7.1.2 Forces Are Interactions Between Matter

Unit:	Utah SEEd Standard / NGSS Performance Expectation:	Time:
7.1.2 Apply Newton's Third Law **to design a solution** to a problem involving the motion of two colliding objects in a system.	**SEEd 7.1.2 FORCES ARE INTERACTIONS BETWEEN MATTER**: Apply Newton's Third Law **to design a solution** to a problem involving the motion of two colliding objects in a system. Examples could include collisions between two moving objects or between a moving object and a stationary object. (PS2.A, ETS1.A, ETS1.B, ETS1.C)	Two 45-minute class periods

Access to all material for this lesson: Link to final lesson folder

Anchor Phenomenon	Cars crashing past to present Car Crash 1930 video
Driving Question(s)	How has engineering addressed protecting the pringle caused by collisions? In the zipline system, design a solution to protect "Mr. P" in a collision, applying Newton's Third Law.
Performance Task	Apply Newton's Third Law to **design a solution** to a *problem involving the motion of two colliding objects in a system.* Design, test, improve, and retest a device to protect a pringle from a collision.

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Lesson Summary:			
	Time	**Guiding Question / Learning Objective**	**How are students answering the guiding question or meeting the learning objective?** (Highlight the SEPs, DCIs, and CCCs in the corresponding color.)
Engage	3-5 min	Phenomena Car Crash 1930 Cars colliding with stationary and moving objects. What changes have been made to protect humans? Information/Review Newton's 3rd Law Astronauts Newton's Third Law (1:55-2:56) Newton's Third Law (3:24-5:10)	Students observe the collisions in the video. What happened to the vehicle and passenger? How are today's vehicles different? Students are able to define Newton's 3rd Law of Motion.
Explore	20 min	In the zipline system, design a solution to protect "Mr. P" in a collision, applying Newton's Third Law. Demonstrate Pringle going down a fishing line to crash into a wall. Assure that students understand that we use scientific principles to solve engineering problems. Define the system model. What are the parts of the system model? Review the engineering process that students will be doing.	Students are given a simple example of the solution they need to design. Students are introduced to system models and identify the parts in the zipline model. The students will discuss and understand the engineering process. Students will be ready to design a solution to protect their pringle.
Explain		Students are given the constraints and limitations. Students draw a design individually. They build a chosen design in student groups.	Students will ask questions and ensure they understand the engineering project's constraints and limitations. Students will design, build, and test a prototype for their device to keep "Mr. P" from damage. In a group, students design a device to protect "Mr. P."

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Elaborate		Design and build a device for protecting a pringle chip.	Students will test a prototype for their device to keep "Mr. P" from damage.
Evaluate	15 min	Final Test What was successful about your design? How would you improve your design? Students develop a model of the system showing the forces that saved Mr. P. This evaluates their understanding of Newton's 3rd Law of Motion, system models, and designing a solution.	Students will test the solution they designed. Students will be able to explain how their solution design was successful and ways to improve it. Students will identify action/reaction forces.

Three Dimensions Focused on in This Lesson		
Disciplinary Core Idea: [NGSS Appendix E] **7.1.2:** Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects in a system.	**Science and Engineering Practices:** **Design a Solution** [NGSS Appendix F] • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.	**Crosscutting Concept:** **Systems and System Models** [NGSS Appendix G] Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study.
Learning Objectives - Design a solution to protect "Mr. P" in a collision - **Utah SEEd Standard 7.1.2** **Apply Newton's Third Law to design a solution** to a *problem involving the motion of two colliding objects in a system.* Examples could include collisions between two moving objects or between a moving object and a stationary object. (PS2.A, ETS1.A, ETS1.B, ETS1.C)		

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Related Knowledge and Skills from Prior Grades		
Disciplinary Core Idea: NGSS Appendix E **Grades K – 2** Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it. **Grades 3 – 5** The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	**Science and Engineering Practices:** **Design a Solution** NGSS Appendix F Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. Construct an explanation of observed relationships (e.g., the distribution of plants in the backyard). Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. Identify the evidence that supports particular points in an explanation. Apply scientific ideas to solve design problems. Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	**Crosscutting Concept:** **Systems and System Models** NGSS Appendix G **Grades K-2** Students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together. **Grades 3-5** Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions.

