RESOURCE LIBRARY
LESSON

Solving a CHALLENGE-ing Problem

Inspired by James Cameron's historic *DEEPSEA CHALLENGE* dive, students will investigate pressure, biological adaptations, and the engineering process through hands-on activities.

GRADES

6 - 8

SUBJECTS

Arts and Music, Biology, Earth Science, Oceanography, Engineering, Geography, Physical Geography, Mathematics, Physics

CONTENTS

5 Activities

Program

DEEPSEA CHALLENGE

ACTIVITY 1: ANIMAL ADAPTATIONS IN THE OCEAN | 25 MINS

DIRECTIONS

1. Introduce or review the concept of adaptations.
Write the word *adaptation* on the board. Ask students to define this word as it relates to animals. Ask:

- *Why do animals have special adaptations to their habitats?*
- *What examples of animal adaptation can you think of near where you live?*
- *What types of adaptations in marine animals have you previously learned about?*

Encourage students to think about adaptations in marine animals related to obtaining food, providing camouflage or safety from predators, or dealing with changes in temperature, salinity, pressure, lack of sunlight, and need for oxygen.

2. Have students identify animal adaptations in a National Geographic photo gallery.
Show students the photo gallery and have them take turns reading aloud the captions as the class looks at each photo. Ask students to identify information about adaptations in each caption. For those captions that do not include adaptation information, challenge students to find visual evidence of adaptation. For example, needlefish travel in schools to protect themselves from predators; their color and size help them blend into their surroundings. Portuguese man-of-wars have air bladders that allow them to float on or near the surface of the ocean. These communal organisms use their air bladders like sails, allowing wind to move them through the water. The green sea turtle's shell protects it from predators.

3. Have students make predictions about ocean habitats.
Ask students to predict how different ocean habitats might affect the animal adaptations seen there. Ask:

- *How different is life at the surface of the ocean from life at the bottom?*
- *What types of adaptations might marine animals need to have near the surface versus near the bottom?*

OBJECTIVES

Subjects & Disciplines

Biology

Learning Objectives

Students will:

- identify visual evidence of adaptations
- make predictions about how marine animal adaptations vary by habitat

Teaching Approach

- Learning-for-use

Teaching Methods

- Discussions
- Visual instruction

Skills Summary

This activity targets the following skills:

- Critical Thinking Skills
  - Understanding
- Geographic Skills
  - Acquiring Geographic Information

National Standards, Principles, and Practices

NATIONAL SCIENCE EDUCATION STANDARDS

• **(5-8) Standard C-5:**
Diversity and adaptations of organisms

Preparation

BACKGROUND & VOCABULARY

Background Information

Animals adapt to their environments to help them survive. Ocean animals have unique adaptations depending on what ocean habitat they live in.

Prior Knowledge

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Recommended Prior Activities

- Ocean Habitats and Animal Adaptations

Vocabulary

Term	Part of Speech	Definition
adaptation	*noun*	a modification of an organism or its parts that makes it more fit for existence. An adaptation is passed from generation to generation.
habitat	*noun*	environment where an organism lives throughout the year or for shorter periods of time.
marine	*adjective*	having to do with the ocean.
predator	*noun*	animal that hunts other animals for food.
salinity	*noun*	saltiness.

FUNDER

This activity is made possible by a generous grant from the National Oceanic and Atmospheric Administration (NOAA) National Marine Sanctuary Program.

Before Moving on to the Next Activity

In Activity 2, students learned about the different ocean zones and identified animal adaptations in these zones. In the next activity, students will further investigate the deepest ocean zone and apply what they know about pressure and animal adaptations in the ocean to create an animal that could survive in the Mariana Trench.

ACTIVITY 2: ADAPTING UNDER PRESSURE | 1 HR 30 MINS

DIRECTIONS

1. Activate prior knowledge by introducing or reintroducing James Cameron's historic Challenger Deep dive.

Explain that Cameron's submersible was under 8 tons of pressure per square inch while he was in the Challenger Deep at depths of up to 10,898 meters (35,756 feet). Ask: *Could Cameron (or any person) survive under that much pressure at those depths without being protected inside of something? Could other living creatures survive at those depths and that pressure? How? What other living creatures do you think Cameron was likely to encounter at those depths?*

2. Divide students into pairs and have them review the characteristics of the ocean zones and match ocean animals with the ocean zones in which the animals are found.
Briefly review the characteristics of each ocean zone, using the provided NOAA Layers of the Ocean website if necessary to refresh students' memories. Give each pair of students a photo of an ocean animal from one of the provided websites or point them to an animal on one of the websites. Have students look at the photos of the animals, read the captions, and list as many characteristics and adaptations of the animals as they can. Then have them compare the lists of characteristics and adaptations to the different ocean zones to predict in which zones the creatures live.

