MIDDLE SCHOOL PHYSICAL SCIENCE: FORCES AND MOTION

Standards Bundle

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon potential for related phenomena that can be used throughout a unit.

MS-PS2-1 Design a solution to a problem involving the motion of two colliding objects that illustrates Newton’s Third Law. (SEP: 6; DCI: PS2.A; CCC: Systems, Technology) [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*.]

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. (SEP: 3; DCI: PS2.A; CCC: Stability/Change) [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*.]

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

An unbalanced force is required in order to change the speed or direction of an object’s motion. The change in motion of an object is affected by the mass of the object and the size of the force applied. Forces between objects occur in pairs known as action/reaction pairs. Whenever one object pushes or pulls another object, the second object pushes or pulls back on the first object in the opposite direction with an equal force.

Phenomena

Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- A rocket is propelled up into space.
- Ripping a tablecloth off a table, the settings all stay.
- When you slam on your front bike brakes you fly over your handlebars.
- Two football players with varying masses and speeds collide head to head during a game.
- A large pickup and small car are in a head-on collision. Both vehicles come to a stop, but the front of the car has much more damage than the front of the large pickup.

Storyline

This section aims to decode not only the DCI connections, but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions ● Apply scientific ideas or principles to design an object, tool, process or system. **Planning and Carrying Out Investigations** ● 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 much data is needed to support a claim.	**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). ● 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.	**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. **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.

In this bundle, students will investigate Newton's First Law of Motion by examining and explaining how balanced and unbalanced forces, along with varying strengths of forces, impact the motion of objects. The SI Unit of force is the newton (N). The motion of an object is determined by the sum of the forces acting on it (net force). When the forces acting on an object do not result in a change in motion, the forces are balanced (net force = 0 N). For example, if two students push on opposite ends of a piano with the same amount of force, the piano will not move. However, if one of the students is pushing with more force than the other student, the piano will move. When the total force applied to an object results in a change of motion, the forces are unbalanced (net force ≠ 0 N). This concept is known as Newton's First Law of Motion (or the Law of Inertia) and is stated, "An object at rest remains at rest and an object in motion maintains its velocity unless it is acted upon by an unbalanced force."

Newton's First Law supports students in their understanding of Newton's Third Law, which can be summarized by the following statement, "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." For example, when a book is sitting on a table, the book is pushing down on the table with the same force the table is pushing back up on the book. Students can explore action-reaction pairs by modeling how motion changes through systems of colliding objects. Example systems could include: (1) a low mass cart and a high mass cart colliding (2) two carts of the same mass colliding (3) or a cart colliding with a stationary object. Students can use physical models of colliding objects or they can diagram models (free body diagrams) to explain the interaction of the objects and discuss the energy inputs and outputs involved in the systems. Students can use the models to construct an explanation for the phenomena they observe with Newton’s Third Law.

The masses of objects interacting plays a role in the amount of force applied or required to change the motion of the objects (F=ma). Providing students with opportunities to collect evidence from multiple investigations, manipulating one variable at a time, will allow them to use data to support the claim that a larger force will cause a greater change in the motion of an object when compared to a smaller force. This is known as Newton’s Second Law of Motion and is stated, “Force is equal to the mass multiplied by the acceleration of an object.”

Students can then apply Newton’s Laws of Motion to design a solution to a problem involving the motion of two colliding objects. For example, students could design a solution to minimize the impact on an object during a collision. It is beneficial to engage students in engineering design projects in which they can use science concepts to explain why a designed solution works or does not work.

Formative Assessment

Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students’ three-dimensional science learning as described in a given bundle, standard or lesson-level performance expectation.

SEP Constructing Explanations and Designing Solutions

- Describe a scenario where a bus driver slams on the brakes and all of the students hit their head on the seat in front of them. Ask students to write an evidence-based account of what caused this to happen.

SEP Planning and Carrying Out Investigations

- Present students with the scientific law that a more massive object requires more force to change its motion. Ask students to plan an investigation to test this law and describe how the investigation will generate relevant patterns of evidence to support this law of motion.

CCC Systems and System Models

- Provide students with a scenario such as pulling a wagon full of landscaping rocks versus pulling a wagon full of fallen leaves. Have students draw the parts of the system described including the extent of the forces acting on the wagon.
    - What would happen if you increase the mass in the wagon?
    - What would happen if you decrease the mass in the wagon?

CCC Stability and Change

- How might a system be affected by unbalanced forces? Balanced forces?

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain-size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Construct an explanation** *using models* to show that 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.
- **Ask questions** to *identify the relationship* between forces that are balanced and unbalanced.
- **Carry out investigations** to *provide evidence* that the motion of an object is determined by the sum of the forces acting on it.
- **Use mathematical and computational thinking** to *explain* that if the total of the forces applied to an object is not zero, its motion will change.
- **Collect and utilize data** as evidence *to test and explain* Newton's First Law of Motion (also known as the Law of Inertia), which states that an object in motion will remain in motion and an object at rest will remain at rest unless acted upon by an unbalanced force.
- **Plan an investigation** to *provide evidence* that the greater the mass of an object, the greater its inertia, requiring a greater force to achieve a change in motion.
- **Plan an investigation** to *compare the change in motion* for an object with small and large forces applied, where the larger force causes a larger change in motion.