Connections to Mathematics and ELA/Literacy Standards	
ELA/Literacy Standards: **English Language Arts:** • **RST.6-8.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. • **RST.6-8.3:** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. • **WHST.6-8.7:** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	**Mathematics Standards:** • **MP.2:** Reason abstractly and quantitatively. • **7.EE.B.3:** Sole multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

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Materials

Handouts	Lab Supplies	Other Resources
Crash Test Pringle Worksheet Crash Test Rubric	Materials: • One sheet of 8.5x11 paper • 15 cm of tape • Tinfoil sheets, same size as paper • 1 Straw • Clear Filament (fishing line) • Pringles – enough for 1 per group • ½ inch PVC pipes cut 1" long for each group class period • Scissors • Fishing swivels (optional) makes it easier to attach/un-attach • Rulers • Optional make a container that is 10x8x5 cm for students to observe or place their design in to make the limit of the size easier for students and teachers.	Video Links Car Crash 1930 Newton's Third Law (3:24-5:10) Astronauts Newton's Third Law (1:55-2:56) Slide presentation link Crash test Pringle Presentation Timer in slide show; - Install Google Slides timer in Chrome Extensions - Go to the "Slides Timer" website and select 'add extension.' - Watch the video to see how to change the countdown, etc.

ENGAGE

Slide 2: Show video: Car Crash 1930 As you watch the video, think about observations you can share. • Have students share in pairs so all have a voice to share thoughts. (about 30 seconds) **Slide 3:** Whole class discussion: (Draw on students' prior knowledge of safety features of cars. 2 minutes) • What happened to the vehicle and passenger? • How are today's vehicles different? **Slide 4:** Have students recognize the exact wording of Newton's Third Law of motion. **Slide 5:** Show video: Astronauts Newton's Third Law (1:55-2:56) **Slide 6:** Show video: Newton's Third Law (3:24-5:10) • During the video, describe the equal and opposite forces being shown.	**Teacher Tips:** - Possible student ideas: seatbelts, airbags, crumple zones, tempered glass, and vehicle material - Be sensitive to student triggers of car crash experiences. - Remind students there are no other forces in space. - Point out the arrows in the astronaut video showing the opposite forces. - Arrows can be drawn on the other examples in Newton's Third Law video. Emphasize the size of the arrows for mass and the opposite forces shown in the examples.

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- Teacher can pause after each collision to look for student understanding of action/reaction forces.

Assure that students understand that we use scientific principles to solve engineering problems.

Distribute student worksheets.

EXPLORE/Define Design (ETS1.A)

Worksheet #1: Have students describe Newton's Third Law.

Slide 7: Share objective: In the zipline system, design a solution to protect "Mr. P" in a collision by applying Newton's Third Law

- Teacher transitions to the demonstration.
- Demonstrate the PVC on a test wire, showing there will be a collision and what it does to the Pringle. (One inch of ½ inch PVC with a pringle, attached to the bottom with hot glue, goes down a fishing line zipline from at least teacher height to six inches to a foot above the ground, crashing into the wall)
- Tie Newton's Third Law back into the demonstration.

Slide 8: Teacher describes the parts of the system and why they are a system (i.e., parts interacting together as a whole). Encourage students to identify which part of the system they will be modifying.

Slide 9: Students describe the system and its parts. (Fishing Line, PVC, Pringle, Wall)

Worksheet #2: Students list the parts of the system

Worksheet #3: Students define the problem

- Guiding Question: *How can we protect the pringle (Mr. P)? from* shattering when it collides with the wall?

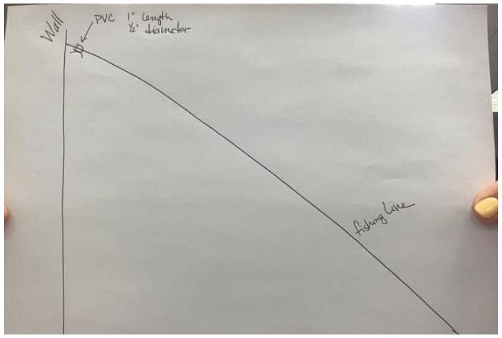
Check that students have answered questions 1-3 on the worksheet.

- Make sure students are correctly identifying the problem for question #3

Slide 10: Discuss / Review Engineering process (Ask, Imagine, Plan, Create, Improve)

Teacher Tips

- Test the zipline before the lesson begins.
- Have students summarize what they learned from the videos about Newton's 3rd law.
- Demonstrate the zipline system to the students. Send just the chip down the zipline without any protection. **You want the chip to break**.
- What the zipline setup should look like:



- Questions you may want to ask: What are the parts of the system you just observed? Which parts are interacting together as a whole?
- Define the problem by focusing on the guiding question: How can we protect the Pringle?
- As you review, let the students know that the

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	engineering process does not go in sequential steps but will flow from one step backward, forward, and/or skip steps until there is enough iteration to create the desired product.

