EDUCATOR'S GUIDE

Design a Heat Shield

Preparation

Overview and Objectives

This lesson is geared toward students in grades 2–5.

Participants will learn about the technology needed to protect astronauts and spacecraft from intense heat upon leaving Earth's atmosphere as well as re-entry into the atmosphere. Sense-making and kinesthetic activities will help students apply their understanding of friction to the need to design a heat shield in order to protect space capsules and shuttles. Participants will be introduced to the engineering design process. Using this model will guide them in designing and testing their own heat shields in order to protect a chocolate astronaut from the heat.

This lesson includes a slideshow in which an instructor leads participants through activities and discussions about heat shields prior to students engineering and testing their own design. As a safety precaution, only adults should handle the hot plate and metal stand. Do not use an open flame.

By the end of this lesson, participants will be able to identify ways in which heat shields protect spacecraft during re-entry into Earth's atmosphere.

Standards

Common Core Anchor Standards

MP.2 Reason abstractly and quantitatively. (5-LS1-1),(5-LS2-1)

Next Generation Standards

3-5-ETS1-1 Engineering Design

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

Instructional Modalities

This activity was designed for synchronous instruction only.

For **synchronous instruction**, we recommend a platform that allows both for whole class discussion and for students to interact in small groups.

Materials

- **Design a Heat Shield slideshow**
- **Design a Heat Shield Worksheet** (pp. 7-9)
- **Design challenge materials:**
    - The sensitive cargo or "astronaut"
      chocolate squares (1 per group)
    - To generate the heat (for use by teacher/adult only):
      Hot plate
      Steel Ring Stand Set to rest projects on ring clamp a few inches above hot plate
    - Heat Shield Material:
      Graham Crackers
      Aluminum foil 6"x 6" square
      Tissue paper 6"x 6" square
      Cardboard piece
      Paper clips
      Craft sticks
      Coffee filter
      Construction paper

Lesson

1. **Introductory Activity**
    - **What is friction?**
    - Participants will brainstorm ideas about friction. Ask participants to share their thoughts.
      o After validating all responses, guide participants through the kinesthetic exercise with rubbing their hands together.
        - Place both of your hands out like you are going to clap. Start rubbing your hands together slowly.
        - Now increase the speed.
        - What do you notice?

    Ask participants to share as many as many observations as possible as the instructor records their answers. Discuss the science behind the experience. First, the rubbing causes a scraping of the surface of your skin as you move both hands back and forth against each other. This causes the molecules in your skin to move a little faster. As a result, the temperature increases when the molecules move faster and faster. That is how the friction of rubbing your hands together makes them feel warmer. Discuss why this is important for protecting people going to space.

2. **Core Activity**
   - **What is happening to a spacecraft when it launches into space or returns from space?**
   - Show participants the image on slide 6. Guide them through a silent visual analysis of what is happening in the image, where they are making their own observations without speaking for 30 seconds. After that amount of time, have them turn and talk with a partner to share their observations. It is helpful to use the following questions in guiding their observations, where all discussion points are validated:

     - **What do you notice?**
     - **What makes you say that?**
     - **What more can you tell me?**

   - Have a whole-group discussion about the observations, making sure to repeat their observations without adding to them.
   - On slide 7, share some potential observations they may have made. With these ideas in mind, participants will now explore ways in which astronauts and spacecraft are protected from intense heat.
   - *Intrepid* was used to help NASA recover early spacecraft and their astronauts during the early phases of the space race. This happened before landing on the moon. Scott Carpenter was an astronaut that launched into space on a rocket, as shown next to his image. Just like the friction participants experienced in rubbing their hands together, astronauts and their vessels are experiencing even higher temperatures when they launch into space and when they return to Earth. Because of extreme temperatures that can reach up to 3,000 degrees Fahrenheit, his space suit would not protect him from this heat alone.

   - **How can we design something to protect astronauts and spacecraft from the heat?**
   - Show participants the image of the Mercury capsule on slide 9. Discuss more observations about how the capsule is protected from the heat. Explain how NASA was tasked with developing a space program in baby steps before going to the moon in 1969. This capsule did not travel to the planet Mercury. Instead, it received its name because it held one astronaut, and Mercury is the first planet in our solar system. This

capsule was testing the ability to safely send Scott Carpenter and the capsule into orbit around the Earth in 1962.

Ask participants:

- **Can you think of something needed on the outside to protect the vessel and its astronaut from the intense heat?**

- Discuss possible solutions before sharing the location of the Mercury capsule heat shield. Point out the curved bottom. Honeycomb-shaped aluminum and layers of glass and fiber made this heat shield. It boiled away upon re-entry into our atmosphere, but it did its job in protecting Scott Carpenter. Thermal protection technology improved with each capsule mission, where we saw other materials used on Gemini missions, for example.
- Show participants the images of the thermal protection tiles for the space shuttles. There are different types of heat shields, and over time, they have developed stronger thermal protection tiles as technology advances. The shields on a capsule are different than the ones used on space shuttle orbiters. Space shuttles used tiles, like the one you see on the top right. Each tile requires specialized tools to produce precise shapes to match each spacecraft. These are carefully tested in lab facilities.

