RESOURCE LIBRARY
ACTIVITY : 3 HRS

You Can Take the Pressure!

Students engineer a model vessel that can rise slowly to the surface from a depth of 3 meters (10 feet) under water.

GRADES

6 - 8

SUBJECTS

Earth Science, Oceanography, Engineering, Geography, Mathematics, Physics

CONTENTS

3 Links, 4 PDFs, 1 Video

OVERVIEW

Students engineer a model vessel that can rise slowly to the surface from a depth of 3 meters (10 feet) under water.

For the complete activity with media resources, visit:
http://www.nationalgeographic.org/activity/you-can-take-pressure/

Program

DEEPSEA CHALLENGE

DIRECTIONS

1. Activate students' prior knowledge by having them list some engineering challenges that James Cameron and his team had to solve in order to travel to the Mariana Trench.

Remind students that Earth's ocean is largely unexplored in part because of the engineering challenges presented by deep-sea exploration. If necessary, have students visit the provided *DEEPSEA CHALLENGE* website to review some of the challenges. Distribute the Engineering Process handout and review the steps in the process with students. Tell students that they will be using their journals to respond to prompts in the steps on the Engineering Process handout and to take notes as indicated throughout this activity. When reviewing step 1 of the handout, remind students what constraints and considerations are, and give examples of each. Constraints are absolute requirements or limitations in a design or decision-making process. If a choice or solution doesn't meet the constraints, then it must be eliminated. For example, if you are shopping for new bookshelves for your living room, there will be a size constraint. The bookshelves must be small enough to fit in the available space in your living room. Any bookshelves that are too big must be eliminated as a choice, even if they are otherwise perfect. Considerations are desired, but not necessary, elements in a design, solution, or decision. Considerations can be used to rank choices and solutions. For example, if your living room has a lot of dark wood, the tone of the wood for your bookshelves would be a consideration; you might prefer to have dark wood so that it will match the other wood in the room. However, you wouldn't necessarily eliminate a shelf just because it has lighter wood.

2. Watch the "Cracking the Code" video of James Cameron describing one of the major engineering challenges his team faced on the *DEEPSEA CHALLENGE* expedition.

Provide students with the following focus questions prior to watching the video: What was the big challenge James Cameron describes? Why was this challenge unexpected? What was the problem with commercially available foam? Have students take notes as they watch the video, and use the questions to launch a discussion at the end of the video.

3. Have students describe objects using the terms "positively buoyant," "negatively buoyant," and "neutrally buoyant."

Have students use the palms of their hands to push several objects to the bottom of a tub of water, and ask students to describe what they feel and see as the objects either remain on the bottom or push on their hands back toward the surface. Include objects that will float as well as objects that will sink. If students do not use the term "buoyant" to describe what they see, introduce the term to them. Explain that objects can be positively, negatively, or neutrally buoyant. Ask students to describe the objects in the tub using these terms. Discuss how pressure is related to buoyancy. Refer to the background information section for support with this discussion.

4. Have students redefine the problem description from the Problem Scenario: You Can Take

the Pressure handout in their own words.

Read aloud the problem description section of the Problem Scenario: You Can Take the Pressure handout to students. Explain to students that they will use the Engineering Process handout they were given earlier to plan, design, and test solutions to the problem presented in the scenario. Working in small groups, have students define the problem in their own words per step 1 of the handout. Invite groups to share their problem definitions with the class, and then go over the problem definition provided on the Problem Scenario: You Can Take the Pressure handout. Briefly review the concepts of constraints and considerations. Have each group list constraints and considerations for the problem. Have groups share their ideas with the class, and then provide the final list of constraints for the problem as listed on the Problem Scenario: You Can Take the Pressure handout.

