Force & Motion Lesson 3: *The Engineer*

Educator's Resource Guide

Objective

In *The Engineer*, students will:

1. Research car crash collision in order to understand the forces and safety mechanisms involved in collision science.
2. Relate gained knowledge of car collisions to redesigning shopping carts in an effort to protect precious cargo inside them.
3. Design, construct, and test a shopping cart prototype to analyze effectiveness of their design.
4. Create an investment pitch in order to convince Ms. Newton to invest in their product.

Time Required: 250 minutes

Materials Required
● Computer for research ● Appendix A (Ideas to Spark Student Designs) ● Appendix B (Additional Resources – optional) ● Appendix C (Class Shopping Cart Testing Data Chart) ● Suggested classroom ramp materials: ○ Wooden board (as ramp and crash board) ○ Cardboard ○ Meter sticks as guides or rails on ramp to direct car motion ● Student team testing materials: ○ Stopwatch ○ Meter stick (to measure ramp length) ○ Ruler ○ Plastic egg (for egg dimensions when building) ○ 2-3 raw eggs (for testing) ○ Sharpie markers ● Suggested cart construction materials (students must bring in their own cart construction materials unless provided by the teacher) ○ Paper ○ Glue (varieties) ○ Wooden dowels or skewers for wheel axles ○ Bottle caps (wheels) ○ CDs (wheels) ○ Popsicle sticks ○ Toothpicks ○ Cardboard boxes (tissue boxes, small shipping boxes)

<table>
<tr><td colspan="2">

Styrofoam
Sponges
Cotton balls
Aluminum foil
Plastic wrap
Markers

*Any other materials you or students can bring in from home
</td></tr>
<tr><td>Safety/Other Considerations</td><td>Science & Engineering Practices</td></tr>
<tr><td>A raw egg will be used for testing during this project. Be sure to check student allergies prior to the start of this project. Additionally, since raw eggs may carry salmonella, have a disinfectant spray available to clean egg if it breaks during testing. As another suggested option, eggs can be boiled first to prevent egg yolk exposure.

Be sure to use caution if operating a hot glue gun during construction in class. A teacher hot glue station is recommended in order to supervise students.

Before having students test their vehicles, wrap the raw egg in a thin layer of plastic wrap. If the egg breaks, this will help contain the break and will prevent damage and contamination to student designs.</td><td>● Developing and Using Models
● Designing Solutions
● Communicating Findings/Design (Oral Presentation)</td></tr>
</table>

Inquiry Scale: Leveling Information

Level 1 (*recommended for grades 4-5)*

- Review *The Engineer* design challenge scenario with the entire class, being sure to review all requirements and constraints with students. Complete the first section of the Design Guide ("Understand the Problem") with students as a whole-class activity.
- Next, direct students onto the Research section of their Design Guide where a number of research links are shown. As a whole-class activity, play/project each research link with students to gather research. After viewing all research links, complete and discuss the research questions with students.
- Direct students onto the Brainstorming and Materials sections of the Design Guide. While students are working through these sections, circulate the classroom, assisting students as needed and providing feedback on their design ideas. Instruct students that they are to bring in the materials for constructing their cart prototypes. You will supply the "test" eggs, but students will need to collect and bring in the rest of the materials. Students should be given a day to gather and bring in materials from home.
- Once student teams have collected materials, move teams on to the prototype construction and testing phase. While teams are constructing their prototypes, provide each student team with a plastic egg so that students can determine the dimensions for the inner compartment of the cart.

- For test day, provide student teams with real test eggs (up to 3 eggs/team may be used during testing). Direct students to wrap raw eggs in a thin layer of plastic wrap before testing to prevent any cracked eggs from destroying their prototypes. Students teams should be given time to test their cart prototypes, collect data, and redesign their carts if need be.
- Once all teams have finalized testing, review the presentation "Investment Pitch" criteria with students. Students should create their "Investment Pitches" and present their final prototypes and pitches to their peers.
- As a finale, to help Ms. Newton choose the best cart design, conduct a final test on all cart prototypes as a whole-class activity. Use the Class Shopping Cart Testing Data Chart in Appendix C to record and analyze final data. Each student team must be supplied with one new raw egg during this final competition.

