MS-PS2-1 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas or principles to design an object, tool, process or system.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

- -

Connections to Engineering, Technology, and Applications of Science

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

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Observable features of the student performance by the end of the course:		
1	Using scientific knowledge to generate design solutions	
	a	Given a problem to solve involving a collision of two objects, students design a solution (e.g., an object, tool, process, or system). In their designs, students identify and describe*:
		i. The components within the system that are involved in the collision.
		ii. The force that will be exerted by the first object on the second object.
		iii. How Newton's third law will be applied to design the solution to the problem.
		iv. The technologies (i.e., any human-made material or device) that will be used in the solution.
2	Describing* criteria and constraints, including quantification when appropriate	
	a	Students describe* the given criteria and constraints, including how they will be taken into account when designing the solution.
		i. Students describe* how the criteria are appropriate to solve the given problem.
		ii. Students describe* the constraints, which may include:
		1. Cost.
		2. Mass and speed of objects.
		3. Time.
		4. Materials.
3	Evaluating potential solutions	
	a	Students use their knowledge of Newton's third law to systematically determine how well the design solution meets the criteria and constraints.
	b	Students identify the value of the device for society.
	c	Students determine how the choice of technologies that are used in the design is affected by the constraints of the problem and the limits of technological advances.

MS-PS2-2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]

The performance expectation above was 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 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Crosscutting Concepts

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Observable features of the student performance by the end of the course:				
1	Identifying the phenomenon to be investigated			
	a	Students identify the phenomenon under investigation, which includes the change in motion of an object.		
	b	Students identify the purpose of the investigation, which includes providing evidence that the change in an object's motion is due to the following factors:		
		i.	Balanced or unbalanced forces acting on the object.	
		ii.	The mass of the object.	
2	Identifying the evidence to address the purpose of the investigation			
	a	Students develop a plan for the investigation individually or collaboratively. In the plan, students describe*:		
		i.	That the following data will be collected:	
			1.	Data on the motion of the object.
			2.	Data on the total forces acting on the object.
			3.	Data on the mass of the object.
		ii.	Which data are needed to provide evidence for each of the following:	
			1.	An object subjected to balanced forces does not change its motion (sum of $F=0$).
			2.	An object subjected to unbalanced forces changes its motion over time (sum of $F\neq0$).

		3. The change in the motion of an object subjected to unbalanced forces depends on the mass of the object.
3	Planning the investigation	
	a	In the investigation plan, students describe*:
		i. How the following factors will be determined and measured:
		1. The motion of the object, including a specified reference frame and appropriate units for distance and time.
		2. The mass of the object, including appropriate units.
		3. The forces acting on the object, including balanced and unbalanced forces.
		ii. Which factors will serve as independent and dependent variables in the investigation (e.g., mass is an independent variable, forces and motion can be independent or dependent).
		iii. The controls for each experimental condition.
		iv. The number of trials for each experimental condition.

MS-PS2-3 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-3. **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	**PS2.B: Types of Interactions** • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:				
1	Addressing phenomena of the natural world or scientific theories			
	a	Students formulate questions that arise from examining given data of objects (which can include particles) interacting through electric and magnetic forces, the answers to which would clarify:		
		i.	The cause-and-effect relationships that affect magnetic forces due to:	
			1.	The magnitude of any electric current present in the interaction, or other factors related to the effect of the electric current (e.g., number of turns of wire in a coil).
			2.	The distance between the interacting objects.
			3.	The relative orientation of the interacting objects.
			4.	The magnitude of the magnetic strength of the interacting objects.
		ii.	The cause-and-effect relationship that affect electric forces due to:	
			1.	The magnitude and signs of the electric charges on the interacting objects.
			2.	The distances between the interacting objects.
			3.	Magnetic forces.
	b	Based on scientific principles and given data, students frame hypotheses that:		
		i.	Can be used to predict the strength of electric and magnetic forces due to cause-and-effect relationships.	
		ii.	Can be used to distinguish between possible outcomes, based on an understanding of the cause-and-effect relationships driving the system.	
2	Identifying the scientific nature of the question			
	a	Students' questions can be investigated scientifically within the scope of a classroom, outdoor environment, museum, or other public facility.		

MS-PS2-4 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-4. **Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*]

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

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

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

1	Supported claims		
	a	Students make a claim to be supported about a given phenomenon. In their claim, students include the following idea: Gravitational interactions are attractive and depend on the masses of interacting objects.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence that supports the claim, including:	
		i.	The masses of objects in the relevant system(s).
		ii.	The relative magnitude and direction of the forces between objects in the relevant system(s).
3	Evaluating and critiquing the evidence		
	a	Students evaluate the evidence and identify its strengths and weaknesses, including:	
		i.	Types of sources.
		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence, and why the evidence supports the given claim as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the appropriate evidence about the forces on objects and construct the argument that gravitational forces are attractive and mass dependent. Students describe* the following chain of reasoning:	
		i.	Systems of objects can be modeled as a set of masses interacting via gravitational forces.
		ii.	In systems of objects, larger masses experience and exert proportionally larger gravitational forces.

		iii. In every case for which evidence exists, gravitational force is attractive.
	b	To support the claim, students present their oral or written argument concerning the direction of gravitational forces and the role of the mass of the interacting objects.

MS-PS2-5 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.	**PS2.B: Types of Interactions** • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon to be investigated		
	a	From the given investigation plan, students identify the phenomenon under investigation, which includes the idea that objects can interact at a distance.	
	b	Students identify the purpose of the investigation, which includes providing evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	
2	Identifying evidence to address the purpose of the investigation		
	a	From the given plan, students identify and describe* the data that will be collected to provide evidence for each of the following:	
		i.	Evidence that two interacting objects can exert forces on each other even though the two interacting objects are not in contact with each other.
		ii.	Evidence that distinguishes between electric and magnetic forces.
		iii.	Evidence that the cause of a force on one object is the interaction with the second object (e.g., evidence for the presence of force disappears when the second object is removed from the vicinity of the first).
3	Planning the investigation		
	a	Students describe* the rationale for why the given investigation plan includes:	
		i.	Changing the distance between objects.
		ii.	Changing the charge or magnetic orientation of objects.
		iii.	Changing the magnitude of the charge on an object or the strength of the magnetic field.
		iv.	A means to indicate or measure the presence of electric or magnetic forces.
4	Collecting the data		
	a	Students make and record observations according to the given plan. The data recorded may include observations of:	
		i.	Motion of objects.
		ii.	Suspension of objects.
		iii.	Simulations of objects that produce either electric or magnetic fields through space and the effects of moving those objects closer to or farther away from each other.
		iv.	A push or pull exerted on the hand of an observer holding an object.

5	Evaluation of the design	
	a	Students evaluate the experimental design by assessing whether or not the data produced by the investigation can provide evidence that fields exist between objects that act on each other even though the objects are not in contact.