5. Have students conduct research that will help them solve the problem.

Have each group brainstorm questions they have, information they need, and keywords and topics to solve the problem, and have them list these per step 2 of the Engineering Process handout. Have students begin their research by using the MapMaker interactive to find the Mariana Trench on a world map. Ask them to label the trench's depth and the pressure that would be exerted on the *DEEPSEA CHALLENGER* at that depth on the map. Have students review information about how much pressure is exerted per foot of water depth and then calculate how much pressure their models will need to withstand at a depth of 3 meters (10 feet). Allow them additional time to conduct research for any information they identified as important to their solutions. Provide students with a variety of materials for use in building their prototypes, such as plastic or Styrofoam cups, small lengths of PVC pipe, a variety of insulating materials (foam pipe insulation, bubble wrap, packing peanuts, etc.), waterproof duct tape, pennies or washers, and other available materials. Ask students to test how the various materials behave in water. Have students summarize the results of their research and list characteristics of the materials they explored per step 2 of the handout. Ask students to predict how they think the materials will react to changes in pressure. Provide each group with a cooler or large bucket filled with water to a depth of about 0.3 meters (1 foot).

6. Have students propose solutions.

Have students review the problem, including the constraints and considerations they identified. Ask students to propose solutions and describe them in their journals (step 3 of the Engineering Process handout). Encourage students to be specific and thorough in their proposals.

7. Have students develop designs.

Have students draw detailed designs for their proposed solutions as described in step 4 of the Engineering Process handout. Have them label their designs, include possible materials, and make any other notes necessary for clarity. Ask students to describe how their designs will work to solve the problem.

8. Have students build prototypes.

Have students build prototypes of their designs, using the available materials they explored in step 5 of the activity. Remind students of the size constraints for their prototypes. Have students list the materials they use, including amounts, per step 5 of the Engineering Process handout. Have them include step-by-step instructions for how to build their prototypes. Point out that these instructions must be specific and thorough enough that someone else could use them to replicate the prototypes.

9. Have students prepare a testing procedure.

Describe the basic testing procedure to students. Tell students that they will conduct three sets of tests: the first set will use containers of water filled to a depth of about 0.3 meters (1 foot); the second and third sets will use water up to 3 meters (10 feet) deep. The deeper water tests will be done in a teacher-created water column (see Preparation section and How to Build a Water Column handout for information). Tell students that they will be able to test, evaluate, adjust their prototypes, and retest at each level. Following step 6 of the Engineering Process handout, have students list the data they need to collect in order to evaluate their solutions and describe how they will use that data to improve their designs. Have students specify how they want to conduct the tests. Ask: *How will you collect data? What role will each team member play in the testing process?* Have students create tables to record the data for each test. Review the testing procedures with each group before moving on to the next step. Check to be sure that students plan to gather basic data such as the depth of the test, the orientation of the prototype as it ascends, and the length of time it takes to rise to the surface.

10. Have students conduct the first test in 0.3 meters (1 foot) of water.

Have students test their prototypes in 0.3 meters (1 foot) of water and record their data. To conduct a test, students will need to push their prototypes to the bottom of the container and then let go of them to determine whether they are positively buoyant and thus able to rise to the surface on their own. The slower a prototype rises, the closer it is to being neutrally buoyant. A negatively buoyant prototype will remain on the bottom of the container. Have students use the data they collect to evaluate the success of their designs. Have them determine what, if any, changes need to be made to their designs to have them better solve the problem. Give students time to re-make their prototypes and make any adjustments needed. Then have them test again. Provide students as many opportunities as time permits to test and retest their prototypes in 0.3 meters (1 foot) of water.

11. Have students conduct tests at depths of 1.5 meters (5 feet) and 3 meters (10 feet).

Next, give students two opportunities to test at 1.5 meters (5 feet) and two opportunities to test at 3 meters (10 feet), using a water column. For each test, students should use a pole to submerge their prototype to the designated depth and should then remove the pole to see what happens to the prototype. A negatively buoyant prototype will sink; a neutrally buoyant prototype will hover at the depth where it is released, and a positively buoyant prototype will rise to the surface. The slower a positively buoyant prototype rises, the closer it is to being neutrally buoyant. Encourage students to consider the differences in pressure between the two sets of tests and make adjustments accordingly. A prototype that is positively buoyant at 1.5 meters (5 feet) might or might not remain positively buoyant at 3 meters (10 feet). Make sure students record detailed data for each test, including any adjustments made to their designs. Have students write summaries of their test results and the adjustments they made based on those results.

