	a	Students clearly define the system of the interacting objects that is mathematically represented.
	b	Using the given mathematical representations, students identify and describe* the gravitational attraction between two objects as the product of their masses divided by the separation distance squared ($F_g = -G \frac{m_1 m_2}{d^2}$), where a negative force is understood to be attractive.
	c	Using the given mathematical representations, students identify and describe* the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared ($F_e = k \frac{q_1 q_2}{d^2}$), where a negative force is understood to be attractive.
2	Mathematical modeling	
	a	Students correctly use the given mathematical formulas to predict the gravitational force between objects or predict the electrostatic force between charged objects.
3	Analysis	
	a	Based on the given mathematical models, students describe* that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance.

b	Students describe* that the mathematical representation of the gravitational field ($F_g = -G \frac{m_1 m_2}{d^2}$) only predicts an attractive force because mass is always positive.
c	Students describe* that the mathematical representation of the electric field ($F_e = k \frac{q_1 q_2}{d^2}$) predicts both attraction and repulsion because electric charge can be either positive or negative.
d	Students use the given formulas for the forces as evidence to describe* that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects.