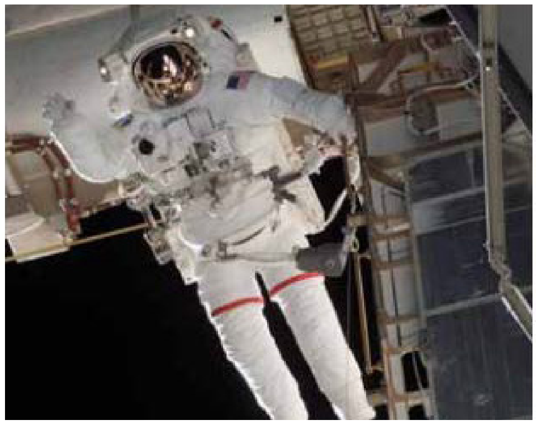
UNDER PRESSURE

Experimenting with a Hands-On Vacuum Environment and Pressure Suits

Based on NASA's Museum in a Box: Why Do We Really Need Pressure Suits?

OBJECTIVE – Students will be able to create a miniature pressure chamber and observe the effects of various amounts of air pressure. Students will be able to design a prototype for retaining an object at normal pressure, simulating the effects of a pressure suit.

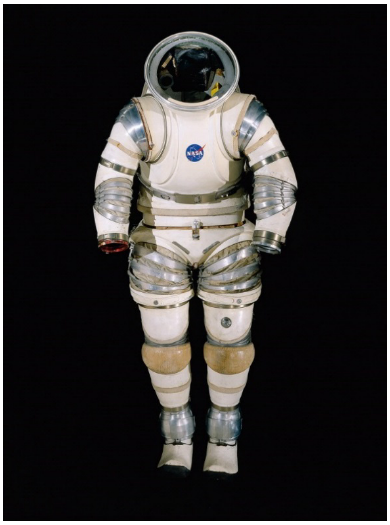


NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
- Disciplinary Core Idea Progressions
  - Life Science Progression
    - HS LS1.A: Structure and function
  - Physical Science Progression
    - HS PS1.A: Structure of matter
    - HS PS2.A: Forces and motion
    - HS PS3.C: Relationship between energy and forces
    - HS PS4.C: Information technologies and instrumentation
- Crosscutting Concepts
  - Energy and matter
  - Systems and system models
  - Stability and change
  - Structure and function
- Science and Engineering Practices
  1. Asking questions (for science) and defining problems (for engineering)
  2. Developing and using models
  3. Planning and carrying out investigations
  4. Analyzing and Interpreting Data
  6. Constructing explanations (for science) and designing solutions (for engineering)
  8. Obtaining, evaluating, and communicating information

BACKGROUND – (from https://www.nasa.gov/sites/default/files/atoms/files/dressing_for_altitude.pdf)
Pressure is defined as the amount of force applied per unit area or as the ratio of force to area (P=F/A). The pressure an object exerts can be calculated if its weight (the force of gravity on an object) and the contact

surface area are known. For a given force (or weight), the pressure it applies increases as the contact area decreases. Air pressure decreases with increasing altitude.

Humans are relatively permeable to air (it can move easily in and out of our bodies) and that is why our internal pressure stays the same as the pressure of the surrounding (ambient) air. This is the same reason why fish are not crushed in the depths of the ocean; they are permeable to water. Although the atmosphere exerts a significant amount of pressure on everything in our environment, the only time most people are aware of air pressure is when it changes (such as changes in altitude, for example, as you drive up a mountain).



Engineers who design airplanes study air pressure. Airplane cabins are "pressurized." This means the inside of the plane maintains a constant pressure of about 14 pounds per square inch regardless of the pressure outside of the cabin. At high altitudes, the air has a very low pressure, which affects the way we breathe.

As elevation increases, air pressure decreases, and when we fly at high altitudes, the low pressure in these areas would be impossible for humans to survive in if it weren't for human made enclosures. In airplanes and spacecraft, internal cabins or cockpits are pressurized to help humans function. Since outside air pressure and density are higher near the ground, commercial aircraft have a higher internal air pressure during takeoff and landing to more closely match the outside air pressure.

Spacewalkers must wear pressurized spacesuits in order to work in space. These suits have pressures significantly lower than the ambient cabin pressure of a spacecraft. This makes spacewalkers subject to decompression sickness, more commonly known as the "bends." Decompression sickness results from nitrogen bubbles forming in the tissues or blood stream and moving to other areas of the body. Therefore, spacewalking crew members must perform a pre-breathe protocol, which is designed to wash out any excess nitrogen from the body, before a spacewalk.

Because of the human body's vulnerability in low-pressure environments, there has been years of research and development of methods to help humans both survive and function in low-pressure situations. These situations can be anything from spacewalking astronauts to high altitude pilots and balloonists. The higher the altitude, the more serious the effects on the human body. To understand exactly what would happen if your body was exposed to the vacuum of space, watch this video by SciShow: https://youtu.be/pm6df_SExVw.

Pressure Suits

When high-altitude pilots and astronauts travel above the lower layers of Earth's atmosphere, the air pressure exerted on them would be significantly reduced if they were not protected from the outside environment by a pressurized cockpit or capsule or a specially designed suit. This reduction in air pressure would be harmful or even fatal to a pilot or astronaut.

To protect pilots from this situation, engineers have developed various types of pressure suits that allow pilots and astronauts to function in these environments. Pressure suits exert pressure on the human body when external environments lack the pressure usually provided by the air at lower altitudes. In the event of aircraft cabin pressure loss at high altitudes, like 70,000 feet, where high-altitude aircraft such as the U-2 fly, engineers have developed partial pressure and full pressure suits. Development of high-altitude pilot suits led to the evolution of the spacesuit. Loss of cabin pressure on aircraft flying at lower altitudes results in hazards to flyers such as loss of consciousness or hypoxia but does not lead to other medical problems experienced by flyers at higher altitudes. So, how does a reduction in air pressure, whether high in Earth's atmosphere or in space, affect living organisms? The following activities allow students to simulate the effects of reduced pressure on objects and to develop their own "pressure suits" to tackle the challenge of preventing those effects.

Activity Eight: Under Pressure

MATERIALS (per group) –

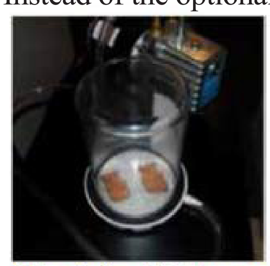
a. Large plastic syringes with caps or pieces of clay to plug the ends of the syringes (must be large enough for a small marshmallow to fit inside easily and can be purchased through a medical supply company or pharmacy)
b. Small marshmallows
c. Various materials for students to develop a pressure suit for their marshmallows (items could include tape, latex or nitrile gloves, and small pieces of paper that could be used to cover the small marshmallow)
d. Student Data Sheets
e. Optional for demonstration purposes: Peep® or large marshmallow and vacuum pump and jar

MANAGEMENT TIPS – Advise the students that they should never eat their experiments, even if the materials are edible. Eating during experiments is not a good safety practice. Also, always use a cap or piece of clay to cover the syringe tip opening (don't use your finger as a cap) to avoid injury. When students are designing a pressure suit for their small marshmallow, remind them that the marshmallow encased in the pressure suit needs to fit completely inside the plastic syringe to perform the testing. Activity hints: There are also many variations to a pressure suit that work for this activity: cutting off fingers from rubber gloves (not latex, but thick, cleaning gloves), using tape to restrict expansion, etc.

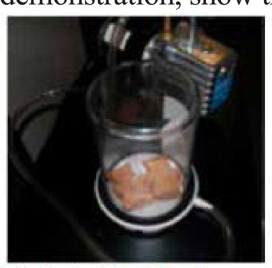
PROCEDURE –

Part 1: Experimenting with a Marshmallow and a Vacuum Chamber

1. Show the video "What happens to Peeps® in a vacuum chamber?" (https://www.youtube.com/watch?time_continue=171&v=EIvkOCRiSoI) and follow the video with a conversation on what happened to the Peep® when the vacuum chamber was turned on as well as when it was repressurized. Have them explain the reaction.
   Optional for demonstration purposes: Introduce the activity by showing the students a marshmallow or Peep® and asking what they think will happen when you place it in the vacuum and why. Discuss the predictions as a class and then place the marshmallow or Peep® in the bell jar. Turn on the vacuum pump and have the students observe how the size changes. Ask the students why they think this is happening. When finished, turn off the pump and repressurize the chamber. Have students observe what happens to the marshmallow or Peep®. If necessary, explain that the air has been forced out of the marshmallow or Peep® during the vacuum process. Based on that piece of information, ask them to explain why the marshmallows are now shriveled once air pressure has been reintroduced.
   Note: Instead of the optional demonstration, show the picture below or a video demonstration.



Marshmallow Peeps before the vacuum pump was turned on.



Marshmallow Peeps during air evacuation from pump.

Marshmallow Peeps at full vacuum.

Marshmallow Peeps after repressurization.

2. Discuss the background information with the students. Have them discuss what the purpose of a pressure suit is and the situations in which you would use one (e.g. high-altitude pilots, spacewalkers, high-altitude balloonists, deep-sea divers.)
3. Explain to the students that although watching demonstrations about pressure is helpful, allowing them to create a vacuum and manipulate their own mini vacuum chamber will strengthen their understanding about the effects of air pressure.
4. Allow the students to work in small groups of 2-3, pass out the Student Data Sheet and have them gather the materials.

5. Instruct the students to follow the steps listed on the Student Data Sheet to complete the experiment. Suggested answers are below in italics.
    1. Have students place a small marshmallow inside their syringe.
    2. Have students replace the plunger of the syringe, making sure the rubber piece is about halfway down the syringe.
    3. Once the plunger is in place, have students put the cap or the piece of clay on the tip of the syringe.
    4. Once students have capped the tip of the syringe, ask students to pull back on the plunger, creating a lower pressure environment. Students should note what happens to the marshmallow. (*a. pressure is decreasing, b. the marshmallow expands)*
    5. Also have students push the plunger in as far as they can to create a higher-pressure environment, again noting what happens to the marshmallow. (*a. pressure is increasing, b. the marshmallow will shrivel up*)
6. Let students experiment on their own with the marshmallow, noting the effects of changes in air pressure inside the syringe as they do so. Remind students that the effects of pressure on the marshmallow are similar to effects on human bodies as they go higher into Earth's atmosphere and then into space (the higher they go, the less pressure is exerted on them), but also as they travel underwater (the deeper they dive or swim, the more pressure is exerted on them).

Part 2: Designing a Pressure Suit for a Marshmallow

7. Review again the results of the experiment and provide more background information about pressure suits, specifically, and the needs for humans to have the restraint layer of the suit as they function in high altitudes and/or in space.
8. Explain to the students that they will need to design a pressure suit for their marshmallow that will keep it from expanding like it did in the earlier demonstration.
9. Have the students follow the Student Data Sheet to brainstorm and design their pressure suit, making sure to label the materials needed. Remind them that the pressure suit needs to fit on the marshmallow and must still be able to be inserted into the syringe.
10. Allow the students to build their suits from the available materials.
11. Test the designs in the syringe vacuum chamber. If there is room in the syringe, use an unprotected marshmallow as the control inside the chamber. Record results on the Student Data Sheet.
12. Allow students to refine their designs and retest, using a new marshmallow.
13. Finally, have the students present their pressure suit prototypes to the class. Encourage students to explain and share their designs, along with any challenges, hurdles, or failures along the way.
14. Go over the Post-Lab Questions as a class and extend as necessary.