12. Have students evaluate the final designs and the engineering process.

Have each group present a summary of their design and the results of their tests. Discuss the engineering process the students followed and analyze why some designs worked and others did not. Ask: *What kinds of materials were used in the successful designs? What functions did those materials serve? What effect did pressure have on the prototypes as they dove deeper? How did those effects match the predictions you made in step 5 of the activity? What adjustments did you make to counteract those effects?* Read the provided *DEEPSEA CHALLENGE:* Systems and Technology website and discuss how James Cameron and his team solved the problem of the foam. Tell students that they will write reflections of the process they used to solve the problem presented to them. Distribute the Reflection Rubric to each student and review the criteria you will use to assess their written reflections. Tell students to refer to the Engineering Process handout, their journals, and any other notes they took to write their reflections. Explain that the reflections should include summaries of the problem they had to solve, explanations of how pressure affected their designs in deeper water, and evaluations of how well their designs worked, including what they would change to make them work better.

Modification

As an alternative to using a water column built from soda bottles, you can use a 3 m (10 ft) length of 10 cm (4 in) PVC, capped at the bottom. Clear PVC works best and is available for order online if you can't find it at local home improvement stores.

Tip

Decrease your preparation time by enlisting students to help cut the bottles for the water column.

Tip

During any downtime resulting from groups finishing a step early, have students collaborate to create a recovery rod that can retrieve a prototype if it gets stuck at the bottom of the water column.

Tip

Hand-held PVC pipe cutters can be used to cut PVC pipe to whatever length necessary. Consider pre-cutting the pipe into 2.5 cm (1 in) or 5 cm (2 in) segments for students. For safety reasons, do not allow students to handle the pipe cutters.

Modification

If you have access to an existing body of water at least 3 meters (10 feet) deep, such as a swimming pool, you can test the prototypes there instead of constructing the water column. Be sure to create submersion and retrieval tools that match the depth of the water.

Tip

Increase students' motivation by turning the trials at 3 meters (10 feet) into a competition. Award one point for each second that it takes a prototype to return to the surface. After all teams have completed their testing, offer prizes for the highest score and the most improved score.

Tip

Keep safety in mind while testing with the water column. One person will need to be able to reach the top of the (3 meter) 10 foot water column in order to launch the prototype. Consider drafting an adult helper for this role. If possible, locate the water column near an outdoor stairwell or by playground equipment. If necessary, a ladder can be used to reach the top of the water column, and the water column can be attached to the ladder for stability.

Tip

Note that all tests with the 3 meter (10 foot) water column should be done outside in case of large leaks or spills. If you opt to do the 0.3 meter (1 foot) tests inside the classroom, keep in mind that many of the designs are likely to retain water. Surround the coolers or buckets with towels, give each group a towel for drying materials, and have students place their materials directly into a plastic bag after testing.

Informal Assessment

Observe students throughout this activity and review their journal entries in response to the prompts on the Engineering Process handout to assess how well they are applying problem-solving strategies and their knowledge of pressure.

Use the provided Reflection Rubric to assess students' final reflections.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Oceanography

- Engineering

Geography

- Mathematics
- Physics

Learning Objectives

Students will:

- design, model, test, and revise an engineering solution
- apply a knowledge of pressure and buoyancy to solve an engineering problem

Teaching Approach

- Learning-for-use

Teaching Methods

- Cooperative learning
- Discussions
- Hands-on learning
- Research

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Creativity and Innovation
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Creating
  - Evaluating
- Geographic Skills

- Analyzing Geographic Information

National Standards, Principles, and Practices

NATIONAL GEOGRAPHY STANDARDS

• **Standard 15**:
How physical systems affect human systems

NATIONAL SCIENCE EDUCATION STANDARDS

• **(5-8) Standard B-2**:
Motions and forces
• **(5-8) Standard E-1**:
Abilities of technological design

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

• **Principle 7a**:
The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

ISTE STANDARDS FOR STUDENTS (ISTE STANDARDS*S)

• **Standard 1**:
Creativity and Innovation
• **Standard 2**:
Communication and Collaboration
• **Standard 4**:
Critical Thinking, Problem Solving, and Decision Making