Level 2 (*recommended for grades 5-6)*

- Review *The Engineer* design challenge scenario with the entire class, being sure to review all requirements and constraints with students. Complete the first section of the Design Guide ("Understand the Problem") with students as a whole-class activity.
- Next, direct students onto the Research section of the Design Guide where a number of research links are shown. Allow students to view each link provided to gather research. Students should independently complete the research questions while viewing the links provided. Once all students have finished this Review section, review answers with students to be sure that students understand the science of collisions as well as vehicle safety features.
- Next, direct students onto the Brainstorming and Materials sections of the Design Guide. While students are working, circulate the classroom, assisting students as needed and providing feedback about their design ideas. Instruct students that they are to bring in the materials for constructing their cart prototypes. You will supply the "test" eggs, but students will need to collect and bring in the rest of the materials. Students should be given a day to gather and bring in materials from home.
- Once student teams have collected materials, move teams on to the prototype construction and testing phase. While teams are constructing their prototypes, provide each student team with a plastic egg so that students can determine the dimensions for the inner compartment of the cart.
- For test day, provide student teams with real test eggs (up to 3 eggs/team may be used during testing). Direct students to wrap raw eggs in a thin layer of plastic wrap before testing to prevent any cracked eggs from destroying their prototypes. Students teams should be given time to test their cart prototypes, collect data, and redesign their carts if need be.
- Once all teams have finalized testing, review the presentation "Investment Pitch" criteria with students. Students should create their "Investment Pitches" and present their final prototypes and pitches to their peers.
- As a finale, to help Ms. Newton choose the best cart design, conduct a final test on all cart prototypes as a whole-class activity. Use the Class Shopping Cart Testing Data Chart in Appendix C to record and analyze final data. Each student team must be supplied with one new raw egg during this final competition.

Level 3 (*recommended for grades 6-7)*

- Review *The Engineer* design challenge scenario with the entire class, being sure to review all requirements and constraints with students.
- Next, direct students onto the "Understand the Problem" and "Research" sections of the Design Guide. Students should independently review all research links provided and complete all research questions while viewing the links. Review answers to the research questions with student to ensure accurate understanding of collision science as well as safety features incorporated into vehicle design.
- Following the review of the Research Section, instruct students that they will be independently completing the remaining stages of *The Engineer* design process, with teacher assistance, as needed. Student teams independently complete remaining aspects of the design process at their own pace, including brainstorming, prototype construction, and testing, as well as the creation of the "Investment Pitch." Provide students with "daily goals" to keep teams on task and on schedule so that they can finish work within the required amount of time. For example: Day 1 = complete brainstorming and materials list, Days 2–3 = prototype construction and testing, and Day 4 = Investment Pitch.
- Keep in mind the following points and address them at the appropriate times as students proceed through the design challenge:
    - Instruct students that they are to bring in the materials for constructing their cart prototypes. You will supply the "test" eggs, but students will need to collect and bring in the rest of the materials.
    - While teams are constructing their prototypes, provide each student team with a plastic egg so that students can determine the dimensions for the inner compartment of the cart.
    - For test day, provide student teams with real test eggs (up to 3 eggs/team may be used during testing). Direct students to wrap raw eggs in a thin layer of plastic wrap before testing to prevent any cracked eggs from destroying their prototypes.
- As a finale, to help Ms. Newton choose the best cart design, conduct a final test on all cart prototypes as a whole-class activity. Use the Class Shopping Cart Testing Data Chart in Appendix C to record and analyze final data. Each student team must be supplied with one new raw egg during this final competition.

Level 4 (*recommended for grades 7-8)*

- Review *The Engineer* design challenge scenario with the entire class, being sure to review all requirements and constraints with students.
- Next, instruct students that they will be independently completing all stages of *The Engineer* design process, with teacher assistance, as needed. Student teams independently complete all aspects of the design process at their own pace, including research, brainstorming, prototype construction, and testing, as well as the creation of the "Investment Pitch." Provide students with "daily goals" to keep teams on task and on schedule so that they can finish work within the required amount of time. For example: Day 1 = complete research, Day 2 = complete brainstorming and materials list, Days 3–4 = prototype construction and testing, and Day 5 = Investment Pitch.
- Keep in mind the following points and address them at the appropriate times as students proceed through the design challenge:
    - Instruct students that they are to bring in the materials for constructing their cart prototypes. You will supply the "test" eggs, but students will need to collect and bring in the rest of the materials.
    - While teams are constructing their prototypes, provide each student team with a plastic egg so that they can determine the dimensions for the inner compartment of the cart.

- For test day, provide student teams with real test eggs (up to 3 eggs/team may be used during testing). Direct students to wrap raw eggs in a thin layer of plastic wrap before testing to prevent any cracked eggs from destroying their prototypes.

- As a finale, to help Ms. Newton choose the best cart design, conduct a final test on all cart prototypes as a whole-class activity. Use the Class Shopping Cart Testing Data Chart in Appendix C to record and analyze final data. Each student team must be supplied with one new raw egg during this final competition.

***The Engineer* Agenda**

I. Show PowerPoint to introduce *The Engineer* Activity (10-15 minutes)

The PowerPoint will review essential concepts learned in *The Make* and provide context for the students' upcoming *Engineering* challenge.

PowerPoint Slide Guide

II. Engineering Activity (235 minutes)

As guided by their Student Guide Planning Organizer, students will:

1. Research collision science and relate concepts to Newton's Laws of Motion
2. Brainstorm and design a shopping cart, capable of protecting precious cargo during a collision
3. Construct, test, and evaluate their shopping cart prototype
4. Create an investment pitch to convince Ms. Newton to invest in their product. Students will explain how shopping cart design will effectively protect precious cargo during a collision based on their knowledge of forces and motion.

5. Optional but recommended: After all student teams have delivered their "Investment Pitches," conduct a final test as a whole-class activity by evaluating competing design solutions. Use Appendix C with students to test and compare final shopping cart designs. Each student team must be supplied with one new raw egg during this final competition.

Classroom Ramp Construction

Classroom test ramps can be constructed from a variety of materials including cardboard, wood, gutters, or anything flat you have in your classroom. At the end of the ramp, a "wall" should be constructed for the cart prototypes to crash against. The "wall" can be made from any variety of sturdy objects, including cinder blocks, bricks, wood, textbooks, etc. The height and length of the classroom test ramp is at your discretion. See images for classroom test ramp ideas and inspiration.

***The Engineer* Assessment:** Project Grade and Rubric Score Sheet – Newton's Laws

Project Submitted by _____

Shopping Cart Engineering Design Checklist

Your Challenge: Redesign a supermarket shopping cart capable of protecting precious cargo during a collision.

Project Completeness:

- ❑ All aspects of *The Engineer* planning organizer are complete
- ❑ Shopping cart prototype:
  - ❑ Prototype is constructed from approved materials
  - ❑ Data and testing is completed for prototype design
  - ❑ Prototype design is revised based on testing data
- ❑ Shopping Cart Investment Pitch:
  - ❑ Includes product name
  - ❑ Includes student company name
  - ❑ Includes photo/sketch of prototype with dimensions and mass
  - ❑ Explains how shopping cart design will effectively protect precious cargo during a collision based on knowledge of forces and motion
  - ❑ Provides convincing argument to make Ms. Newton invest in design

DCI Standards Checklist:

- ❑ Research accurately describes and specifically references:
  - ❑ How Newton's First Law of Motion applies to the motion of passengers inside of a vehicle during a collision
  - ❑ Safety devices that have been installed and utilized in car design to reduce the impact of collisions
- ❑ Shopping Cart Prototype:
  - ❑ Accurately constructed according to brainstorm sketch and approved materials
  - ❑ Safely protects precious cargo inside of the cart during collision
  - ❑ Withstands multiple and repeated collisions without falling apart

