MYSTERIES FROM THE DEEP

EXPLORING UNDERWATER ARCHAEOLOGY

EDUCATOR GUIDE

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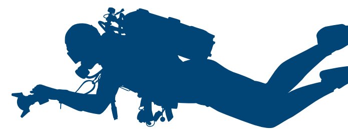
EDUCATOR GUIDE: UNDERSTANDING AND TEACHING IN THE EXHIBITION



Exhibition Overview

Underwater archaeology is so much more than sunken treasures lost at sea. Underwater archaeological sites have objects and artifacts from our history that give insight into ancient civilizations, lost people or vessels and powerful stories of the past. This exhibition uncovers many of these mysteries while exploring the rigorous science, varied expertise and exciting technology that underwater archaeology involves.

PLAN YOUR VISIT

- Read the Essential and Compelling Questions to understand how themes in the exhibition connect to your classroom teaching.
- Review the Teaching in the Exhibition section to understand which objects best fit the needs of your students.
- The exhibit is divided into Zones, but there is no right or wrong way to move throughout the space.
- Decide how your class will explore the exhibition:
    - Teachers and chaperones may facilitate the visit using the **Teaching in the Exhibition** section, or students may explore on their own.
- Key definitions are provided in the Vocabulary section of this Educator's Guide, with a special Vocabulary section for younger learners. A Visual Vocabulary is available for extra support.

TEACHING IN THE EXHIBITION

Educational Standards