3. Have students investigate the hadalpelagic zone.
Distribute the Deep-Sea Creature Project Planner worksheet to each pair of students. Have students read the information about the Mariana Trench from the provided *DEEPSEA CHALLENGE,* Windows to the Universe, and NOAA Layers of the Ocean websites. Have them list unique characteristics of the hadalpelagic zone in the first column of the worksheet.

4. Have students brainstorm adaptations related to the characteristics of the hadalpelagic zone.
For each characteristic of the hadalpelagic zone that students listed on the Deep-Sea Creature Project Planner worksheet, have them brainstorm possible adaptations that would allow an animal to survive and thrive in a place with that characteristic. Ask them to also consider adaptations related to senses or physical characteristics that would not be needed there. For example, if they listed that the hadalpelagic zone is dark, they might include adaptations such as acute hearing or sonar to aid in navigation and/or the loss of eyesight because it would be of little use in that environment. Encourage students to list as many possible adaptations as they can.

5. Have students predict what Cameron saw on his dive by drawing never-before-discovered creatures that could survive in the Challenger Deep in the Mariana Trench.
Distribute the Deep-Sea Creatures Rubric, paper, pencils, and colored pencils, pens, or markers to each pair of students. Review the Deep-Sea Creatures Rubric with students and make sure they understand how they will be assessed. Ask students to select adaptations for their

animals from their brainstormed lists. Adaptations should cover all the unique characteristics of the hadalpelagic zone, although some adaptations might address more than one characteristic. Have students draw, color, and clearly label their creatures.

6. Have students share their creatures with each other.
Arrange the class into groups of two to three pairs each. Have each pair present its creature to the other pair(s) in the group and describe how the creature is adapted for survival in the hadalpelagic zone. After group members have presented to each other, display all the creatures in the classroom and give students a chance to walk around and look at each other's work. Use the Deep-Sea Creature Rubric to assess students' creatures. Discuss how the creatures are similar to and different from one another. Ask: *How does the diversity of the creatures you and your classmates designed compare to the diversity of real animals in the hadalpelagic zone?*

7. Show the "Absolute Edge of Life" video and discuss what James Cameron actually saw during his historic dive into the Mariana Trench.
Ask: *How did your predictions compare to what Cameron saw? How was what Cameron saw different from what he expected to see? What lesson did he take away from that? Do you believe there are animals in the deep oceans that haven't been discovered yet? Why or why not?*

Informal Assessment

Use the provided Deep-Sea Creatures Rubric to assess students' creatures.

Extending the Learning

Provide students with a variety of art supplies and throw-away materials such as soda bottles, colored paper, Styrofoam, and sequins. Have them create a three-dimensional model of the creature they designed.

Have students research a creature that lives in the hadalpelagic zone. Have them sketch and label the creature and identify specific adaptations the creature has for surviving in the deep-sea environment.

OBJECTIVES

Subjects & Disciplines

- Arts and Music
  Biology
  Earth Science
  - Oceanography
  Geography
  - Physical Geography

Learning Objectives

Students will:

- identify characteristics of the ocean zones
- use the physical characteristics of an animal to predict the ocean zone in which the animal lives
- design a creature that could survive in the hadalpelagic zone

Teaching Approach

- Learning-for-use

Teaching Methods

- Cooperative learning
- Discussions

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

National Standards, Principles, and Practices

NATIONAL GEOGRAPHY STANDARDS

• **Standard 8:**
The characteristics and spatial distribution of ecosystems and biomes on Earth's surface

NATIONAL SCIENCE EDUCATION STANDARDS

• **(5-8) Standard C-5:**
Diversity and adaptations of organisms

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

• **Principle 5c:**
Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Preparation

BACKGROUND & VOCABULARY

Background Information

The ocean is vast and teeming with life. Because of its size and depth, the ocean contains more than one habitat for aquatic life. Scientists divide the ocean into various zones. These include the epipelagic zone (sunlight zone), mesopelagic zone (twilight zone), bathypelagic zone (midnight zone), abyssopelagic zone (abyssal zone), and the hadalpelagic zone. The zones are differentiated based on depth, and each has unique characteristics and unique forms of life that are adapted to conditions in that zone.

