MITIGATING FORCE DURING IMPACT: Newton’s Third Law of Motion in Action

Lesson Plan for Grades 6 - 8, Science
Duration: 120 minutes

SUMMARY

From bubble wrap surrounding glass plates to helmets protecting the heads of football players, there are so many ways we use to try to keep objects, including us, safe. All of these methods are meant to limit the force of impact if an object is hit, but have you noticed some materials limit the force of impact better than others? Is there a way we test a material to see how well it limits the force of impact when two objects collide to decrease the likelihood of an object breaking or an injury occurring?

During this lesson, students will put on their engineering hats to answer this question! They will use their understanding of Newton’s Second Law of Motion to observe how force is affected by both the mass and the acceleration of an object and determine ways in which people mitigate the effects of force while learning about Newton’s Third Law of Motion. Students will be immersed in a storyline, reflective of the Next Generation Science Standards pedagogy. For this storyline, students will be required to determine which material to use to keep the cargo, a fragile robot, inside a spacecraft safe during its descent onto the surface of Mars.

To accomplish this challenge, students will conduct impact tests by placing pieces of various materials in a device that will obtain the force of impact to determine which has material is best to pack their robot in during its descent. Students will use their data to support their claim. In the next lesson, students will develop a model of a spacecraft with their cargo inside to see if their claim is valid – it’s an eggdrop, of course!
ENGINEERING CONNECTION

During this investigation, students will be working as engineers at NASA to find a solution to a real world problem! Students will be employing several of the science and engineering practices as outlined by Next Generation Science Standards. At the end of the investigation, students will be using their data collected in lab to develop a solution to the problem.

EDUCATION STANDARDS

1. Next Generation Science Standards.
   a. MS-PS2-1. Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects
2. International Technology and Engineering Educators Association
   a. Students will develop an understanding about design. This includes knowing about:
      i. Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. (Grades 6 - 8)
      ii. Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions. (Grades 6 - 8)
      iii. Design involves a set of steps, which can be performed in different sequences and repeated as needed. (Grades 6 - 8)

OBJECTIVES

1. Students will be able to plan and carry out an investigation to determine (1) force of impact on a material during a collision, and (2) which material has the lowest force value during a collision to mitigate the effects of a force of impact.
2. Students will be able to use their data to create a claim to answer the investigation question, identify evidence that supports their claim and provide reason to how their evidence supports their claim.
MATERIALS NEEDED

1. Impact Tester
2. Accelerometer
3. Load Cell (measures force)
4. Go!Link
5. Chromebook
6. Tape
7. Materials to test (cut to 1” x 1”):
   a. Cardboard
   b. Bubble Wrap
   c. Yoga Mat
   d. Styrofoam

INTRODUCTION/MOTIVATION

During this activity, introduce students to the story line. One of my favorite ways to do this, as highlighted by NGSS, is by presenting students with a phenomenon. Since our activity focuses on landing on Mars, your phenomenon could be the landing of the Mars Rover. Here is a link to a great video. There are several approaches you could take to pique interest. One example would be to have students create a driving question wall based on questions they may have regarding this phenomenon. You might ask,

“On a sticky note, record ONE consideration that will impact the success of the landing of the Mars Rover when the Mars Rover collides with the surface of Mars. Consider the DESIGN of the spacecraft, its movement through the atmosphere and the outcome of coming in contact with the surface of Mars.

You will have ONE consideration per sticky note. (Hint: How can you build a successful design? Consider what you KNOW about FORCE and ENERGY and what you still need to learn).”

Students could post their considerations within a group of 3 to 4 other students or as a class. Next, they could remove duplicates and create a driving question wall or board. To do so, have students sort these questions into categories that your class could explore later in the unit.
Ideally, one group would have listed considerations such as, “limiting the force of impact,” and “the material the craft is made out of.” If not, ask guiding questions that will assist students to identify these considerations. As always, if students are stuck, use a visual model to help, or ask probing questions based on concepts that elicits relatable, prior knowledge, such as, “How are ways that people prevent their cellphones from breaking?” “Do all phone cases provide equal protection?” From there, ask students additional questions such as, “How can we limit the force of impact when the spacecraft lands on Mars to keep our robot safe,” or “How would changing the material affect the success of landing?” Here, the goal would be to have students identify that changing the material mitigates the effects of force during the collision.

After students have identify these variables, share out a problem related to the phenomenon and assign them a role in solving the problem. Here is an example.

Congratulations! You have recently hired by NASA as an engineer on a special team of fellow engineers and scientists working on determining if there is life on Mars! The goal of your team is to safely deliver a fragile robot to the surface of Mars. The robot will travel inside of a spacecraft and emerge from the spacecraft after landing. The robot will examine the surface of Mars and transmit pictures back to Earth. Scientists will evaluate these images and determine if there are any signs of life!

