Sounds of the Sea

Program Type: Classroom Program	***Audience Type:*** Grades 3–8

Description: Students will engineer carriers to hold different objects underwater at particular depths.

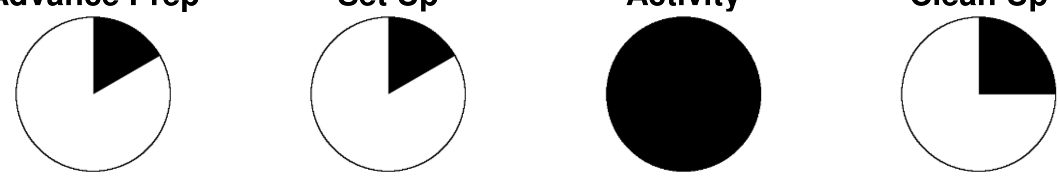
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- Students will create different models to test the concept of buoyancy.
- Students will learn about engineers that study marine mammals.

TIME REQUIRED

Advance Prep	Set Up	Activity	Clean Up
10 minutes	10 minutes	60 minutes	15 minutes



SITE REQUIREMENTS

- Table space for each group of 3–5 students
- Access to a water source
- Easy clean-up area in case of water spills (i.e., non-carpeted flooring)

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large group discussion	15 min
Design, Test, Improve	Group activity	40 min
Wrap-Up	Large group discussion	5 min

SUPPLIES

Permanent Supplies	Amount	Notes
Clear container	1/group	At least 8’’ deep
Ping pong ball	1/group	Or balls of similar size and density Metal ball bearings can be found online or at hardware stores
Bouncy ball	1/group	
Large metal ball – 1” diameter	1/group	
Craft foam	1–2 sheets/group	Cut into approximately 2-inch squares
Rubber bands	8–10/group	
Craft wax sticks	5–6/group	Wikki Stix® or similar
Paper clips	10/group	
Binder clips	8/group	
Scissors	1/group	
Washers	8/group	a variety of washers between 1/4” and 1/2’’ works best
Hand towels or rags	1/group	
Interview with an Engineer printout	1/student	See the *Appendix* for the transcript. Alternatively, you can display the document using a projector and screen
Additional clear container(s)	1-3	*(Optional)* See Extension
Table salt	About ¼ cup	*(Optional)* See Extension
Ice	About ½ cup	*(Optional)* See Extension
Hot water		*(Optional)* See extension

ADVANCE PREPARATION

- Draw three marks on the side of each container: one 2” from the bottom, one 2” below where the water line will be, and one halfway in between both those lines. See diagram below.

Figure 1: Example markings on a clear container.

- Print out the Interview with an Engineer sheets (see Appendix) for students to “meet an engineer.” Alternatively, you may choose to display the document on a screen using a projector.

SET UP

- Fill each of the clear containers with water 2” above the top mark
- Each group should receive:
  - 1 ping pong ball
  - 1 bouncy ball
  - 1 ball bearing
  - 1 pair scissors
  - Variety of building materials such as:
    - 1–2 sheets craft foam
    - 8–10 rubber bands
    - 5–6 craft wax sticks
    - 8 washers
    - 10 paper clips
    - 8 mini binder clips
- Place a hand towel or rag at each table, with the container of water on top

INTRODUCTION

15 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

Today we are going to learn about an engineer who studies the sounds in the ocean to learn about animals.

Pass out the Interview with an Engineer printout or display it using a projector and screen. You can have students take turns reading aloud. For example, have two student volunteers play the role of interviewer and interviewee, respectively, while other students read the introduction.

What does Elizabeth study? What does she do? *Elizabeth studies the sounds marine mammals make. She records the sounds and measures how many animals are in different parts of the ocean.*

How does she record these sounds? *She uses underwater robots.*

What are some challenges you think she faces in her job? *Students' answers will vary, but may include: How to design the underwater robots, how to make something electronic work underwater, how to know where to send the robots, etc.*

The biggest challenge in designing these underwater robots is engineering them so they do not float above the water or sink all the way down to the bottom of the ocean. They have to remain neutrally buoyant so they can work and record all the sounds.

Has anyone heard the word buoyant before? What do you think it means? *Answers will vary but some may be: It means to float, not sink, or be underwater.*

Buoyancy is the force that causes objects to float. If something is *positively buoyant* it floats, if it's *negatively buoyant* it sinks, and if it's *neutrally buoyant* it will neither sink nor float.