The deepest ocean zone, the hadalpelagic, was the focus of James Cameron's historic *DEEPSEA CHALLENGE* expedition. The hadalpelagic zone is found from about 6,000 meters (19,700 feet) to 10,911 meters (35,797 feet) in ocean trenches such as the Mariana Trench where the *DEEPSEA CHALLENGE* expedition took place. The characteristics of the hadalpelagic zone include extreme cold, extreme pressure, and complete darkness. The temperatures in this zone remain just above freezing and the pressure reaches more than 8 tons per square inch. Though much of the deep ocean remains to be explored, scientists have identified organisms that can survive in these extreme conditions, including tubeworms, jellies, sea cucumbers, and foraminifera. These creatures have adapted to their environment in unique ways. For example, tubeworms survive near hydrothermal vents where volcanic activity can create areas of very high temperatures. Bacteria living inside the tubeworms have adapted to use the chemicals in the hot waters rising from the vents to produce energy in the absence of sunlight. Other adaptations of organisms in this zone include diminished use of eyes and sight, soft bodies, slow movement, limited pigmentation (red, black, or transparent), and bioluminescence.

Prior Knowledge

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Recommended Prior Activities

- Ocean Habitats and Animal Adaptations

Vocabulary

Term	Part of Speech	Definition
abyssopelagic zone	*noun*	zone of the open ocean, starting at 3,962 meters (13,000 feet) below sea level.
adaptation	*noun*	a modification of an organism or its parts that makes it more fit for existence. An adaptation is passed from generation to generation.
bathypelagic zone	*noun*	zone of the open ocean, starting at 914 meters (3,000 feet). Also known as the midnight or aphotic zone.
epipelagic zone	*noun*	upper zone of the ocean. This zone goes down to approximately 183 meters (600 feet). Also called the euphotic or sunlit zone.

Term	Part of Speech	Definition
hadalpelagic zone	*noun*	deepest zone of the open ocean, starting at around 6,000 meters (20,000 feet).
mesopelagic zone	*noun*	zone of the open ocean, extending from about 183 to 914 meters (600 to 3,000 feet). Also known as the twilight or dysphotic zone.
pressure	*noun*	force pressed on an object by another object or condition, such as gravity.

FUNDER

Alfred P. Sloan Foundation

Before Moving on to the Next Activity

In Activities 2 and 3, students investigated adaptations in ocean animals. In the next activity, students will explore how animal adaptations can inspire technological innovations.

ACTIVITY 3: ENGINEERING INSPIRATIONS FROM NATURE | 3 HRS

DIRECTIONS

1. Activate prior knowledge by reintroducing James Cameron's *DEEPSEA CHALLENGE* expedition to the Mariana Trench.

Review the *DEEPSEA CHALLENGE* website to refresh students' memories about the expedition. Have students brainstorm what they remember from previous activities about conditions in the trench and about the kinds of adaptations animals have developed to survive in those areas. Ask students to rephrase some of those adaptations as problem-solution pairs. For example: no light (problem)-bioluminescence (solution).

2. Project the provided handout James Cameron's Quote about the *DEEPSEA CHALLENGE* Expedition and read it with students.

Discuss the quote from James Cameron. Ask: *What was his motivation for designing the DEEPSEA CHALLENGER submersible? Why was designing a new submersible necessary*? Explain that Cameron and his team had to engineer a submersible that was specifically adapted to explore the deep ocean. Brainstorm challenges that Cameron and his team had to address in order to explore in the hadalpelagic zone. Elicit responses that include that they had to be able to withstand 8 tons per square inch of pressure, be able to operate in near-freezing temperatures, have time to explore the bottom, and provide some sort of lighting for visibility. Have students read and discuss the *DEEPSEA CHALLENGE:* The Sub website to identify some of the solutions Cameron and his team of engineers came up with for these challenges. As students discuss and share ideas, create a list on the board of problems and solutions related to the expedition.

3. Ask students to describe what an engineer is and what an engineer does.

Accept multiple answers from students and write them on the board. Encourage students to think about what they have read about James Cameron and the team of engineers that designed the *DEEPSEA CHALLENGER*. Then review what you wrote on the board and guide students to come up with a working definition of an engineer. Explain that engineers follow a general procedure to solve an engineering problem or design a solution. Distribute the Engineering Process handout and review the steps in the process with students. When reviewing step 1, define the terms “constraints” and “considerations,” 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.