- **Historical Sources and Evidence:** Use other historical sources to infer a plausible maker, date, place of origin, and intended audience for historical sources difficult to identify.
- **Perspectives:** Analyze how current interpretations of the past are limited by the extent to which available historical sources represent the perspectives of people at the time.
- **Causation and Argumentation:** Integrate evidence from multiple relevant historical sources and interpretations into a reasoned argument about the past.
- **Engineering Design:** 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.

Essential Questions

- Why are underwater archeological sites important?
- How are the challenges of underwater archaeology addressed?

Students may write down observations and questions as they walk through the exhibition. Then, have students use their notes to discuss the question: *What do scientists discover about the past by exploring underwater archaeological sites?*

Zone A: Underwater Archaeology 101

Underwater archaeology focuses on recovering historical artifacts, like shipwrecks or pottery, to learn about past people, cultures and places, with the goal of sharing these findings to enhance our understanding of history.

Compelling Questions:

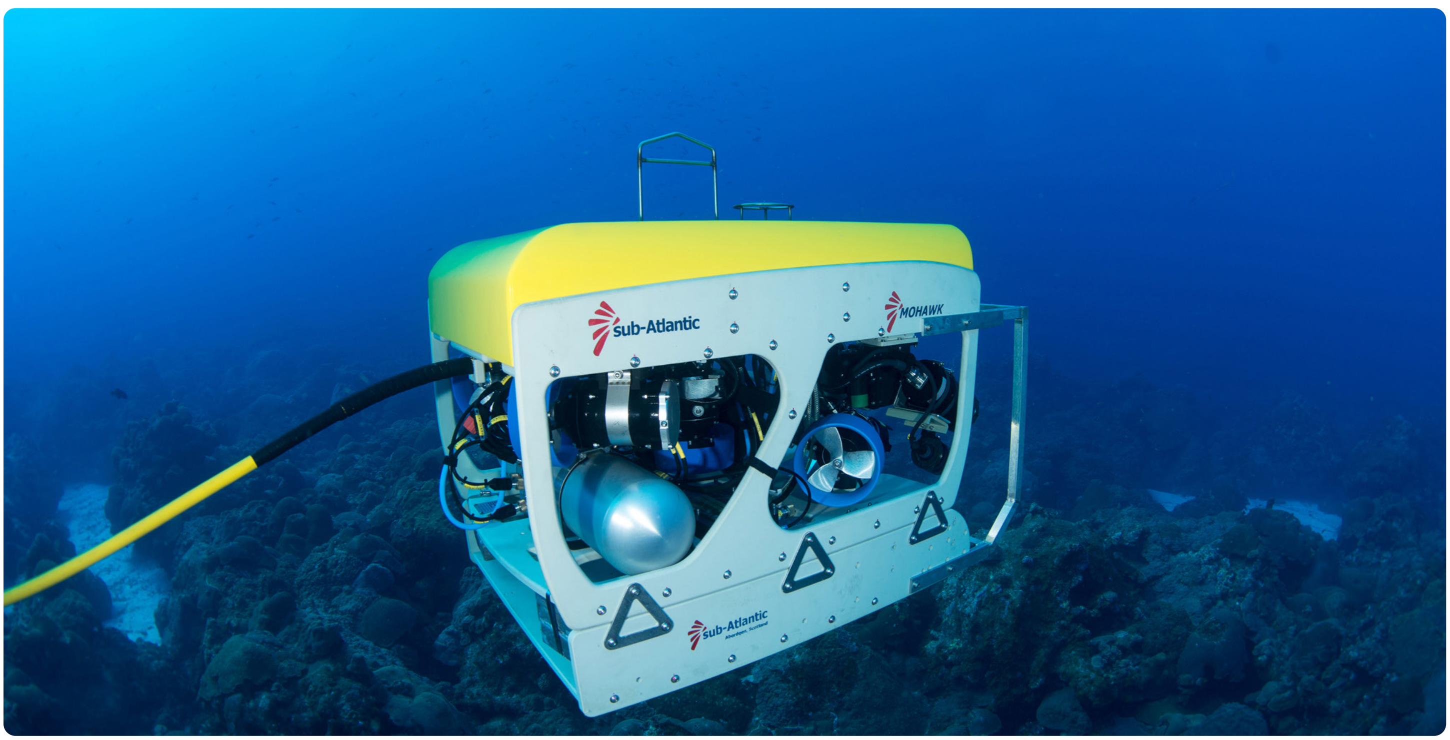
- What can scientists discover by exploring underwater archaeological sites? What does this exploration tell us about people and cultures from the past?
- What are the challenges faced by underwater archaeologists?

