Hypersonics STEM Curriculum

Trash Can Rocket Ship

Grade	Time	Subject Area	Key Concepts
3-5	105 min	Engineering Design	Engineering Design Process

Lesson Overview

In this lesson, students will be challenged to help Robbie Racoon convert his trash can into a rocket ship. They will need to work to make it more aerodynamic and add wings to it. Students will be given a mini trash can (a coffee cup or plastic cup) to modify and test in their homemade wind tunnels. They will need to design, build, and test their model rocket followed by redesign based on analysis from their testing.

NGSS Standards

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Learning Objectives

By the end of this lesson, students will be able to:

- Design a model ship that is built from a model trash can (coffee cup).
- Test a model rocket ship in a homemade wind tunnel and analyze the results.
- Re-design a model rocket ship based on their analysis.

Essential/Overarching Question

How can we design a rocket ship using a trash can as its base?

Key Vocabulary

Speed – the rate at which an object is moving. Speed is calculated by dividing the distance travelled by the time it took to travel that distance.

Speed of Sound – the rate at which sound moves through a medium. The speed of sound depends on both the density and the temperature of the medium. The speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph).

Mach – the ratio of the speed of an object to the speed of sound or how many times the speed of sound an object is moving. It is often followed by a number indicating the ratio; for

example: Mach 1 is the speed of sound, Mach 2 is twice the speed of sound, Mach 5 is five times the speed of sound.

Sonic – speeds equal to the speed of sound (Mach 1).

Subsonic – speeds smaller than the speed of sound (less than Mach 1).

Transonic – speeds near (Mach 0.8-1.2) the speed of sound where drag is highest (e.g. sound barrier).

Supersonic – speeds greater than the speed of sound (Mach 1 and greater).

Hypersonic – speeds greater than five times the speed of sound (Mach 5 and greater).

Fluid – a substance with no fixed shape; a liquid, gas, or plasma. A substance that flows when an external force is applied to it.

Flow – the motion of a fluid (liquid, gas, or plasma) when it experiences unbalanced forces.

Astronaut – a person trained and equipped to travel in a spacecraft.

Heat – high temperatures or kinetic energy in transit between two objects or systems that have different temperatures.

Friction – resistance to movement. A force that opposes motion.

Aerodynamic – having a shape which reduces the drag from air moving past.

Wind Tunnel – a large tube with air moving inside. Wind tunnels are used to investigate air flow around an object placed in the passage.

Science Concepts Overview

In this lesson, students are given a problem to solve – build a rocket ship out of a trash can that is aerodynamic enough to travel at hypersonic speeds. This lesson steps students through the engineering design process as defined by NGSS: defining and delimiting engineering problems, designing solutions to engineering problems, and optimizing the design solution.

In this challenge, students are specifically asked to create an aerodynamic rocket ship, meaning that the rocket ship has a shape that allows air to move past it easily. Rocket ships

require high speeds to exit Earth's atmosphere and enter outer space. In doing so, they reach hypersonic speeds. Hypersonic speeds are those that are greater than five times the speed of sound, so greater than 1715 m/s = 6147 km/h = 3836 mph. At these speeds, the rocket ship experiences a lot of heat and friction. By using an aerodynamic shape, heat and friction are minimized.

To test how the rocket ship will interact with the moving air, or flow, we will use a wind tunnel. Wind tunnel testing is used to investigate how objects interact with flow. It can be used to simulate objects moving through a fluid, such as an aircraft moving though air, or a fluid moving around an object, such as wind moving around a building. Wind tunnel testing can be done on a smaller scale model, as we are doing, or with full size objects if the wind tunnel is large enough.

Materials List

- ☐ Cardboard box (enough to make one wind tunnel per group)
- ☐ Clear plastic (overheads, sheet protectors, acrylic sheet, etc. – one per wind tunnel)
- ☐ Small fan with different speed settings (one per wind tunnel)
- ☐ Disposable coffee cup or plastic cup (one per group or student)
- ☐ An assortment of materials to build their rocket ship (aluminum foil, cardstock, glue, tape, cardboard, popsicle sticks, balsa wood, foam, thick dial rods, straws, chopsticks, modeling clay, etc.)
- ☐ An assortment of materials to build an aircraft stand (small blocks, popsicle sticks, modeling clay, balsa wood, etc.)
- ☐ Scissors
- ☐ Box Cutter (for teacher use)
- ☐ Tape (duct tape is best)
- ☐ Goggles or other eye protection (one per student)
- ☐ Rulers (one per group)
- ☐ Trash Can Rocket Ship handout (one per student)
- ☐ Trash Can Rocket Ship Exit Ticket handout (one per student – there are two handouts per page)

Lesson Preparation

Prior to the lesson, the instructor should gather materials to build the wind tunnel and rocket ship as well as make copies of the Trash Can Rocket Ship handout and exit ticket.

As different fans will provide different amounts of flow, it is suggested that the instructor tests the fans ahead of time to make sure the fans are strong enough to create a flow that has a noticeable interaction with the model rockets.