EXPLAIN/Develop Design (ETS1.B)	
Slide 11: Show students the constraints for their project. Designing Constraints: • Time Limit: Class Period minus 15 min. • Materials: One sheet of 8.5x11 paper, 15 cm of tape, Tinfoil that is same size as paper, 1 Straw, 1 piece of PVC • Size limit of vehicle: 10 x 8 x 5 (cm); Pringle size: 6.5 x 4.5 x 1.7 (cm) Give students the time that the final design must be completed. You can set the time for each class period on the slide show. (See Materials, Other Resources for how to set up the timer.) **Slide 12 Part 1** • Give students one minute to draw their design ideas individually on their worksheets. **Worksheet #4** Design Idea first box Put the students into their groups (2-3 per group) **Slide 12 Part 2: Design** • After sharing with their partners, groups need to come to a consensus on a final design. **Worksheet #4 Final Design (second box)** • Draw or add a picture of their final design to the student worksheet.	**Teacher Tips** - Answer questions about the constraints. - Give students completion time for design. Have them write the time on their worksheet under constraints. - Giving students time to draw their designs will help them get ideas before sharing. - Emphasize the importance of group work—listening/sharing each other's designs and using correct communication, such as "I like what you have and I would like to add..."; I disagree that ____ will work, so what do you think about ____?" - Put students into groups. Depending on your class, you may let them choose, do a classroom shuffle (such as pair up, share their design, find another partner, share their designs, then pair up again), or assign groups. - Suggest having no more than 3 in each group. - Ensure students draw their final design on the worksheet.

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ELABORATE/Optimizing Design (ETS1.C)

Set timer. **Test/Retest: Give students until the end of the first day and about 10 – 15 minutes at the beginning of day two to prepare for the final test on the 2nd day.** **Worksheet #5** • Make sure students fill in the table "What worked?" "What failed?" and "Improvements/Evaluation." Check for the final design by having students explain it to show understanding. Distribute supplies to groups. Students build, test, and redesign at their test stations, recording on the student worksheet what happened on each test and any improvements they made. Students may create a substitute test subject since they won't be given a pringle until the final test. Students will take or draw pictures for each prototype,	**Teacher Tips** - In real life, dummies are tested and not real people. - Time saver tip: have supplies ready for each group beforehand. - Test Stations are miniature versions of the final test setup at each table. - Ensure you have a timer to stop testing to leave time for the final test. - Make sure students are filling in the table for each prototype. - The teacher should visit each group and use guiding questions to help groups progress, such as "What about your design doesn't work? What are you going to do to fix it? How are you planning on using this material?" - Encourage students to focus on force rather than energy.

EVALUATE

FINAL TEST RUN to protect the Pringle chip. Allow one person in each group to showcase their design while the other is threading the fishing line through their device. **Worksheet #6** Circle how well Mr. P survived with their design. **Worksheet #7** Individual Activity on Worksheet • What was successful about your design? • How could you improve your design? **Worksheet #8.** Students develop a model of the system showing the forces that saved Mr. P. Randomly pair students to present their system models (#8) to each other.	**Teacher Tips** - This activity could lead to a discussion on learning from failures. - Emphasize that students need to make observations of each of the other designs made in class. - Students can determine what they could improve from successful designs to answer #7 on their worksheet. - Walk around and ask students questions about their models. Try to have them delve deeper into showing the forces involved.

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Self-evaluation rubric: Each student could use the rubric for self-evaluation, or the teacher could use it for final evaluation. Whole class discussion or small group discussion on successes and failures	- Review force arrows as needed. - Encourage students to identify other forces such as friction, gravity, etc. Ask clarifying questions to help students develop their models.

POSSIBLE EXTENSION / ALTERNATIVE ADAPTATIONS

Have students share their model with another student and use the self-evaluation rubric to evaluate another student's model.

Students could research any of the following to further investigate how we design solutions for different types of collisions:

- Mars Rover (Link to NASA) Video of Spirit Rover landing Video of Perseverance Rover landing (2020)
- Phone Cases
- Football Helmets/Pads (Link 2)
- Parachutes/Bungee Cords
- Phet Simulation Collision Lab

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