Unit 8.1 Contact Forces

Content Area: **Science**
Course(s): **Science 8**
Time Period: **Marking Period 3**
Length: **4 weeks**
Status: **Published**

Essential Questions

Why do things sometimes get damaged when they hit each other?

- Lesson 1: What happens when two things hit each other?
- Lesson 2: What causes changes in the motion and shape of colliding objects?
- Lesson 3: Do all objects change shape or bend when they are pushed in a collision?
- Lesson 4: How much do you have to push on any object to get it to deform (temporarily vs. permanently)?
- Lesson 5: How does changing the mass or speed of a moving object before it collides with another object affect the forces on those objects during the collision?
- Lesson 6: What have we figured out about objects interacting in collisions? How can we apply our new learning to answer questions about objects interacting in collisions?
- Lesson 7: How much does doubling the speed or doubling the mass affect the kinetic energy of an object and the resulting damage that it can do in a collision?
- Lesson 8: Where did the energy in our launcher system come from, and after the collisions where did it go to?
- Lesson 9: How do other contact forces from interactions with the air and the track cause energy transfers in the launcher system?
- Lesson 10: Why do some objects break or not break in a collision?
- Lesson 11: What can we design to better protect objects in a collision?
- Lesson 12: What materials best reduce the peak forces in a collision?
- Lesson 13: How (and why) does the structure of a cushioning material affect the peak forces produced in a collision?
- Lesson 14: How can we use our science ideas and other societal wants and needs to refine our designs?
- Lesson 15: How can we use what we figured out to evaluate another engineer's design?
- Lesson 16: OPTIONAL How can we market our designs to our potential investors?

Big Ideas

Unit Summary and Storyline

Oh, no! I've dropped my phone! Most of us have experienced the panic of watching our phones slip out of our hands and fall to the floor. We've experienced the relief of picking up an undamaged phone and the frustration of the shattered screen. This common experience anchors learning in the Contact Forces unit as students explore a variety of phenomena to figure out, "Why do things sometimes get damaged when they hit each other?" Student questions about the factors that result in a shattered cell phone screen lead them to investigate what is really happening to any object during a collision. They make their thinking visible with free-body diagrams, mathematical models, and system models to explain the effects of relative forces, mass, speed, and energy in collisions. Students then use what they have learned about collisions to engineer something that will protect a fragile object from damage in a collision. They investigate which materials to use, gather design input from stakeholders to refine the criteria and constraints, develop micro and macro models of how their solution is working, and optimize their solution based on data from investigations. Finally, students apply what they have learned from the investigation and design to a related design problem.

This unit uses two anchors, one to drive student questions and investigations in the first two lesson sets off the unit, and one to drive student questions and engagement in the use of engineering ideas and the iterative design process in the last third of the unit. This unit begins with students considering national statistics on the frequency and cost of cell phone breakage. Students share situations in which they have seen cell phones break. Students then contrast these situations with other situations where something else collided with another object and either did break or, surprisingly, did not break. Students then attempt to identify the factors that contribute to damage occurring in some collisions and not others, as well as try to explain what is happening during the collision that causes some items to become damaged in a collision, when others are not. Students then develop a Driving Question Board (DQB) to guide future investigations.

This introduction, using a commonly broken and widely used device, allows students to engage in the investigation of ideas regarding energy and forces in a collision. The ideas of deformation and breaking point examined in Lesson set 1 apply widely to phone use, as some collisions result in damage while others surprisingly do not. In Lesson set 2, students also have the ability to re-examine how different collisions can lead to damage or no damage on their devices. Lesson set 3 re-anchors students thinking about the question of why some phones still break when in protective cases. They identify an object of their choice to design protection for in a collision, they define related criteria and constraints for such design solutions and they develop initial models for why their solutions would affect the outcome of a collision. Students then add new questions to their Driving Question Board (DQB) to guide future investigations.

Enduring Understandings

NGSS Performance Expectations

Physical Science PEs

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.]
MS-PS-2-2 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 and in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]
MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]
MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
The following PE will be developed over three OpenSciEd units: OpenSciEd Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit), OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit), and OpenSciEd Unit 8.2: How can a sound make something move? (Sound Unit). This unit will address only the mechanical inputs that transmit signals to the brain through touch. The other units will address electromagnetic and other mechanical inputs (sound) and chemical inputs as well as the connection to signals processing in the brain. This unit, however, does make an important connection to how those signals are stored as memories and how damage to particular structures (axons on neurons) can cause memory loss in concussions.

MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. [Assessment Boundary: Assessment does not include mechanisms for transmission of this information.]

