## Big Idea/ Topic

**Forces, motion, and energy conservation**

## Standards Alignment

**SP2. Obtain, evaluate, and communicate information about how forces affect the motion of objects.**

- a. Construct an explanation based on evidence using Newton’s Laws of how forces affect the acceleration of a body.
  - Explain and predict the motion of a body in absence of a force and when forces are applied using Newton’s 1st Law (principle of inertia).
  - Calculate the acceleration for an object using Newton’s 2nd Law, including situations where multiple forces act together.
  - Identify the pair of equal and opposite forces between two interacting bodies and relate their magnitudes and directions using Newton’s 3rd Law.

- b. Develop and use a model of a Free Body Diagram to represent the forces acting on an object (both equilibrium and non-equilibrium).

**SP3. Obtain, evaluate, and communicate information about the importance of conservation laws for mechanical energy and linear momentum in predicting the behavior of physical systems.**

- c. Plan and carry out an investigation demonstrating conservation and rate of transfer of energy (power) to solve problems involving closed systems.

## Connections to other content:

**ELAGSE9-10RI8:** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning.

**ELAGSE9-10SL4:** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance and style are appropriate to purpose, audience and task.

**ELAGSE9-10W7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem, narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
PHENOMENON: Rockets are large and extremely heavy, yet they lift off.

ENGAGE:

Rocket Launch Video: Begin by showing students a short video of a rocket launching off. Conduct a discussion to assess prior knowledge of students concerning rockets. Have students develop initial models of what forces act on a rocket at various points in a flight. These models can be shared and discussed among students; initial models can be improved or adjusted as the lesson continues.

This lesson is designed to give students a basic understanding of the physics of launching rockets. Some resources found in this lesson are from Soda Straw Rockets: NASA Jet Propulsion Laboratory, a free website for teachers; the activity includes an educator guide.

Unplugged: This can be done without technology if the teacher wants to display or send home pictures of rockets launching.

EXPLAIN:

Teacher Instruction: Guide students through the formulas needed to generate enough energy to launch a rocket as well as how Newton’s Laws of force apply to motion.

Present student with various scenarios of forces and objects in motion. Students complete the Free Body Diagram Simulation form PhET (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu). Students complete the activity sheet as they move through the scenario.

Unplugged: This can be done without technology by providing students with printed copies of the diagrams and information and printed copies of the simulation.

EXPLORE:

Teacher Instruction: Review the Engineering Process with students emphasizing that it is a CYCLICAL PROCESS, and it can move in either direction if necessary.

Divide students into small groups or pairs and give each the Straw Rocket Student Packet; this sheet is a GUIDE and they are responsible for assembling their designs so they need to be something they can actually build.

Unplugged: This entire activity can be completed without technology. Students will need access to
EXTEND:

As students are conducting trials of the straw rockets, build on the discussions of force by introducing the concept of energy conservation. As students gain familiarity with the equations and concepts, they can use their straw rockets to test and calculate various components of energy conservation. Energy conservation could also be addressed in this section of the lesson through the roller lab in GPB’s Physics in Motion series. An additional or alternative format would be to use an online simulation, such as PhET lab Energy Skate Park or Energy Forms and Changes, where energy forms and changes are seen/played with. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu).

If time permits, allow students to build an entirely new rocket from the lessons learned from their first prototype.

EVALUATION:

You can have students answer assessment questions either individually or as a group as they complete the rocket or during the activity.

- Why was your rocket launch a success or failure? (Listen to each group’s description.)
- What factors contributed to the success or failure of your prototype rocket launch?
- If you could redesign your rocket, using the same procedure, what would you do differently to improve its flight?
- What could you do to make your rocket fly straight?
- What steps of the engineering design process do engineers follow when creating any system or device? Which steps did you go through in this activity?

Unplugged: This can be completed without technology. Students will need to complete assessment with printed copies or verbally.

<table>
<thead>
<tr>
<th>Evidence of Student Success</th>
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<td>Student mastery is assessed throughout this unit using formative and summative components. Student discussion, explanations and products should reflect the understanding indicated in the sections above. Each activity in the segment functions as an assessment opportunity as well to plan targeted supports or provide extension items. Formative options using the self-evaluation checklist and at various points during the segment.</td>
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<th>Student Learning Supports</th>
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Georgia Department of Education
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5.15.2021 Page 3 of 8
The vision for science education in the state of Georgia is as follows: All Students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.

The learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions.

This lesson includes the disciplinary core ideas, science and engineering practices and crosscutting concepts to actively engage students in exploring science concepts with real world topics. As part of the vision, we must support the inclusion of all students in science learning. Some general ideas to consider when designing things to support students that struggle are as follows:

- Be sure that students can access the information that you they are learning. Make sure that you can answer the following questions:
  - Do students have what they need to get the information? This is about them having the book or internet access to get to the information.
  - Once students obtain the information, are students able to determine what information is important? This is about the students having materials on the appropriate grade level and that is in a format that students can understand.
  - Is the material presented in multiple ways that allows all students to interact with information in a way that works for them? Such as video, audio, and articles.
  - Consider read aloud as a potential option for students that have reading deficits as an option to assist students in accessing the material. This could be done using video, read aloud or via phone.