Zone B: Discovering

Locating an underwater archaeology site is both challenging and exciting. A team could use research materials to narrow down a search area, or sometimes discover sites by accident. Teams of experts survey the underwater using various methods from robotic tools to divers. Once a site is found, scientists can use different technologies or tools to learn more about the site and the objects it contains.

Compelling Questions:

- How have advancements in technology and tools helped humans with underwater exploration?
- What type of evidence or results do researchers look for when using various technologies and methods?

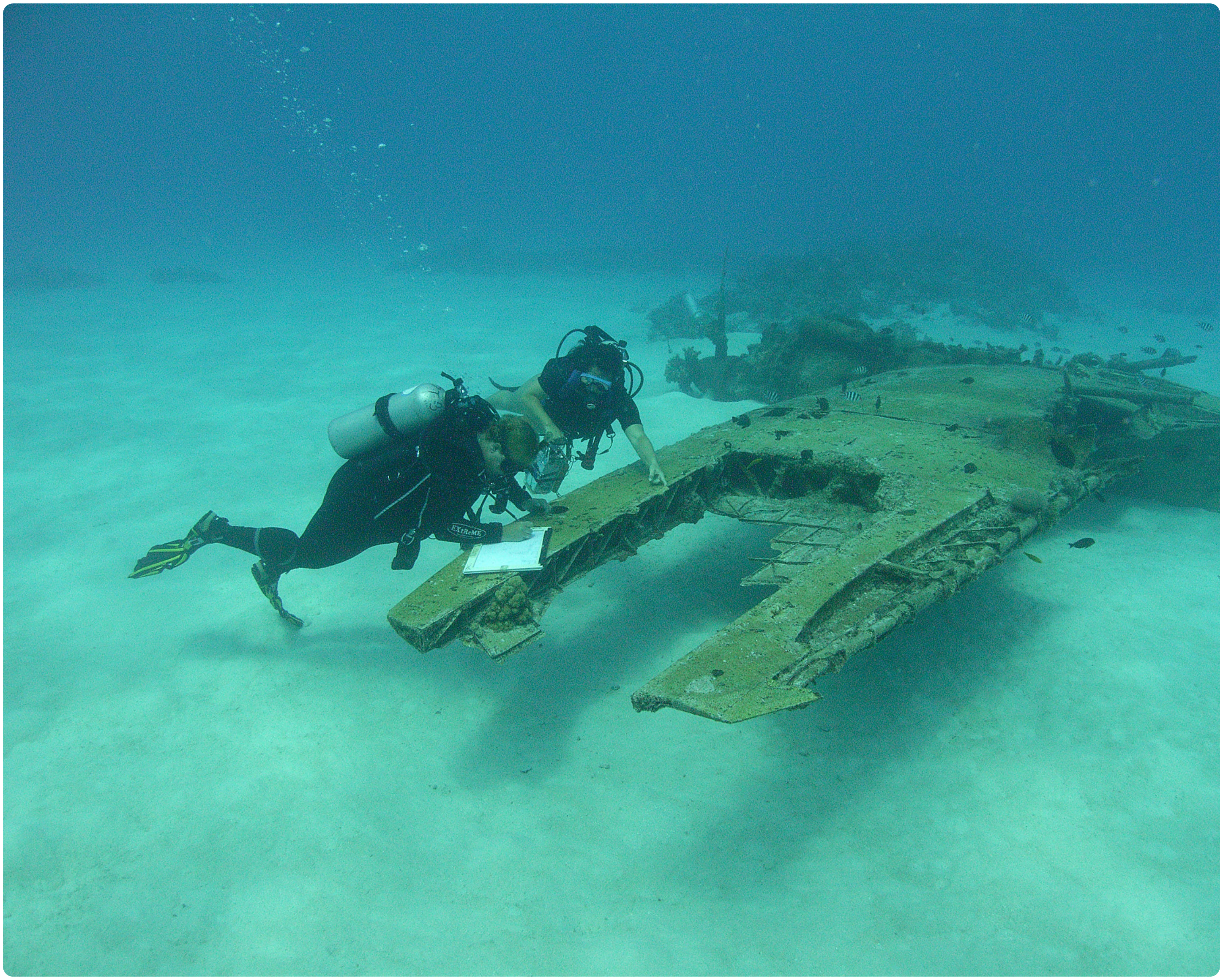


Zone C: Uncovering

After identifying a site, underwater archaeology teams focus on documenting it in detail, a crucial step to capture information about it. This process, which can take weeks to years, involves divers or robots capturing images, measuring artifacts and sometimes retrieving items for study and display.

Compelling Questions:

- What tools and technologies are needed to excavate and document underwater sites? How have these tools and technologies changed over time?
- What are some ethical challenges researchers face when working in underwater sites?
- How have specific discoveries, such as the uncovering of the *Clotilda*, provided evidence and insight into communal and cultural history?



Zone D: Recovering

Underwater archaeology teams collect various clues from artifacts, such as measurements, photos, sediment samples, and written records, which are analyzed over time to build a clearer understanding of the site's history. This process can take weeks, months, or even years. When an artifact is recovered from an underwater site, it will require conservation treatment to stabilize and preserve it for study or display. Conservation treatment depends on the material of the object and how it reacts to being underwater.

Compelling Questions:

- What are clues researchers can pull from artifacts while studying underwater sites that may help build a clearer understanding of the past?
- What type of materials can be found in underwater sites that may help researchers? Why is conservation challenging when working with materials found at underwater sites?

Zone E: Forecasting the Future

Water is essential to human history, and underwater archaeology helps uncover stories from our past. Studies of the past and historical artifacts can offer new insights about our ancestors, Earth's changing climate and provide opportunities for reconciliation and healing. Water contains our shared history, and the future of underwater archaeology holds the key to uncovering those stories.

Compelling Questions:

- Why should underwater archaeological sites be preserved?
- How can humans learn about the past and future of humanity and the planet Earth from studying underwater sites?