4. Introduce the idea of biomimicry through examples and a guessing game.

Explain that animal adaptations like the ones students explored in the Adapting Under Pressure activity can sometimes be a source of inspiration for engineers who are trying to solve a particular design challenge. Open the provided Humpback Breaching webpage and read aloud to students the last bullet point, which explains how the whale is an inspiration for cutting-edge technology. Discuss what biomimicry is and why looking at examples from nature might be helpful to engineers. Divide students into small groups. Display three examples of biomimicry from the provided WebEcoist: Brilliant Bio-Design webpage, and have students work with their groups to identify the inspiration from nature behind these designs.

5. Focus students' attention on one of the engineering challenges faced by James Cameron and his team.

Provide students with the following focus questions:

- What heat-related problem did James Cameron face in early dives? What caused the problem?
- What effect did the heat have on Cameron?
- What solutions did he and his team come up with to address the problem?

Show the "105 Degrees" video and have students use the focus questions to take notes as they view the video. Then have students read the description of the dangers from extreme temperatures faced during the *DEEPSEA CHALLENGE* dive from the provided *DEEPSEA CHALLENGE* Expedition Risks and Dangers website. Discuss the focus questions and the reading as a class.

6. Have students make observations about the effects of extreme heat and cold on a marshmallow.

Place a large marshmallow in boiling or near-boiling water for about 30 seconds to one minute. Spoon the marshmallow out of the water and show it to students. Ask students to make observations about what happened to the marshmallow. Students should observe that the marshmallow melted or got smaller. Place another marshmallow in ice water for 30 seconds to one minute and then pass it around to students. Have students make observations about what happened to the marshmallow. They might observe that it shrank slightly, and they should definitely observe that it became very cold to the touch. Explain that students will be using marshmallows as stand-ins for explorers in an engineering challenge of their own.

7. Have students redefine the problem statement.

Challenge students to work in small groups to come up with designs inspired by nature that will protect their explorers (represented by the marshmallow) from extreme heat (boiling or near-boiling water) and extreme cold (ice water). Read aloud to students the problem description section of the Problem Scenario: Engineering Inspirations handout. Explain that students will use the Engineering Process handout they were given earlier to guide them through the process as they 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 Engineering Process handout. Invite groups to share their problem definitions with the class, and then go over the problem definition provided on the Problem Scenario: Engineering Inspirations handout. Briefly review the concepts of constraints and considerations. Have each group list constraints and considerations for the problem scenario. 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: Engineering Inspirations handout.

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

Explain that students should utilize biomimicry and look for inspiration from nature to help them solve the problem. Have each group brainstorm questions they have, information they need, and keywords and topics to use in their research to solve the problem, and have them list these per step 2 of the Engineering Process handout. Have students use the provided National Geographic Animal Photo gallery to look for inspiration. Also allow time for them to conduct research about any other information they identified as important to their solutions. Have students summarize the results of their research and describe their inspirations from nature per step 2 of the Engineering Process handout.

9. Have students propose solutions.

Have students review the problem, including the constraints and considerations they identified. Students should then propose solutions based on inspiration from nature and describe their solutions per step 3 of the Engineering Process handout. Encourage students to be specific and thorough in their proposals.

10. Have students develop designs.

Have students draw detailed designs for their proposed solutions as described by 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 they think their designs will work to solve the problem.

11. Have students build prototypes.

Provide students with materials such as small soda bottles, medicine bottles, small lengths of PVC pipe, a variety of insulating materials (foam pipe insulation, bubble wrap, packing peanuts, etc.), waterproof duct tape, conductive materials (such as aluminum foil), rags, sponges, and other available materials. Have students build prototypes of their designs using these available materials. Remind students of the size constraints for the 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 the prototypes. Point out that these instructions must be specific and thorough enough that someone else could use them to replicate the prototypes.

12. Have students test the prototypes.

Describe the basic testing procedure to students. Tell them that each group will first immerse their prototype in hot water and then open the prototype and check the status of the marshmallow. They will then use the same prototype to repeat the process in cold water. Tell them that a test using a successful prototype will show no effect on the marshmallow. However, if their marshmallow is altered after the first test they can use a new marshmallow for the second test. Have students specify how they want to conduct the tests per step 6 of the Engineering Process handout. Ask: *How will you open the prototype after it is removed from the water? How quickly will you need to open the prototype after it is removed from the* *water?* Have students list the data they need to collect in order to evaluate their solutions and describe how they will use the data to improve their designs. Have students create tables to record the data for each test. Have students conduct the first test in hot water and record their data. Because prototypes will need to be opened in order to check the effects of the test on the marshmallow, students will need to repair the prototypes or use the information they recorded to build identical prototypes for use in the next test. Have them test the prototypes in cold water and record their data. Have students use the data they gathered to evaluate the success of their designs. Have them determine what, if any, changes need to be made to their designs to solve the problem. Give students time to re-make their prototype and make any adjustments needed. Then have them test again. Provide students at least three opportunities to adjust and re-test their prototypes. Make sure they 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.