(Optional): Show video on buoyancy:

Kids Want to Know - "Buoyancy: What Makes Something Float or Sink?" (2005) https://www.youtube.com/watch?v=nMIXU97E-uQ (Duration 3:28)

GROUP ACTIVITY

Design, Test, Improve

40 minutes

If students are not already sitting in groups, divide them into groups of 3–4 students.

Today, you are going to design a case that can carry different objects (“sensors”) underwater without floating to the surface or sinking to the bottom. You will be engineering a carrier for three different objects that represent the sensors: a ping pong ball, a bouncy ball, and a ball bearing.

Hold the objects up one at a time.

These objects are of slightly different size and density, so you will need to modify your design to fit each one.

In order for your design to be successful, your carrier will need to remain neutrally buoyant in between the two lines marked on the container.

Show a container and point out the lines.

You will be working in teams to engineer three different carriers, one for each round object. These are the materials you may use to build your marine sensor carriers.

Show and quickly describe the materials.

Start with your design plan for building the “robot” carrier for your ball “marine sensor.” Work as a team and make sure everyone’s ideas are being heard. Once you have drawn/discussed a final plan, gather your materials and begin building! Please keep any wet materials on the towel.

If groups get all three “sensors” between the lines, have them try to get it to float at exactly the middle point. You can also gently shake the container with each iteration to simulate waves and see if the object remains neutrally buoyant despite the movement.

Faster-working groups can also be challenged to design a carrier that can hold all three sensors at the same time. Or they can try testing their carrier in salt water, hot water, and/or ice water (see Extension).

WRAP-UP

5 minutes

If time allows, hold a final showcase to test all of the designs. Before testing, let each group point out the notable aspects of their designs to the rest of the class.

Test one design from each group and note what works and what could be improved.

Did the size of the sensor matter? Which sensors were easier to work with? Which ones were more difficult? Which materials were the most useful?

CLEAN UP

15 minutes

- Place all of the wet materials on the towel to dry
- To prevent mold, allow the materials to dry before returning them to storage
- Dump the water out

EXTENSION

As an optional extension, let students test their carriers in “ocean” water. Remind them that, so far, they have been testing their carriers in room-temperature fresh water, but in reality, these devices are meant to go in the ocean, which is salty.

In the front of the room, have an extra clear container filled with water. Add salt and stir until you can’t dissolve any more. Invite students to test their carriers again. Do the carriers tend to float more or sink more? What does that tell you about the density of salt water versus fresh water?

You can try the same extension with ice water and very hot water.

BACKGROUND INFORMATION

Buoyancy is an object's ability to float, and it is directly related to density. If an object is more dense than the fluid it is placed in, it will sink to the bottom. If it is less dense, it will float on the surface of the fluid. The density of water varies with salinity and temperature. Saltwater is more dense than freshwater and; therefore, an object will float in saltwater more readily than in freshwater. Likewise, cold water is more dense than warm water.

For an introductory video about buoyancy, see:

Kids Want to Know - "Buoyancy: What Makes Something Float or Sink?" (2005)
https://www.youtube.com/watch?v=nMIXU97E-uQ
(Duration 3:28)

Bioacoustics is a type of science in which researchers study the sounds organisms make and how outside sounds affect those organisms.
Marine biologists may study whale sounds to understand how those animals communicate, mate, and migrate. They also study how humanmade sounds from boats and sonar affect whales and other marine mammals.

In order to study the bioacoustics of marine animals, scientists place marine sensors underwater. To use a sensor in the ocean, researchers must submerge it in water and have it stay neutrally buoyant at a certain height—neither sinking to the ocean floor, nor floating to the surface—to collect data.

Accomplishing neutral buoyancy is a real engineering challenge! Submarines and underwater robots are designed to be able to change their density by opening and closing ballast tanks; if a tank fills with water, the submarine becomes more dense and moves downward in the water column. By expelling water from the same hatch, the submarine becomes less dense and moves upward in the water column.

Figures 2 and 3: The Hawai'i Institute of Marine Biology uses Ecological Acoustic Recorders to study coral reefs. The devices are placed at different depths, depending on the kinds of sounds they are hoping to detect. (Images: NOAA Fisheries https://www.pifsc.noaa.gov/cred/ear.php).