- Discuss the two main types of tiles for shuttles:
    - Black-coated tiles that are meant to withstand high temperatures
    - White-coated tiles that are mean to withstand at lower temperatures
    - The process for making these tiles is long, but it starts with pure silica and sand that are baked.

- Watch astronaut Mike Massimino talk about the heat shield tiles on Enterprise.

3. **Design Challenge**
    - Introduce participants to the design challenge on slide 13. Make connections to the observations of thermal protection on capsules and space shuttles. Participants will become engineers with the task of designing a method to protect a chocolate astronaut from melting.

- Have participants observe the engineering design process model on the slide. Ask them about what they notice.
- Explain how engineers are problem solvers. In order to solve problems, engineers must know what they are trying to solve. For this challenge, we want to design thermal protection to keep our chocolate from melting. **How can we do that?**
  - Discuss participant ideas
  - In particular, allow time to discuss each stage in the process, noting these important steps:
    - Research the problem. Look for what's been done before.
    - List possible solutions.
    - Sketch your ideas to form a plan
    - Build, test, and redesign.
  - Remind participants that even NASA has limitations with money and materials, so for this challenge, they will also have limits.
  - Participants can work in pairs, small groups, or alone.
  - Use the worksheet and discuss the financial limitations. The goal is to spend the least amount of money possible but also design the best device to protect the chocolate.
  - NOTE: Because this challenge requires a hot plate, teacher or adult supervision is necessary.

4. **Reflect**
   - After testing and recording results, engage participants in the following reflection questions:
     - What did you notice in the most successful design?
     - What worked well? What did not work well?
     - What changes would you make in redesigning the heat shield?
   - If time permits, allow participants to redesign and retest.

Extension Activities

To deepen student engagement with this content, you may choose to add the following activities :

MEDLI2: Mars Entry, Descent, and Landing Instrumentation 2

https://www.nasa.gov/sites/default/files/atoms/files/best-medli2-tagged.pdf

NASA Engineering Design Challenges

https://www.nasa.gov/pdf/221638main_EDC_TPS.pdf

Additional Resources/ References

Thermal Protection Tiles

Engineering Design Process

NASA Heat Shield Testing

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ACTIVITY: DESIGN A HEAT SHIELD

Directions:

NASA is looking to hire a team to design a heat shield able to protect a heat sensitive cargo, represented by a piece of chocolate, for a period of 180 seconds (3 minutes) on a hot plate, simulating a spacecraft reentering Earth's atmosphere. Your team is not the only team competing for the job. Your team must budget for, design, build, and evaluate your own spacecraft heat shield. The team that has the most successful design with no melting chocolate and the least amount of money spent, wins the challenge!

You have these materials available to you, but keep in mind your team only has $1,000 in your budget to spend:

A. The sensitive cargo or "astronaut"
   - chocolate squares (1 per group)

B. To generate the heat (for teacher/adults to manage during experiment):
   - Hot plate
   - Steel Ring Stand Set to rest projects on ring clamp 3-4 inches above the hot plate

C. Heat Shield Material:

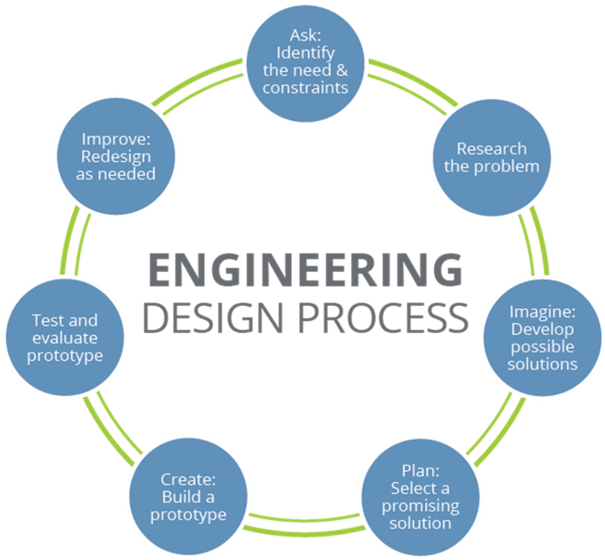
"High price" items:

- Graham Crackers: $300 each
- Aluminum foil 6"x 6" square: $300 each
- Tissue paper 6"x 6" square: $200 each
- Cardboard piece: $150 per piece

"Low price" items:

- Paper clips: $50 each
- Craft sticks: $20 each
- Coffee filter: $20 each
- Construction paper: $20 each sheet

Look at the engineering design process model below. Write down some notes for each step. **Graphic Credit: TeachEngineering.org**



1. Start with *Ask*. What do you need to do? What are your limitations?

2. Research the problem. You can use the internet, books, or explore your other knowledge.

3. *Imagine and Plan* possible solutions. Sketch the solution you choose to use.

4. Go shopping for your materials and start building! List your materials and their price here:

5. *Test, evaluate and redesign*. Record all your results so they help you find ways to improve.

Team	**Materials used and total cost**	**Results** ***Did the chocolate melt?***	**Improvements to design for retesting.**