13. Have students evaluate their final designs and the engineering process.

Have each group present a summary of their design and testing. 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?* Tell students that they will write a reflection 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 and any other notes they took to write their reflections. Explain that the reflection should include a summary of the problem they had to solve, an explanation of how their design was inspired by nature, and an evaluation of how well their design worked, including what they would change to make it work better. They should then compare what they did in this activity to what an engineer does.

Modification

Adjust the size constraint for students' capsule prototypes based on the sizes of the pots they will use for testing.

Modification

Instead of or in addition to looking through a photo gallery for inspiration, take students outside to look for inspiration directly from nature.

Tip

In step 10, if possible, allow students to see the materials you have gathered for use in creating their designs.

Tip

In step 12, the main change to the marshmallow if it is not well protected from cold is that the marshmallow itself gets cold. Be sure students touch their marshmallow as quickly as possible after removing their prototype from the water and record whether or not the marshmallow is cold to the touch.

Tip

In step 12, use safety precautions when placing the prototypes in the boiling water, removing them from the water, and opening them after removal. Let the prototypes cool down before cutting them open, and use heat-protective gloves and tongs for added safety. Depending on the students, the teacher might want to conduct this step.

Tip

In step 4, be careful not to give away the animal inspiration before students have had a chance to guess. The page displays images and text making these connections, so be sure to avoid these images and text when displaying the images to students. If you use the video of the robotic arm, start the video at 1:25 to avoid giving away the inspiration.

Modification

Place small, liquid crystal thermometers inside the prototypes and read the temperature before the prototypes are submerged and after they are opened to see how much the temperature changes.

Tip

Some data students might include in their data tables include temperature of the water (hot/cold), condition of the marshmallow before being put in the water, and condition of the marshmallow after coming out of the water.

Modification

This activity can be conducted over multiple class periods. Complete steps 1–5 in one class period and conduct the testing over a second class period. If needed, students can complete the final evaluation step during a third session or as homework.

Tip

When showing the robotic arm video (start at minute 1:25) on WebEcoist, note that care should be taken not to show the image above the video, since it gives away the answer. Show two other designs from this page, taking care not to display the titles.

Informal Assessment

Observe students as they design, plan, and conduct tests to make sure they are following each step of the engineering process. Use the provided Reflection Rubric to assess students' final written reflections.

OBJECTIVES

Subjects & Disciplines

Biology

Earth Science

- Oceanography

- Engineering

Geography

- Physics

Learning Objectives

Students will:

- design an engineering solution to a problem, using nature as an inspiration
- construct a definition of an engineer and identify examples of biomimicry
- identify the constraints and considerations of the DEEPSEA CHALLENGE expedition

Teaching Approach

- Learning-for-use

Teaching Methods

- Brainstorming
- Cooperative learning
- Discussions
- Hands-on learning

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

National Standards, Principles, and Practices

NATIONAL GEOGRAPHY STANDARDS

• **Standard 15:**

How physical systems affect human systems

NATIONAL SCIENCE EDUCATION STANDARDS

- **(5-8) Standard E-1**:

Abilities of technological design

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

BACKGROUND & VOCABULARY

Background Information

An engineer is a person who applies a wide range of science knowledge and skills, problem-solving, information technology expertise, and mechanical expertise to design and build complex products, machines, systems, or structures. Engineers are problem-solvers. Engineering has given us many of the systems and products we rely on daily. Items such as the cars we drive to school, the computers on which we do research, and even the complex systems that bring water and electricity to our homes were all engineered. Engineers apply a wide range of science knowledge and skills, problem-solving, and information technology and mechanical expertise to design and build complex products, machines, systems, or structures. Engineering often involves complex designs that have to be broken down into smaller chunks and problem-solved. For example, the *DEEPSEA CHALLENGER* submersible is made of many parts, including the body design, the mechanics involved in moving the submersible, the communication systems, the cameras and lighting used for exploration, the safety systems, and much more. James Cameron and his team had to address each of these parts of the *DEEPSEA CHALLENGER* to optimize it for its mission to explore the deepest parts of the ocean.