GLOSSARY

Buoyancy	The ability and tendency for something to float in a fluid.
Bioacoustics	The field of acoustics concerned with sounds produced by or affecting living organisms, especially as relating to communication.
Density	Weight (mass) per unit volume used as a measure of the compactness of a substance.
Neutrally buoyant	The state of not moving up or down within a fluid.

NEXT GENERATION SCIENCE STANDARDS

	Practices
✓	Asking questions and defining problems
✓	Developing and using models
	Planning and carrying out investigations
	Analyzing and interpreting data
	Using mathematics and computational thinking
✓	Constructing explanations and designing solutions
	Engaging in argument from evidence
✓	Obtaining, evaluating, and communicating information

	Crosscutting Concepts
	Patterns
✓	Cause and effect
	Scale, proportion, and quantity
✓	Systems and system models
	Energy and matter
✓	Structure and function
	Stability and change

	Disciplinary Core Idea	3	4	5	MS
	Physical Science				
PS1	Matter and Its Interaction	n/a	n/a		
PS2	Motion and Stability: Forces and Interactions		n/a		
PS3	Energy	n/a			
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	
	Life Science				
LS1	From molecules to organisms: Structures and processes				
LS2	Ecosystems: Interactions, Energy, and Dynamics		n/a		

LS3	Heredity: Inheritance and Variation of Traits		n/a	n/a	
LS4	Biological Evolution: Unity and Diversity		n/a	n/a	
Earth & Space Science					
ESS1	Earth's Place in the Universe	n/a			
ESS2	Earth's Systems				
ESS3	Earth and Human Activity				
Engineering, Technology, and Applications of Science					
ETS1	Engineering Design	✓	✓	✓	✓

DCI Grade Band Endpoints

3-5 ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (By the end of Grade 5)

3-5 ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (By the end of Grade 5)
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (By the end of Grade 5)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (By the end of Grade 5)

3-5 ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (By the end of Grade 5)

MS ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (By the end of Grade 8)

MS ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (By the end of Grade 8)

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (By the end of Grade 8)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (By the end of Grade 8)
- Models of all kinds are important for testing solutions. (By the end of Grade 8)

MS ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (By the end of Grade 8)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (By the end of Grade 8)

3-5 ESS3.C: Human Impacts on Earth Systems

- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. For example, they are treating sewage, reducing the amounts of materials they use, and regulating sources of pollution such as emissions from factories and power plants or the runoff from agricultural activities. (By the end of Grade 5)

Performance Expectations

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
5-ESS3-1	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Sounds of the Sea

Appendix

Inspiration from the Ocean Sound

Interview with an Engineer

By Raquel Stewart

Elizabeth Küsel, originally from Brazil, is an engineer with a background in oceanography and mathematics. She designed a robot that goes underwater and records whale and dolphin sounds, and with those sounds and some math she is able to figure out how many of those animals live in certain parts of the ocean.

We asked Elizabeth some questions so we could give you a glimpse into the life of this engineer.

Do you remember when you first learned about engineering? How did it make you feel?
In my family, my father and three uncles are all engineers in the fields of electrical, mechanical, and computer engineering. I don't think engineering was something I learned about –it was already present in my life. I always had an inquisitive mind and was drawn to science. The thing about engineering is that it gives you tools to build things and fix things.

What do you study and research?
My research focuses on developing methods to estimate whale and dolphin population density from recorded sounds they produce.

How does your work help others?
My work helps understand whale and dolphin populations and create other means of managing and studying them. It contributes to our understanding of wild animals, and how we can help their populations be and stay healthy.

Who do you look up to, in your career and in your personal life?
We meet all sorts of interesting people in our lives, and I have been trying to learn something from everyone that crosses my path.

Elizabeth Küsel at work with her underwater robot.

What do you do in your free time?
I like to be active, run, hike, travel, and take pictures. Sometimes though, all I want is to watch movies or cook a good meal at home.

What is your favorite part about being an engineer?
I can build and understand the instruments I use, and because I understand how they work, I can think of ways to improve them.

What advice would you give to your younger self?
Don't be so hard on yourself.

Even though Elizabeth inherited her passion for the ocean from her father, an Officer in the Navy, she credits both her mother and her father as being big influences in her life because they always supported her decisions and endeavors.

Elizabeth encourages young students to be open to every opportunity that may arise. "Try everything you can, so you can decide what is best for the life you want." As far as what influences her own life decisions, she says, "I don't want to be like anyone else. I want to do what I like, which is study acoustics and the oceans."