Preparation

What You'll Need

MATERIALS YOU PROVIDE

- Bubble wrap
- Duct tape or other strong tape
- Additional materials to use in the construction of prototypes
- Cups, clear plastic
- Cups, Styrofoam
- Objects to demonstrate positive, negative, and neutral buoyancy
- Pennies or washers
- PEX pipe
- Pole (at least 3.3 m (11 ft) long—can be constructed out of PVC pipe and connectors)
- PVC pipe cutters
- PVC pipe
- Several types of foam

REQUIRED TECHNOLOGY

- Internet Access: Required
- Tech Setup: 1 computer per small group, Projector, Speakers

PHYSICAL SPACE

- Classroom
- Outdoor recreation space

SETUP

You will need to build a water column (described in the How to Build a Water Column handout) before beginning the activity. Allow 3 to 4 days to build the column and let it dry before use. The testing phase of the activity should be completed outside. The water column will need to be placed so that the top of it (3 m (10 ft)) is easily accessible. An outside stairwell, playground equipment, or a ladder could be used to access the top of the column. Keep safety in mind when placing and using the water column and be sure it is secure and that the method you use for students to access the top of it is safe. Your testing location should also include a safe place to drain the water from the column at the conclusion of the activity. See modifications for other ways to test the prototypes if you do not have time to build the water column described.

GROUPING

- Large-group instruction

OTHER NOTES

This activity is best conducted in two sessions. Complete step 1 through the shallow testing phase in the first session, and then complete testing and evaluation in the second session. If shorter sessions are needed, steps prior to the testing phase can be completed in one session, and the testing and evaluation can be completed over two sessions.

BACKGROUND & VOCABULARY

Background Information

One of the biggest challenges for the *DEEPSEA CHALLENGE* expedition, as for any deep-sea expedition, was the extreme pressure at the bottom of the ocean. This extreme pressure affects all parts of a deep-sea vehicle and can cause materials to condense or to crack or fail. Pressure is also related to buoyancy. Buoyancy is the upward force exerted by a fluid on an object, equal to the weight of the fluid displaced by the object. (Note that both liquids and gases are considered fluids.) Buoyancy works to make objects float because the pressure at the bottom of the object, which is deeper in the fluid, is greater than the pressure at the top of the object. This creates a net upward force. When an object is placed in a fluid, it displaces some of that fluid. As an object is lowered into a fluid, the buoyant force increases; it reaches a maximum when the object is completely submerged. This maximum force is equal to the weight of the volume of fluid displaced. The volume of fluid displaced is equal to the total volume of the object.

It is not necessary to calculate the maximum buoyant force to determine if an object will float. Simply compare the density (mass/volume) of the object to the density of the fluid. The net force acting on an object placed in a fluid depends on the relative weight of equal volumes of the object and the fluid. With equal volumes, greater density means greater weight. When the density of the object is less than that of the fluid, the object is positively buoyant and will float. When the density of the object is the same as that of the fluid, it is neutrally buoyant and will “hover” under the surface without sinking. When the density of an object is greater than that of the fluid, it is negatively buoyant and will sink. In the deep ocean, pressure can also affect buoyancy by compressing materials. This compression will make the materials more dense (the same mass but a smaller volume), and thus less buoyant. The *DEEPSEA*

CHALLENGER was designed with syntactic foam because the foam is light, strong, and not as compressible as other types of foam. This helped keep the *DEEPSEA CHALLENGER* light and minimized the effects of pressure on the vehicle's buoyancy.

Prior Knowledge

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Recommended Prior Activities

- Adapting Under Pressure
- Engineering Inspirations from Nature

Vocabulary

Term	Part of Speech	Definition
buoyancy	*noun*	the power to float or rise in a fluid.
consideration	*noun*	a matter weighed or taken into account when formulating an opinion or plan.
constraint	*noun*	limitation or obstacle.
density	*noun*	number of things of one kind in a given area.
engineer	*noun*	person who plans the building of things, such as structures (construction engineer) or substances (chemical engineer).
pressure	*noun*	force pressed on an object by another object or condition, such as gravity.

FUNDER

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