If the instructor does not plan to have each group of students make their own wind tunnel, they should have the wind tunnel stations built and set up ahead of time.

Safety

Due to the nature of this lesson, it is recommended that the class take the following safety precautions:

- Participants should wear eye protection.
- Participants should be reminded to not place objects, including fingers, in the fans.
- Wind tunnels should be placed so the fans blow away from other groups in case of flying objects.
- Participants should be reminded to be mindful of where they walk in the classroom, so they do not walk in the path of a wind tunnel in case of flying objects.

Procedure

Engage (20 minutes)

1. As a class, or individually, read The Challenge section of the Trash Can Rocket Ship handout.
2. Have students work on the Pre-Design Brainstorm section of the Trash Can Rocket Ship handout.
3. Have students share out their ideas either with a think-pair-share or as a whole class discussion.

Explore (40 minutes)

4. Students would ideally work in small groups for this lesson, but it could also be done individually.
5. Either students can build their own wind tunnels, or the instructor can have premade wind tunnels set up around the classroom. If students are building their own wind tunnel, instructions are provided in the Trash Can Rocket Ship handout:
    - Gather your materials: cardboard box, clear plastic, tape, fan.
    - Take a medium sized cardboard box and open/cut the box so that it is open at opposite ends. You may want to make sure any flaps are taped down.

    - On one side of the box, draw an observation window. The window should be slightly smaller than the clear plastic you will use as your window.
    - Ask an adult to cut out the window for you.
    - Tape the clear plastic on the inside of your box. Trim the clear plastic if it is too large to fit in your box. Make sure all sides of the plastic are completely taped down.
    - Place the fan at one open end of the wind tunnel so that it is blowing in the box. Make sure to set up your wind tunnel so that it blows away from other groups.
6. Based on the requirements described in The Challenge section of the Trash Can Rocket Ship handout, students will design a model rocket ship from their model trash

can (disposable coffee cup or plastic cup). Students will need to sketch their model rocket ship and list their materials in the Trash Can Rocket Ship Design section.

7. Students will build their model rocket ship. Students may also need to design a stand for their rocket so that the rocket is off the ground and air can flow around all sides of the rocket.
8. Students will decide how to test their model rocket ship by answering the first three questions in the Trash Can Rocket Ship Testing & Analysis section:
    - Using a wind tunnel, how will you test your trash can rocket ship to see if it can handle traveling at hypersonic speeds?
    - What will you measure or observe?
    - What materials do you need to make your measurements or observations?
9. Students will then place their model rocket ship in a wind tunnel and collect their data. They can record their data in the data table in the Trash Can Rocket Ship Testing & Analysis section.

Explain (30 minutes)

10. Students will analyze their data by answering questions 4-6 in the Trash Can Rocket Ship Testing & Analysis section:
    - What worked well with your model rocket ship design? What data supports that?
    - What did not work well with your model rocket ship design? What data supports that?
    - How would you modify your model rocket ship design?
11. Based on their analysis, students will then explain how they would re-design their model rocket ship. Students will need to sketch their re-designed model rocket ship and list their materials in the Trash Can Rocket Ship Re-Design section.
12. Students will build their model rocket ship re-design.
13. Using the same measurement that they used for their original rocket ship model, the students will place their model rocket ship in a wind tunnel and collect their data. They can record their data in the data table in the Trash Can Rocket Ship Re-Testing & Analysis section.

Elaborate (10 minutes)

14. Students will elaborate on their understanding of the rocket ship design process by answering questions 7-11 in the Trash Can Rocket Ship Re-Testing and Analysis section:
    - What worked well with your model rocket ship redesign? What data supports that?

- What did not work well with your model rocket ship redesign? What data supports that?
- How would you further modify your model rocket ship?
- Do you think that a trash can was a good base for a rocket ship? What makes you say that?
- Moving on to the next step in the design process, how would you launch your rocket?

Evaluate (5 minutes)

15. Students will complete the Trash Can Rocket Ship Exit ticket which asks them to list:
    - Three ideas that you took away from the lesson.
    - Two wonders or questions that you have as a result of the lesson.
    - One thing you want to learn more about.

STEM Career Connections

- Aerospace engineer
- Materials scientists
- Mechanical engineer
- Systems engineer
- Pilot
- Astronaut

Extensions

As a further *elaborate*, students could do research on rocket ships that have gone to space and how the design of those rocket ships compare to their model.