Science & Engineering Practices Rubric

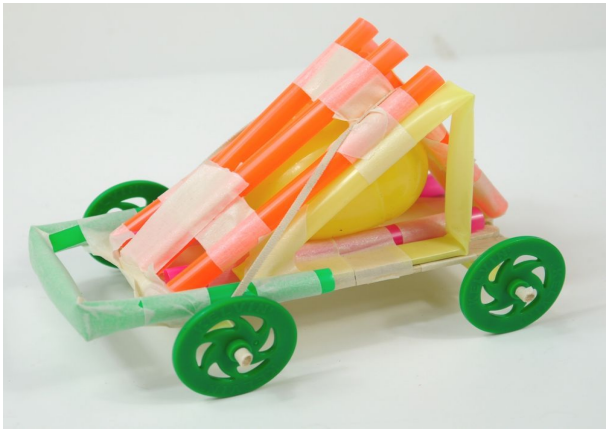
	Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Developing and Using Models	Drawings, diagrams, or visual models include major misconceptions or have missing parts. Explanation of the model is minimal or not present.	Drawings, diagrams, or visual models include minor misconceptions or have missing parts. Explanation of the model is minimal.	Drawings, diagrams, or visual models are complete, but contain a minor misconception. Explanation of the model is complete but lacking complexity.	Drawings, diagrams, or visual models have no misconceptions and contain all details. Explanation of the model is complete and complex.

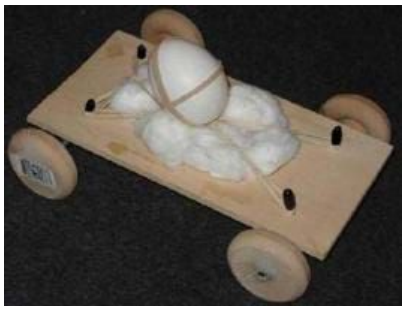
Designing Solutions	Applies no scientific principles and/or data to design, construct, and/or test a design of an object, tool, process, or system.	Applies minimal scientific principles and/or data to design, construct, and/or test a design of an object, tool, process, or system.	Applies adequate scientific principles and/or data to design, construct, and/or test a design of an object, tool, process, or system.	Applies complete scientific principles and/or data to design, construct, and/or test a design of an object, tool, process, or system.
Communicating Findings/Design (Oral Presentation)	Findings/design are incompletely and inaccurately communicated. Or no evidence of using appropriate eye contact, adequate volume, or clear pronunciation.	Findings/design are completely communicated with some misconceptions. Or uses minimal eye contact, inappropriate volume, or inconsistent pronunciation.	Findings/design are completely communicated but lacking depth and complexity. Or often uses eye contact and engaging and appropriate volume and pronunciation, but is inconsistent.	Findings/design are completely communicated with depth and complexity. Or mostly uses eye contact and engaging and appropriate volume and pronunciation.

Teacher Comments:

Final Score: Final Grade:

Appendix A: Ideas to Spark Student Designs





Appendix B: Additional Suggested Resources

1. Washington Post Shopping Cart Accident Article: https://www.washingtonpost.com/national/health-science/despite-warnings-about-24000-kids-are-hurt-annually-in-shopping-cart-accidents/2014/01/27/74aaf620-8523-11e3-bbe5-6a2a3141e3a9_story.html?utm_term=.c8e18bbffeba
2. Huffington Post Shopping Cart Accident Report: https://www.huffingtonpost.com/2014/01/22/shopping-cart-injuries-children_n_4646036.html
3. Action News Shopping Cart Accident News Video: http://www.wtae.com/article/more-than-24000-kids-injured-in-shopping-cart-accidents-every-year/7203249
4. Understanding Car Crashes: It's Basic Physics: https://www.youtube.com/watch?v=yUpiV2I_IRI
5. Guide to Car Safety Features: https://www.consumerreports.org/cro/2012/04/guide-to-safety-features/index.htm
6. PhET Collision Virtual Lab: https://phet.colorado.edu/en/simulation/collision-lab
7. Crash Course Collisions: https://www.youtube.com/watch?v=Y-QOfc2XqOk

Appendix C: Class Shopping Cart Testing Data Chart

Will Ms. Newton invest in your design? Let's find out and test your design against those of your other classmates.

Team #	Cart mass (g)	Time until impact (s)	Total distance traveled (m)	Speed (m/s)	Egg survival rating *Rating Scale of 1-3 with 1 being death and 3 being unharmed*	Shopping cart rating *Rating Scale of 1-3 with 1 being total destruction and 3 being no damage*
1						
2						
3						
4						
5						
6						
7						