- Students may need ideas about where to find information. Providing students with information about what a reliable source is and even where to find reliable sources may be beneficial for students.

- Some students may find it difficult to complete the entire lesson workload. Some students may benefit from a reduced workload (note: this should be used only when absolutely necessary). Be sure that the information that is removed will not negatively impact the student’s understanding of the disciplinary core idea.

- Consider how students show their knowledge. Students need multiple ways and opportunities to show their knowledge. Things to consider:
  - Recording video or audio
  - Drawing
  - Writing
  - Typed
  - Verbal

- Provide students with a way to ask questions in a forum that does not cause anxiety. Frequently students do not want to ask questions in front of their peers because they are afraid of what their peers may think of them. So, be sure to provide students a way to ask questions that is private or anonymous.
• Consider materials that students need to complete the assignments.
  o Do students have needed materials?
  o What are some alternative materials that students may have available to them?
• Have a clear and consistent set of guidelines for providing consistent feedback to all students.
• Utilize graphic organizers such as those from the Wonderofscience.com
• Use high leverage and evidence-based practices to reach all students.

Some ideas for supporting this lesson specifically would be to make sure to consider the following:

• The teacher should consider having students make observations about rocket launches from images if video is not available.
• The teacher may need to consider showing the videos of rocket launches more than once so that students can make observations.
• The teacher should have students discuss their observations. The students may notice some of the same things and some different things about the rocket launches.
• The teacher should consider giving students a blank template of a rocket to begin their model of the rocket.
• The teacher may need to repeat directions to students as needed throughout the lesson.
• The teacher should consider having a read aloud option for any text or directions that students need to read.
• The teacher should consider repeating directions for the hands-on activities as needed for students.
• The teacher should consider providing students with a data table and/or graphic organizer organize thoughts and ideas in the design process of the rocket.
• The teacher should consider having a list of alternate materials that students can use at home for the roller coaster lab.
• The teacher may want to have students compare their straw rockets with the rocket launch from the beginning of the lesson. Students should note similarities and differences between the two launches and discuss why they are the same/different.
• The teacher may want to remind students of lab safety procedures for launching their straw rockets.
• The teacher should provide some time for students to edit their diagrams and models as they gain new information throughout the lesson.
• The teacher may want to consider giving students the assessment rocket launch questions in advance so that students may formulate thoughtful responses as they work.
• The teacher may want to consider using one of the PhET simulations as additional investigations and practice for students as they work.
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<td>Connect to Georgia Home Classroom resources and the GPB Digital Series for high school physics, <em>Physics in Motion</em></td>
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Free Body Diagram Simulation

Directions: Read the background section and then use the Phet simulation [here](https://phet.colorado.edu) to complete the questions. Answer on your own paper. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; [https://phet.colorado.edu](https://phet.colorado.edu))

Background: A free Body diagram, or force diagram, helps us approach and solve physics problems by representing forces. There are a few guidelines about force diagrams:

a. An object is usually simplified by just drawing a box or circle to represent whatever object we are studying. You do not need to spend time accurately drawing the object.
b. Each individual force is represented with an arrow; it starts on the object and points in the direction that it acts. Only forces get arrows—nothing else.
c. Each force arrow (vector) must be labeled.
d. Every force that is acting on the object must be included in the force diagram

Practice: Draw a force diagram for the following situation:

A box is pulled to the right across a flat surface. Construct the diagram and check your result with your partner.

Lab questions:

Net Force

1. Open the Net Force simulation. Before adding any people to the tug-of-war, draw a force diagram of the stationary cart.
2. Add players to make the red team win. Draw a free body diagram.
3. Describe how to make a tie with a different number of players from the red and blue teams.
4. Start the sim with two small red players only, hit go. After the cart starts to move, add the large blue player. What happens? Draw a force diagram of the situation. Also, construct a position-time graph for this entire trial.
5. Make each side have equal players in order for the forces to be balanced. Hit go. Remove one of the red players, wait for the cart to start moving, and then put the same player back. Describe the motion of the cart. If the forces are balanced, why does the cart continue to move?

Motion

6. Open the Motion tab. Check all boxes in the upper right, so values are displayed.
7. Apply a large force to the girl. Draw two force diagrams for this part: one diagram while the girl is being pushed and another for after the pusher lets go. After the pusher lets go, what happens to the speed? Explain why this happens.
8. Load the skateboard with two crates and the fridge. Apply a constant 50 N force by clicking the right arrow once. The pusher will remain. What is different about the speed now compared to when just the girl was on? Draw a force diagram of this situation.
9. How does this part of the sim illustrate the law of inertia?
Acceleration

10. Open the acceleration tab. Check all boxes in the upper right so values are displayed. Apply a constant 50 N force to a crate.
11. How does the acceleration value change?
12. Explain how you can get the acceleration to be zero, but have the crate still moving. Draw a force diagram of this.
13. As the crate is moving with friction, describe the relationship between the applied force, friction force, and the sum of forces.
14. Is it possible to have a non-zero value for acceleration and the sum of forces be zero? Explain.