References & Resources

Education.com. (n.d.) *Science project: Wind tunnel* experiment. https://www.education.com/science-fair/article/physics_experiments-wind-tunnel/

National Air and Space Museum. (n.d.) *How things fly*. https://howthingsfly.si.edu/

SciShow. (2019, July 8). *A surprisingly simple secret to supersonic flight* [Video]. YouTube. https://www.youtube.com/watch?v=kGefMLHJBKA

Talented Tuber. (2017, April 11). *Difference between subsonic, supersonic and hypersonic speed* [Video]. YouTube. https://www.youtube.com/watch?v=LBJ3tXCjzN0

TestTube 101. (2015, November 11). *Flying at hypersonic speeds* [Video]. YouTube https://www.youtube.com/watch?v=vL1qAfS0gic

Dr. Lori M. Stiglitz
JHTO Workforce Development Lead

Dr. Stephanie Stehle
JHTO Curriculum Specialist

Name: _____ Date: _____

Trash Can Rocket Ship

✈ The Challenge

Robbie Racoon has dreams of being an astronaut and traveling into space. Robbie is so determined to go into space that they are working to build a rocket ship from their trash can. But they need help making sure that their trash can rocket ship is strong enough to handle the trip. Robbie's rocket ship will need to travel at high speeds. In order to get into space, rocket ships need to travel from ***subsonic*** (slower than the speed of sound) to ***supersonic*** (faster than the speed of sound 343 m/s) and ***hypersonic*** (faster than five times the speed of sound 1715 m/s) speeds. When traveling that fast, the rocket ship will experience a lot of ***heat*** (high temperatures) and ***friction*** (resistance). To reduce the amount of heat and friction, the rocket ship should be made to be as ***aerodynamic*** as possible. Aerodynamic means that the object has a shape that allows air to move past it easily.

You are tasked with designing, building, and testing a smaller version of a possible rocket ship design for Robbie. You will be given a cup to model the trash can as it is proportional in size and shape to Robbie's trash can. Before we take Robbie's trash can rocket ship into space, we need to make sure that it can handle the speed, heat, and friction that it will experience. We are going to focus on the speed aspect by testing model trash can rocket ships in a ***wind tunnel***. A wind tunnel is a large tube with air moving inside that is used to investigate air flow around an object. This will allow us to see if the trash can rocket ship will survive traveling at extreme speeds.

✈ Pre-Design Brainstorm

1. What do you know about the design of rocket ships?

2. In your own words, what does aerodynamic mean? What makes something aerodynamic? How do you know if something is aerodynamic?

3. What are questions that you still have? Or what are you curious about?

4. What things might you need to consider for your rocket ship as it goes from subsonic to supersonic to hypersonic speeds?

✈ Building a Wind Tunnel

- ☐ Gather your materials: cardboard box, clear plastic, tape, fan.
- ☐ Take a medium sized cardboard box and open/cut the box so that it is open at opposite ends. You may want to make sure any flaps are taped down.
- ☐ On one side of the box, draw an observation window. The window should be slightly smaller than the clear plastic you will use as your window.
- ☐ Ask an adult to cut out the window for you.
- ☐ Tape the clear plastic on the inside of your box. Trim the clear plastic if it is too large to fit in your box. Make sure all sides of the plastic are completely taped down.
- ☐ Place the fan at one open end of the wind tunnel so that it is blowing in the box. Make sure to set up your wind tunnel so that it blows away from other groups.

✈ Trash Can Rocket Ship Design

Based on the requirements Robbie shared for their rocket ship, how would you modify your trash can (cup) to turn it into a rocket ship? You must use the "trash can" in your design. Sketch your model rocket ship, list the materials you will use, and then build it.

Sketch your model rocket ship.	What materials would you use?

✈ Trash Can Rocket Ship Testing & Analysis

1. Using the wind tunnel, how will you test your trash can rocket ship to see if it can handle traveling at hypersonic speeds?

2. What will you measure or observe?

3. What materials do you need to make your measurements or observations?

Place your model rocket ship in your wind tunnel with the top/nose facing the fan. You will need to build a small stand for your model rocket ship so it is off the ground and air can move around it on all sides.

Turn the fan on low and record your data in the table below. Take measurements at all fan speeds.

Flow Speed	**Low**	**Medium**	**High**
Data			

4. What worked well with your model rocket ship design? What data supports that?

5. What did not work well with your model rocket ship design? What data supports that?

6. How would you modify your model rocket ship design?

✈ Trash Can Rocket Ship Re-Design

Based on your data analysis, work to re-design your model rocket ship.

Sketch your model rocket ship.	What materials would you use?

✈ Trash Can Rocket Ship Re-Testing & Analysis

Build your newly designed rocket ship model. Taking the same measurements and observations as you did with your original design, test your new rocket ship model.

Flow Speed	**Low**	**Medium**	**High**
Data			

7. What worked well with your model rocket ship redesign? What data supports that?

8. What did not work well with your model rocket ship redesign? What data supports that?

9. How would you further modify your model rocket ship?

10. Do you think that a trash can was a good base for a rocket ship? What makes you say that?

11. Moving on to the next step in the design process, how would you launch your rocket?

Name: _____ Date: _____

Trash Can Rocket Ship Exit Ticket

3	Three ideas that you took away from the lesson.
2	Two wonders or questions that you have as a result of the lesson.
1	One thing you want to learn more about.

Name: _____ Date: _____

Trash Can Rocket Ship Exit Ticket

3	Three ideas that you took away from the lesson.
2	Two wonders or questions that you have as a result of the lesson.
1	One thing you want to learn more about.