Prior Knowledge

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Recommended Prior Activities

- Adapting Under Pressure
- Ocean Habitats and Animal Adaptations

Vocabulary

Term	Part of Speech	Definition
biomimicry	*noun*	process of using models, systems, and elements of nature as a guide for developing new technology.
consideration	*noun*	a matter weighed or taken into account when formulating an opinion or plan.
constraint	*noun*	limitation or obstacle.
engineer	*noun*	person who plans the building of things, such as structures (construction engineer) or substances (chemical engineer).

FUNDER

ALFRED P. SLOAN FOUNDATION

Before Moving on to the Next Activity

In Activity 4, students learned about biomimicry and applied their knowledge of animal adaptations to solve an engineering challenge. In the next activity, students will develop a solution to another deep-sea engineering challenge, this one involving the effects of pressure.

ACTIVITY 4: YOU CAN TAKE THE PRESSURE!

I 3 HRS

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

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.

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ACTIVITY 5: INVESTIGATING PRESSURE | 1 HR 30 MINS

DIRECTIONS

1. Activate students' prior knowledge with a game of "Would You Rather."
Designate one wall as "A" and one wall as "B." Have students come to the center of the room. Read each of the questions on the "Would You Rather" Questions handout, and have students indicate their response by moving to the wall that matches their choices. After each question, ask a few students to explain their responses. Use the explanations for each Would You Rather question to focus students' thinking on the concepts being addressed.

2. Discuss the relationship among force, pressure, and area using the examples from the Would You Rather game.
Remind students of the cleat example from the previous step. Ask: *What would happen to the pressure you would feel on your foot if the person standing on your foot got heavier? Would the pressure increase or decrease? Why?* Ask students to think about a person pushing a

needle into leather. Ask: *If the person were to increase the force with which he or she is pushing the needle, what would happen to the pressure of the needle on the leather?* Draw a simple graph on the board and label the y-axis “pressure” and the x-axis “force.” Do not include any numbers. Ask a volunteer to draw a line on the graph illustrating what happens to pressure as force increases. (The slope of the line increases.) Ask another volunteer to draw a line illustrating what happens to pressure as force decreases. (This line will be the same as the previous line.) Remind students again of the example of an elephant on a marble from the previous step. Ask: *What would happen to the pressure of the elephant on your foot if the elephant were to balance on a hockey puck instead of on a marble?* (It would decrease.) *What if the elephant balanced on a dictionary?* (It would decrease even more.) Draw a new graph on the board and label the y-axis “pressure” and the x-axis “area.” Have a volunteer draw a line on the graph to show what happens to pressure as area increases. (The slope of the line decreases.) Have another volunteer draw a line to show what happens to pressure as area decreases. (This line will be the same as the previous line.) Ask students to look at the graphs and describe the relationship between force and pressure (directly proportional) and area and pressure (inversely proportional).

3. Introduce the formula for pressure and apply it to a Would You Rather game example.
Write the formula for pressure on the board (pressure = force/area). Refer again to the cleat example from the Would You Rather game, this time plugging in actual numbers (a person weighing 50 kilograms (110 pounds) and wearing shoes with cleats that have a total area of 13 square centimeters (2 square inches)) into the formula. Demonstrate how to calculate the pressure. Ask: *What would happen to the pressure if the person wearing the cleats weighed only 41 kilograms (90 pounds)?* Write out the formula using the new weight, and calculate the pressure. Ask: *What would happen to the pressure if the 41 kilogram (90 pound) person were wearing shoes with larger cleats that have a total area of 19 square centimeters (3 square inches)?* Again write out the formula using the new numbers, and calculate the pressure.

4. Divide students into pairs and have them create pressure-related Would You Rather questions for each other.
Have students come up with scenarios and then manipulate one of the variables in the pressure formula to create Would You Rather questions. Ask each pair to write down at least three questions. Play Would You Rather again, this time inviting a few pairs to ask one of their questions. Collect students’ questions for an informal assessment of their understanding of pressure.

5. Have students model pressure using wooden blocks.
Distribute a large rectangular wooden block, 10 pennies or washers, and a small container of sand or flour to each pair of students. Challenge students to use these items to model different pressures by changing just one variable (for example, laying a block in the sand on its smallest side will create a slightly deeper impression than laying it on one of its larger sides). Have students describe each trial and what changed during that trial in their science journals. After students have had a few minutes to experiment with the blocks, ask for volunteers to demonstrate their models. Ask students to identify the variable in the pressure formula that changed in each of the models. Ask them to use their models to describe the relationships among pressure, force, and area.