VOCABULARY

- **Archaeology:** the scientific study of material remains (such as tools, pottery, jewelry, stone walls, and monuments) of past human life and activities.
- **Archaeologist:** a scientist who studies human history and prehistory through the documentation or excavation of sites and the analysis of artifacts and other physical remains.
- **Underwater Archaeology:** the study of submerged artifacts and underwater sites that leads to the interpretation of past human cultures.
- **Excavate:** to expose to view by removing a covering material.
- **Artifact:** an object made by a human being, typically an item of cultural or historical interest.
- **Water Pressure:** a force that makes a flow of water strong or weak, or the weight of all the water above or around an object.
- **Sonar:** an underwater visualizing tool, it uses sound waves to find things in the water, by sending out a sound and listening for the echo that bounces back when it hits something. The sonar then creates a picture based on sound.
- **Conservation:** a careful treatment, preservation, and protection of an object at risk of being damaged.
- **SCUBA (Self-Contained Underwater Breathing Apparatus):** an apparatus utilizing a portable supply of compressed gas (such as air) supplied at a regulated pressure and used for breathing while swimming underwater.
- **Exosuit:** a wearable device that helps with movement, posture, or physical activity.
- **ROVs (Remotely Operated Vehicles):** ROVs are unoccupied, highly maneuverable underwater machines that can be used to explore ocean depths while being operated by someone at the water surface.
- **AUVs (Autonomous Underwater Vehicles):** uncrewed, untethered vehicles used to conduct underwater research.
- **Submersible:** a usually small underwater craft used especially for deep-sea research.
- **Photogrammetry:** the science of making reliable 3D models and measurements by the use of photographs, especially aerial photographs.
- **Telepresence:** technology that enables a person to perform actions in a distant or virtual location as if physically present in that location.
- **Environmental DNA (eDNA):** genetic material from organisms that has been released into the environment.

VOCABULARY FOR YOUNGER LEARNERS:

- **Artifact:** something made by people in the past
- **Archaeology:** the study of the past through the things people left behind, like tools, buildings, and art.
- **Excavate:** to dig or scoop out (earth, sand, etc.).
- **Sonar:** an underwater visualization tool that uses sound waves to find things in the water. Sonar sensors send out a sound and listen for the echo that bounces back when it hits something. The time it takes and the intensity of the echo are used to create a picture.
- **SCUBA (*Self-Contained Underwater Breathing Apparatus*):** a piece of equipment that allows people to breathe underwater.
- **Exosuit:** a mechanical suit that's attached to the outside of a person's body.
- **Submersible:** a vehicle that can go underwater.

MORE TO EXPLORE: PRE AND POST-VISIT RESOURCES*

The following resources offer more insights into the world of underwater archaeology. Review with students before visiting to "wet" their appetite and explore more after the visit.

Virtual Archaeology Museum

- Virtually visit an underwater archaeology site before your visit! Use Visual Thinking Strategies to analyze the 3D models of an archaeological underwater site. Meant to be open-ended, Visual Thinking Strategies encourage students to co-create knowledge.
  - Visual Thinking Strategies Questions: What do you see? What makes you say that? What more can you find?

Underwater Archaeology

- The **Navy** manages one of the largest collections of submerged cultural resources, featuring more than 3,000 shipwrecks and 17,000 aircraft wrecks scattered across the globe. Have students think about what it means to manage submerged cultural resources. Why and how are these artifacts managed?

Marine Cultural Heritage | From Shore to the Abyss aboard E/V Nautilus

- What is it like to go on a dive? Dr. Justin Dunnavant, Lead Scientist and Principal Investigator on the Nautilus EV voyage investigating the maritime cultural heritage of Hawai'i shares this 360° video to give people on land a taste of the underwater adventure.

NASA Ocean World Explorers Have to Swim Before They Can Fly

- What does **NASA** have to do with ocean exploration? Learn all about **SWIM** (Sensing With Independent Micro-Swimmers) and how this underwater robot will further space exploration.

Maritime Heritage

- **NOAA** (National Oceanic and Atmospheric Administration) goes deep into underwater exploration. Use these resources to dive into shipwrecks, sonar, underwater robots and more.

Underwater Robots

- Underwater archaeologists need a lot of help during exploration and excavation. **NOAA** gives an overview of the types of underwater robots used in ocean exploration, along with supplemental student activities.

Diving With a Purpose

- The team at **Diving with a Purpose** combines maritime archaeology and conservation to share the stories of our ancestors. What other exciting stories do they have to share?

Try an Underwater Experiment!

How does water affect objects over time? Find objects made of varied materials and submerge them in fresh water and salt water. Take pictures and record what happens after a week, two weeks… for as long as you want! Ask students to predict what they think will happen.

*Full Supplemental Classroom Lessons are available separately. Lessons include Next Generation Science Standards and C3 Framework for Social Studies State Standards.

WILL IT SINK OR FLOAT?