Soon, it will be time to land that spacecraft on the surface of the Mars, but there are some details that need to be considered. The trip to Mars is a very long one that requires a lot of jet fuel. Your fellow engineers will be responsible for building a spacecraft that will make it to Mars’ atmosphere, but YOU will be responsible to make sure the robot inside of the spacecraft is safe once it meets Mars’ atmosphere, during its descent and when it lands on the surface of Mars.

Pose this anchoring question to students: **How can we limit the force of impact to keep an object safe when it collides with another object?** This question is essential to ensure students are aware of exactly what they are investigation. Now it is their job to figure out how to do it!

Since this lesson is centered around developing a solution to solve a problem regarding the motion when two objects collide, it is essential for students to understand the principles behind Newton’s Third Law of Motion. Here is a reading called, **Ask the Expert: Finding Evidence to Support Our Investigation** that concisely explains Newton’s
Third Law of Motion and requires students to connect their understanding back to the phenomenon we are investigating.

Once they have done their research, we can now start the investigation! Introduce students to the device they will be using to measure the force of impact. Model how this is used to the students. Show them how to read the force value using the device. While modeling, remind students of the importance of safety during investigations. Depending on the device you are using to measure force, the safety precautions may vary. For further information about the device I used, in addition to the safety precautions I share with students, please see please refer to the lesson background and concepts for teachers.

Assign students to groups of three to four. Next, hand out Planning the Investigation worksheet. Once students have planned their investigation, they are ready to start collecting data.

Each group should have a device to measure the force of impact and a basket with the materials to test. Just like engineers and scientists, students should be mindful of the data they collect. This worksheet on Collecting Data requires students to collect both qualitative and quantitative data and encourages students to ask questions along the way. Once students have finished their data collection, please provide them with the Understanding Outcomes: Analyzing and Interpreting Data worksheet. During this portion of the activity, groups will analyze their own data, but also share out their data with a nearby group.

Next, students are ready to use their data to make a claim, or provide a solution to the investigation question. This worksheet titled, Constructing Explanations and Designing Solutions, CER is in the CER-format which requires students to make a claim, provide evidence to support the claim and explain their reasoning. While your students are working on this task, write the following questions on the board: Does their claim support the investigation question? Does their evidence support their claim? Is their evidence good evidence? Why? Does the reason they give connect the evidence and the claim?” These questions will be used during a class share out when they finish their individual worksheets. As students share individually, ask the students in the audience to answer the questions you posted on the board and provide feedback to the student as they share. You can have one member from each team share if this is best for your class.

In the next lesson, students will take what they learned during this investigation and
create a device for an eggdrop! Here, they will really see if their claim was valid.

**LESSON BACKGROUND and CONCEPTS FOR TEACHERS**

This activity focuses on teaching Newton’s Laws of Motion using the 3-dimensional model as outlined by the Next Generation Science Standards. If you are unfamiliar with these standards, please click [here](#) to learn more.

This activity is founded on the assumption that students understand what a force is and can apply this knowledge to better understand their world! A *force* is a push or a pull on an object. From gravity pulling us towards the center of the Earth, to our seatbelts pulling us back when we stop in a car too fast, forces have two things in common.

1. **Magnitude**
2. **Direction**

Forces are responsible for movement; they cause objects to start moving, stop moving, or stand still. The force exerted on an object can be calculated by multiplying the mass of an object by the acceleration of the object. The equation is:

\[ F = \text{Mass} \times \text{Acceleration} \]

The units for force is Newtons, named after Sir Isaac Newton. Through observation and mathematical analyses, Sir Isaac Newton developed a set of laws that provide explanation to the nature of forces and motion. These laws are referred to as Newton’s Laws of Motion. Newton’s Laws of Motion are a fundamental principle in the world of physical science and outline the nature of forces! Here, let’s go over what these laws are so we can better understand them when we teach them!

**Newton’s First Law of Motion.** *An object at rest stays at rest and an object in motion stays in motion moving at a constant speed in the same direction until acted on by an outside force.*

Newton’s First Law of Motion is also referred to as *The Law of Inertia.* Inertia is an object’s resistance to either stop moving if in motion, or start moving if at rest. Consider this: You are driving in your car with your seatbelt on. Suddenly, a truck pulls out in front of you and you slam on your brakes. You continue to move forward and your seatbelt pulls you back, thankfully! Due to Newton’s First Law of Motion, you continue to
move forward although the car has stopped, but eventually, because of your seatbelt, you are pulled towards your seat, stopping shortly after your car.