6. Introduce the *DEEPSEA CHALLENGE* expedition to students.
Explain that you will watch a brief video describing a historic manned dive to the deepest known part of the ocean. Provide students with the following focus questions:

- Who manned the submersible?
- Where did the submersible dive?
- What effect did pressure have on the submersible under water?
- What did James Cameron do once he reached the bottom of the Mariana Trench?
- Why was the dive important?

Ask students to take notes on these questions as they watch the video. Show the National Geographic News video "James Cameron Breaks Solo Dive Record." At the end of the video, discuss the focus questions. Ask students if they were surprised to hear how much the submersible shrank due to the pressure of the water. Ask: *Why was the pressure on the submersible so great in the Mariana Trench? Which variable from the pressure formula changed as the submersible went deeper? How did it change? Why?*

7. Use a model to introduce the idea that pressure can vary greatly depending on where you are on the planet.
Remind students that molecules in the air and water molecules have mass and therefore exert force. The force applied by the molecules over a specific area equals the pressure of the molecules on the area. Explain that air pressure and water pressure vary based on your elevation above sea level or your depth in the water; note that other variables such as volume and temperature can also influence pressure calculations. Place a marshmallow in the bottom

of a test tube, and fill the test tube with cotton balls. Explain that the marshmallow represents a person, and the cotton balls represent molecules in the air. Explain that this model shows a person at sea level. Remove the marshmallow and cotton balls. Replace half of the cotton balls, then place the marshmallow on top of them and fill the test tube with additional cotton balls. Explain that this model shows a person on a mountaintop. Ask: *At which location will air pressure likely be greater?* (Air pressure will likely be greater at sea level because the air is denser there than at the top of a mountain. There are more molecules in the air, each of which has mass, pressing down on a person at sea level than on the top of a mountain.) Explain that, in general, air pressure decreases as you go up in elevation, although other factors such as temperature and humidity can also affect air pressure. Empty the test tube and place the marshmallow at the bottom again. This time, fill the test tube with marbles and explain that they represent water molecules. Ask students what they think the model represents (a person under water). Rearrange the items in the test tube so the marshmallow is close to the middle of the test tube. Ask students to explain this new model in relation to the previous one. (The person is now in water that is less deep). Ask: *In which of these two models would the person be under more pressure?* (The model showing the person in deeper water.) *Why?* (Pressure on a person increases in deeper water because there is more water and thus more mass above the person.)

8. Have students locate Mount Everest and the Mariana Trench using a wall map or the MapMaker Interactive.

Have students place a marker to indicate each location. Give students the elevation of each location and have them add that information to the map as well. Ask: *In which location would the pressure exerted on a person be greater? Why?* Ask students to predict how much greater the pressure would be at one location versus the other. Distribute the Comparing Pressure handout to each pair of students and ask students to compare their predictions to the actual pressure difference between Mount Everest and the Mariana Trench. Review the handout with students. Explain that the pressures listed on the handout are averages since other factors can also influence air pressure.

9. Explain that students will use the data from the Comparing Pressure handout to create a visual model showing the general differences in pressure at different locations on Earth.

Distribute poster board, pens, beans, rulers, glue, and the Modeling Pressure handout to each pair. Review the handout with students and answer any questions they might have about the activity. Allow time for students to create their models. When students have finished, have them reference their models to write a brief explanation of why pressure is different at different places on Earth. Use the answer key provided in the Assessment section to assess students' explanations.

Tip

In step 8, check students' progress as they finish step 5 to be sure they understand how to use the scale to measure and mark the elevation of the *Titanic* wreckage relative to the Mariana Trench before they move on to the other items on the Comparing Pressure handout.

Tip

In step 8, note that students will need to glue beans on top of each other to fit enough in the one-inch square to represent the pressure at the *Titanic* wreckage and the bottom of the Mariana Trench.

Informal Assessment

Observe students as they create their own Would You Rather questions and explore the block and sand models. Check that students can accurately explain the examples they come up with and how the blocks demonstrate the relationships among force, area, and pressure.

Students' explanations of their models of pressure at different elevations should include the following information:

- Pressure is force applied over a specific area.
- Pressure increases as force increases.
- Pressure decreases as area increases.
- Molecules in air and water have mass and therefore exert force.
- In general, air pressure decreases as elevation increases because there are fewer molecules above any given point (less force).
- Pressure increases as water depth increases because there are more water molecules above any given point (more force).

Extending the Learning

Have half the class investigate how pressure affects deep-sea divers and half the class investigate how pressure affects mountain climbers. Pair students from each group and have them create Venn diagrams comparing and contrasting the pressures experienced by these two groups of people.