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).
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.
PS3.A: Definitions of Energy

Motion energy is properly called kinetic energy ; it is proportional to the mass of the moving object and grows with the square of its speed.
ETS1.B: Developing Possible Solutions

There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
ETS1.C: Optimizing the Design Solution

Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
LS1.D: Information Processing

Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.
Besides the disciplinary core ideas that are part of the foundation boxes for the target PEs in this unit, additional connections to the following DCIs are also developed and used in this unit:

PS3.B: Conservation of Energy and Energy Transfer

When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.
PS3.C: Relationship Between Energy and Forces

When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Crosscutting Concepts

While this unit engages students in multiple CCCs across the lesson-level performance expectations for all the lessons in the unit, there are four focal CCCs that this unit targets to support students' development in a learning progression for the CCCs across the 8th grade year: Systems and system models; Energy and matter; Structure and function; Stability and change.

Cross-Curricular Integration

Additional Mathematics and ELA integration can be found within each lesson plan.

Mathematics Integration

In general, this unit is taught using a conceptual approach to describing the relationship among force, mass, and change in motion during collisions, students need only have experience with qualitatively reasoning about positive and negative associations (e.g., as force increases, change in motion increases; but as mass increases, change in motion from a given force decreases). But because the focus of MS-PS3-1 is on quantitative understanding of the relationship of the kinetic energy of an object to the mass of an object and to the speed of an object, students will need to leverage the following experiences from grade 7 Common Core Math Standards math to use in this unit in Lessons 7 and 10.

In lesson 7, students will be working with unit rates and ratios. By the beginning of 8th grade, students should be well versed in how to do this calculation. It will be leveraged in Lessons 7 and 10 of this unit when students recognize that the relationship between mass and kinetic energy is directly proportional. Such a relationship is one they have encountered in graphs many times in Common Core mathematics since 6th grade. Recognizing the relationship between speed and kinetic energy as nonlinear will also be straightforward. But describing the change in kinetic energy as being related to the square of the speed of an object will be challenging. Students will have encountered working with squared relationships in 6th grade in finding the surface area of a cube with sides of length s, and in 8th grade they will be working with squaring the side lengths of a right triangle in their work with the Pythagorean theorem. Coordinate with your math teachers to determine where you students will be at in their familiarity with thinking about relationships like these.

In lesson 7 students calculate and use a type of ratio called a scale factor. They will use this idea again in the lesson 10 assessment and potentially again in lesson 16 as they develop a scale model of their designs. Students will have encountered this concept before in math class in one or both of these contexts:

7.G.A.1 Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
7.RP.A.2 Recognize and represent proportional relationships between quantities.
There are multiple connections between the work students will be doing in Lesson 7 and the work they will be doing in math class this year (grade 8). These include the following:
8.F.B.5 Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear).
8.EE.A.1 Know and apply the properties of integer exponents to generate equivalent numerical expressions.
In lesson 4, students are introduced to lines of best fit in Lesson 4. They see an example of such a line again in the Lesson 10 assessment. Students do not have to have encountered this idea in previous mathematics instruction. Lesson 4 assumes that this may be the first time students encountered this idea.

Diversity Integration

Connect physics to real-world applications and social contexts
Just as understanding contact forces helps us predict and control the movement of physical objects, understanding the dynamics of diverse interactions is crucial for creating successful and inclusive organizations and communities. Promoting positive "contact" and interaction between individuals of different backgrounds can lead to stronger, more innovative, and more equitable environments.

Labs and Resources

Scientific Inquiry

Energy Transfer in Motion

Objective:
Students will construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

Reflection Questions:

● What happens to the car’s energy as it moves down the ramp?
● How does the ramp's height affect the speed of the car?
● Can you think of a real-life example where energy is transferred in a similar way?
Assessment:

● Write a short paragraph explaining how energy is transferred in this experiment.
● Present your findings to the class.

Science and Engineering Practices

While this unit engages students in multiple SEPs across the lesson-level performance expectations for all the lessons in the unit, there is one focal practice that this unit targets to support students' development in a learning progression across the 8th grade year for the SEPs:

Planning and Carrying Out Investigations
In addition, there are three supporting practices that students will utilize over the course of the unit: Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Engaging in Argument from Evidence.

Science and Society

Isaac Newton: His three laws of motion are fundamental to understanding how forces affect the motion of objects, including those involved in collisions. His laws describe the concepts of inertia, the relationship between force, mass, and acceleration, and the principle of action-reaction.

Newton's Laws and Collisions:
Newton's Third Law: When objects collide, they exert equal and opposite forces on each other. For example, when a bat hits a ball, the force on the ball is equal to the force on the bat, though the acceleration of the ball is much greater due to its smaller mass.
Newton's Second Law: The acceleration an object undergoes is dependent on its mass and the force applied to it (F=ma). This helps explain how forces during collisions cause changes in objects' motion.

CSDT Technology Integration