When an object is in motion, the sum of the forces, termed net force, acting on the object are unbalanced; the net force does not equal zero. As previously stated, all forces have both magnitude and direction. Consider two people trying to move a piano to the right in the same direction. Since both forces are acting in the same direction, we would add their magnitudes. What if the forces applied are not in the same direction? Perhaps one person wants the piano moved to the right while the other person would prefer it moved to the left. Where would the piano end up? Well it would move in the direction of the force with the larger magnitude. The net force would be calculated by again, adding the forces, but since one is moving to the left, the magnitude value would be negative. On the contrary, if an object is at rest, the sum of the net forces acting on the object equal zero.

**Newton’s Second Law of Motion.** The acceleration of an object is proportional to the force of the object and the mass of the object.

Here, we can derive the equation for force as stated above. The amount of force exerted by an object is dependent on its mass. Think about how much more it was hurt dropping a bowling ball on your foot than dropping a golf ball on your foot. Similarly, force is also dependent on acceleration. Again, consider the amount of damage that would occur to a car if that car hit a tree traveling at 10 mph, compared to the same car hitting a tree traveling at 60 mph. Increasing the acceleration, in turn, increases the force. In the classroom, students can engage in investigations that explore how changing an object’s mass or acceleration affects force. See related activities.

**Newton’s Third Law of Motion.** When an object applies a force on another object, the second body simultaneously applies a force equal in magnitude and opposite in direction on the first object.

Newton’s Third Law of Motion is often summarized as follows; “For every action there is an equal and opposite reaction.” Each object exerts a force in the opposite direction of the opposing object. For example, if object A is exerting a force onto object B, object B also exerts a force of equal magnitude onto object A. This is represented by the equation, 

\[ F_A = -F_B \]

where \( F_A \) represents the force applied to object B by object A and \( -F_B \) represents the force applied by object B in the opposite direction (which is why it is negative). To better understand Newton’s Third Law of Motion, consider your cell phone resting on a table. Whether we realize it or not, the cellphone is applying a force to the table and, in turn, the table is exerting a force of equal magnitude back onto the phone.
In this lesson, students will be focused on applying their understanding of Newton’s 1st and 2nd Laws of Motion while exploring Newton’s 3rd Law of Motion. Students will simulate a collision and measure the force of impact to determine how they can design a solution for two colliding objects, the spacecraft and the surface of Mars.

The Impact Tester.

This activity requires a device that will measure force. These devices can be constructed in a variety of ways. Here is an example of the one I used:

The device has a carriage that can be dropped from a given height. Attached to the carriage is a load cell. The load cell measured the force and is connected to an instrumentation amplifier which sends the signal to a Go!Link. The Go!Link connects to a chromebook and allows students to see their data in real time. The setup looks like this...
**VOCABULARY/DEFINITIONS**

- **Force**: Force is the push or pull on an object
- **Inertia**: An object’s resistance to change speed or direction
- **Newton’s First Law of Motion**: An object at rest stays at rest and an object in motion stays in motion moving at a constant speed in the same direction until acted on by an outside force
- **Newton’s Second Law of Motion**: States that force is the product of mass and acceleration
- **Newton’s Third Law of Motion**: When an object applies a force on another object, the second body simultaneously applies a force equal in magnitude and opposite in direction on the first object.
- **Physical Science (physics)**: The study of non-living systems in relation to space and time

**ASSOCIATED ACTIVITIES**

- [What is Newton’s First Law?](#)
- [What is Newton's Second Law?](#)
- [What are Newton’s Laws?](#)
LESSON CLOSURE

- Circle share out.

ATTACHMENTS

- Mars Rover Landing

ASSESSMENTS

Pre-Activity Assessment

Before the investigation, show the video of the Mars Rover. Ask students to use their knowledge of force generate a list of considerations scientists and engineers must make when safely landing a spacecraft on Mars.

Activity-Embedded Assessment

Planning the Investigation

Ask the Expert: Finding Evidence to Support Our Investigation

Collecting Data

Understanding Outcomes: Analyzing and Interpreting Data

Constructing Explanations and Designing Solutions CER

Post-Activity Assessment

The post-activity assessment would be completed during the next lesson, in which students will use their knowledge gathered in this lesson and apply it to their eggdrop!

LESSON EXTENSION ACTIVITIES

Graphing. Students can create bar graphs of their results! If students are in need of challenge, or you are teaching them about line graphs and plotting points, you can incorporate this into this lesson. Rather than having students create bar graphs of their averages, they can plot the values for each trial on a plane for each of the materials. Line
graphs to show trends, so ask the students if the material was able to mitigate the force and protect the object at a constant force value for each trial, or did the material become less effective over time?

Do you have a student who is in need of challenge and LOVES rockets? Have students explore Newton’s Third Law of Motion and how it applies to rocket propulsion and movement in space!

REFERENCES

SUPPORTING PROGRAM

The Joule Fellows Program (NSF-RET) in the Department of Engineering at the University of Connecticut