

## 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: <ol style="list-style-type: none"> <li>Balanced or unbalanced forces acting on the object.</li> <li>The mass of the object.</li> </ol>
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: <ol style="list-style-type: none"> <li>That the following data will be collected:               <ol style="list-style-type: none"> <li>Data on the motion of the object.</li> <li>Data on the total forces acting on the object.</li> <li>Data on the mass of the object.</li> </ol> </li> <li>Which data are needed to provide evidence for each of the following:               <ol style="list-style-type: none"> <li>An object subjected to balanced forces does not change its motion (sum of <math>F=0</math>).</li> <li>An object subjected to unbalanced forces changes its motion over time (sum of <math>F\neq 0</math>).</li> </ol> </li> </ol>

		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.		