EXTENSIONS

- To better understand how pressure increases as the surface area decreases, have students hold a large book flat on their outstretched hands and notice how much pressure the book puts on it. Then, try to balance the book on the tip of their index fingers. How much pressure does it seem to exert now?
- The NASA Dressing for Altitude: U.S. Aviation Pressure Suits— Wiley Post to Space Shuttle, is a book about the development and operation of pressure suits in aviation and access to space via the Space Shuttle. This book contains more detailed information about pressure suits and can be accessed as a free download in multiple formats for most platforms from the following location: http://www.nasa.gov/connect/ebooks/dress_for_altitude_detail.html.
- Investigate these websites for further information:
    - Space Suit Evolution: https://history.nasa.gov/spacesuits.pdf
    - Bill Nye the Science Guy on Pressure: https://www.youtube.com/watch?v=UDdRNXhIDwA

Name: ______________________________ Date: ________________

UNDER PRESSURE: Student Data Sheet

Part 1: Experimenting with a Marshmallow and a Vacuum Chamber

For this activity, you will be creating a miniature pressure chamber with a large plastic syringe and a cap or piece of clay to seal the tip of the syringe. Follow the instructions below and complete the questions.

Be sure to follow the steps in the correct order so you can create the proper pressure within your chamber.

1) Place a small marshmallow inside your syringe.

2) Replace the plunger of the syringe, making sure the rubber piece is about halfway down the syringe.

3) Once the plunger is in place, put the cap or the piece of clay on the tip of the syringe. **Do not place the cap on the tip of the syringe until the plunger is halfway down the inside of the syringe or you will not be able to properly change the pressure inside your chamber.**

4) Once you have capped the tip of the syringe, pull back on the plunger.
   a) What is happening to the pressure as you pull back on the plunger? Explain this in a complete sentence and draw a picture of the air molecules inside the syringe at this point.

   b) What happened to the marshmallow? Explain in a complete sentence and draw a picture.

5) Now push the plunger in as far as you can.
   a) What is happening to the pressure as you push in the plunger? Explain this in a complete sentence and draw a picture of the air molecules inside the syringe at this point.

b) What happened to the marshmallow? Explain in a complete sentence and draw a picture.

6) Experiment on your own with the marshmallow, noting the effects of changes in air pressure inside the syringe as you do so. The effects of pressure on the marshmallow are similar ti effects on the human bodies as they go higher into Earth's atmosphere and then into space (the higher they go, the less pressure is exerted on them). In addition, increasing the air pressure inside the chamber mimics the effects of traveling underwater (the deeper you dive or swim, the more pressure is exerted on you).
   a) Describe some of the effects of your own experimentation with the marshmallow inside the pressure chamber.

Part 2: Designing a Pressure Suit for a Marshmallow
Describe your design for marshmallow pressure suit according to The Engineering Design Process.

1. Ask: State the challenge in your own words. ______________________________

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2. Imagine: Describe your hypothesis or plan of action. ______________________________

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3. Plan: Draw a sketch of your plan and label all materials.

Materials required: ______________________________

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4. Create: Procedure/Notes (What steps did you follow to complete the Design Challenge?)

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5. Experiment: Record your test results on the data chart below.

Test #	Change Made	Observation Notes
1		
2		
3		
4		
5		
6		

6. Improve: Explain how your suit worked and why; identify any areas for improvement.

Type of Suit	Abilities of Suit	Limitations of Suit	Changes from Original Design
Original design: partial or full (circle one)			n/a
1			
2			

Post-Lab Questions

Once you have completed the above activities, answer the following questions:

1) Based on the above activities, explain how a pressure suit would help you if you were working in a high-altitude environment or up in space.

2) What is the difference between a partial pressure suit and a full pressure suit?

3) Take the design you made for your pressure suit, choose two of the following suit requirements, and explain what would have to happen to the design of your suit in order to meet them:

a) Full pressure high-altitude pilot suit

b) Spacesuit designed for working outside the International Space Station

c) Emergency suit for use inside the International Space Station

d) Pressure suit for high-altitude skydiving (high-altitude skydiving occurs at least 23,000 feet above Earth's surface)