Conduct an additional demonstration of pressure: Using a dry syringe, remove the plunger and place a miniature marshmallow in the barrel of the syringe. Choose a second marshmallow of the same size to use as a control. Place the plunger back in the syringe barrel, and push the plunger down to force out as much air as possible without squeezing the marshmallow. Cover the open tip of the syringe with a finger. Pull the plunger back as far as possible without pulling it out of the syringe, hold it in this position, and observe. Compare the size of the marshmallow in the syringe with the control. Predict what will happen if the plunger is released. Release the plunger and observe. (As the plunger is pulled back, the volume of air inside the syringe increases; the pressure decreases; the air trapped in the marshmallow expands; and the volume of the marshmallow increases. When the plunger is released, the volume of air inside the syringe decreases; the pressure increases; the air inside the marshmallow compresses; and the volume of the marshmallow decreases.) The marshmallow might appear shrunken after the demonstration since some of the air initially trapped inside might escape when the marshmallow expands. As an alternative to using a marshmallow for this demonstration, you can also use a small water balloon inflated with a little puff of air and tied off.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Oceanography

Geography

- Physical Geography

- Mathematics
- Physics

Learning Objectives

Students will:

- use models to illustrate the concept of pressure

Teaching Approach

- Learning-for-use

Teaching Methods

- Cooperative learning
- Discussions
- Hands-on learning
- Modeling

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Critical Thinking and Problem Solving
- Critical Thinking Skills
  - Applying
  - Understanding

National Standards, Principles, and Practices

NATIONAL GEOGRAPHY STANDARDS

• **Standard 4:**
The physical and human characteristics of places

NATIONAL SCIENCE EDUCATION STANDARDS

• **(5-8) Standard B-1:**

Properties and changes of properties in matter

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 2**:
Communication and Collaboration

Preparation

BACKGROUND & VOCABULARY

Background Information

Pressure is force over a specific area (pressure = force/area). As force increases, pressure increases proportionally. As area increases, pressure decreases proportionally. Pressure can be measured in a variety of units including pascals (Pa), which is the standard international (SI) unit equivalent to one newton per square meter, or in pounds per square inch (psi). Pressure can be important in describing the behavior of fluids such as air or water. Though we can't see the individual molecules in air or water, they have mass and therefore exert force. Air or water pressure describes that force acting over a specific area. The pressure on an object that is under water is proportional to the weight of the water above the object. Liquid pressure also depends on the density of the liquid. However, liquids are practically incompressible, so, except for small changes produced by temperature, the density of a given liquid is almost the same at all depths. Therefore, the deeper an object goes under water, the more pressure it is under.

As a rule of thumb calculation, pressure under seawater increases at a rate of 0.445 psi per foot of depth. So an object under 10 feet (3 meters) of seawater would be under 4.45 psi of pressure. Just as water pressure is caused by the weight of water, atmospheric pressure is caused by the weight of air. However, air pressure generally decreases with elevation. The air at higher elevations is generally less dense than at sea level, and the pressure is lower since there are fewer "layers" of molecules in the air above pressing down. The lower density of the air at higher elevations also explains why mountain climbers can have trouble getting enough oxygen as they ascend higher and higher. Since there are fewer molecules of oxygen and other gases that make up air at high elevations, mountain climbers have to breathe faster to take in the oxygen they need. Other factors can influence air pressure, making it possible that the air pressure at two different locations at the same elevation, or the air pressure at the same elevation at two different times, can be different. Temperature is one of the factors that can affect air pressure. As air warms up, thermal energy is transferred to the gas molecules in the air; the molecules begin to move faster, moving farther away from each other. This can decrease the density of the air and lower the air pressure. Lower temperatures can increase the density of the molecules in the air, leading to an increase in air pressure.

Prior Knowledge

["An understanding that density is mass per unit volume", "An understanding that weight is the force of gravity on a mass", "A basic understanding of force, including the knowledge that force = mass x acceleration (Newton's Second Law)"]

Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
DEEPSEA CHALLENGE	*noun*	ongoing expedition to study the deepest point in the ocean, with a record-breaking descent to the Challenger Deep in March 2012.
exert	*verb*	to force or pressure.
pressure	*noun*	force pressed on an object by another object or condition, such as gravity.

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Before Moving on to the Next Activity

In Activity 1, students learned about pressure and how it changes at different elevations above sea level and different depths in the ocean. In the next activity, students will explore how animals have adapted to life at different depths and pressures in the ocean.

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