Inspiración de los sonidos marinos

Entrevista con una ingeniera
Por Raquel Stewart

Elizabeth Küsel es una ingeniera brasileña con estudios en oceanografía y matemáticas. Diseñó un robot que navega bajo el agua y graba los sonidos que emiten las ballenas y los delfines. Usando esos sonidos, y algo de matemáticas, Elizabeth logra determinar cuántos de esos animales viven en ciertas partes del océano.

Entrevistamos a Elizabeth para poder darles un vistazo en la vida de esta ingeniera.

¿Te acuerdas de la primera vez que aprendiste sobre la ingeniería? ¿Cómo te sentiste?
En mi familia, mi papá y tres tíos son ingenieros eléctricos, mecánicos, e informáticos. No creo que la ingeniería haya sido algo sobre lo que aprendí –ya era parte de mi vida. Siempre tuve una mente curiosa y me atraía la ciencia. Lo que tiene la ingeniería es que te da herramientas para construir y arreglar cosas.

¿Qué estudias y en qué te especializas?
Investigo métodos para estimar la densidad demográfica de ballenas y delfines, basado en los sonidos que emiten.

¿De qué forma el trabajo que haces logra ayudar a otros?
Mi trabajo nos ayuda a entender las poblaciones de ballenas y delfines y nos ayuda a crear otros medios de estudiarlos. Mi trabajo contribuye a nuestro entendimiento de animales salvajes, y cómo podemos ayudar a esas poblaciones a mantenerse en buen estado.

¿A quién admiras, en tu vida profesional y privada?
En nuestras vidas conocemos a un sinfín de personas interesantes, y yo he estado tratando de aprender algo de cada persona que cruza mi camino.

Elizabeth Küsel trabajando con su robot marino.

¿Qué te gusta hacer en tu tiempo libre?
Me gusta mantenerme activa –correr, hacer senderismo, viajar, tomar fotos. Sin embargo, a veces lo único que quiero hacer es ver películas o cocinarme una buena comida en casa.

¿Qué es lo que más te gusta de ser ingeniera?
Puedo construir y entender los instrumentos que uso, y ya que entiendo cómo funcionan, puedo inventar maneras de mejorarlos.

¿Qué consejo te darías a ti misma cuando eras más pequeña?
No seas tan dura contigo misma.

Aunque Elizabeth heredó su pasión por el océano de su padre (era un oficial marino), ella agradece tanto a su madre como a su padre por ser grandes influencias en su vida ya que siempre apoyaron sus decisiones y proyectos.

Elizabeth anima a jóvenes estudiantes a que estén abiertos a cualquier oportunidad que pueda surgir. “Intenta todas las cosas que puedas, para que decidas qué es lo mejor para la vida que tú quieres”. En cuanto a lo que influye sus propias decisiones, dice que “No quiero ser como nadie más. Quiero hacer lo que me gusta, que es estudiar la acústica y los océanos”.

FACILITATION GUIDE

Sounds of the Sea

Description: Students will engineer carriers to hold different objects underwater at particular depths.

Promoting collaboration and organization

- Circulate the room as student teams are discussing and drawing their carrier. Encourage all students to provide input regarding the design plan.
- You may choose to create a “budget” for materials. Each team will have a certain allowance, which will teach students about planning wisely while reducing material waste.

Encouraging iteration

- Discuss different designs of the carriers:
  - Can you use fewer materials and achieve the same result?
  - Can the carrier be brought to the surface and dropped in the water multiple times?
  - Does it bounce and hit the bottom before settling in the middle?
  - Is there a side that is always pointed to the surface?
  - Can you devise a way to pull the carrier out of the water without dipping your hands in?
  - Can you change how high or low the carrier floats?

Helping those who are stuck

- Try putting the sensor in by itself before putting it in a carrier. Then add one material at a time to make a carrier and do a trial after each building material is added.
- Drop the building materials into the water by themselves to see if they sink or float.
- If the carrier is falling apart try securing or fastening the materials differently.
- Is the sensor completely encased? Are there water bubbles escaping as it sinks?

Real-world applications

- Marine sensors can be used to collect a variety of data. One company developed sensors called *Argo floats* that collect temperature, salinity, current velocity data, and oxygen levels. The probes go down as deep as 2 kilometers and relay data by satellite link when they surface. The data are publicly available within 24 hours.