Grades:
K-4

Program Length:
60 minutes

Next Generation Science Standards
Discipline(s): Physical Sciences
Cross Cutting Concept(s): Energy and Matter
Practice(s): Asking Questions and Defining Problems; Planning and Carrying Out Investigations

Objective:
Students will understand the phenomenon of buoyancy and the property of density.

Assessment:
Students will demonstrate their understanding by:

- Completing the *Sink or Float Challenge* worksheet that shows their hypothesis and test results.
- Drawing, writing, or explaining orally how density and buoyancy are related to the words 'sink' and 'float.'
- Answering the question, "What makes something float or sink?"

MATERIALS:

- *Sink or Float Challenge* Worksheet (printed)
- Picture of an underwater shipwreck
- Picture of a boat floating (can be found using a search engine)
- 1 plastic, clear bucket or tub of water, any size
- Water
- 1 penny
- 1 empty plastic water bottle
- 6 objects in a variety of materials for each group that will either sink or float, such as:
    - Empty milk carton
    - LEGO® piece
    - Metal utensils
    - Plastic utensils
    - Pen
    - Pencil
    - Paperclip
    - Styrofoam cup/material
- Whiteboard/giant sticky note and markers

PREPARATION:

1. Fill a plastic bucket three-quarters of the way full with water. Place this bucket in an accessible area where students can gather around.
2. Gather a variety of materials, in multiples for groups, that can sink or float in water. All materials must be able to go in water.
3. On a giant sticky note or whiteboard, create a T-chart by dividing the paper or board in half with two columns. Label one column 'float' and one column 'sink'. Place this in an area where all students can view it.
4. Print copies of the *Sink or Float Challenge* Worksheet.
5. Differentiation: On the worksheet, students can write the name of the object or draw the object that will be tested, depending on their writing skills.

LESSON:

Introduction (10 minutes)

Ask the students what they remember about underwater archaeology from their visit to the exhibition. ***Underwater archaeology is the careful study and recording of wrecks, crashes and cultural sites found underwater. This scientific practice helps us learn more about past cultures and people.***

Underwater archaeological sites can be found at all water depths. Divers may explore sites up to 300 feet under the surface.

Show students a picture of an underwater shipwreck.

Diver taking video of the USS MACAW wreck at Midway Island. Image courtesy of NOAA/Robert Schwemmer.

Explain to students that ships/boats usually float on top of the water, but this is a picture of an underwater shipwreck after a ship/boat has sunk to the bottom of the ocean.

Ask students the following questions and write down their responses under either 'float' or 'sink' on the t-chart:

- What does it mean when something sinks? Can we think of some examples of items that sink?
- What does it mean when something floats? Can we think of some examples of things that float?

Show students a picture of the shipwreck and a picture of a floating ship. Tell students that:

- When something sinks in water, it falls to the bottom like our broken ship.
- When something floats, it stays on top, like our ship here that is staying on top of the water.

Optional Movement Activity: Together, based on the group definitions of float and sink, create body movements for the words sink and float.

Explain to students that you will be investigating why some things float, and some things sink by experimenting with different objects.

Warm-up (15 minutes)

Invite students to gather around a bucket filled with water. Have a penny and an empty water bottle ready on the table.

Show the penny and empty water bottle to students (materials can be passed around to students to observe what the penny and water bottle feel like [heavy/light; what is it made of?]. With a show of hands, ask students to make predictions about the penny and the water bottle: Will it sink or float?

Write down their votes on a whiteboard/post-it note.

Prompt students to observe what happens when you put the penny into the water. Place the penny in water. Ask students:

- What happened?
- Did the penny sink or float?

Repeat this process with the empty water bottle. Ask students:

- What happened?
- Did the empty water bottle sink or float?

After the experiment, ask students:

- What happened?
- Why do you think the water bottle floated?

Students should understand that though the bottle is bigger (has more volume), the penny is heavier (has more mass or “stuff” tightly packed into a smaller space) than the water. We call this being more dense.

Introduce and explain the words buoyancy and density. Use the visual aids to help explain the meaning of buoyancy and density. Visual aids can be placed next to the filled-in t-chart to illustrate connections between floating/buoyancy and sinking/density.

Explain:

- **Density** is how much “stuff” (mass) is crammed into the space an object takes up (volume).
- **Buoyancy** is the force that helps an object to float. It is the upward push of the water on an object. Water is made up of tiny parts (molecules) that push up on objects to make them float.

The penny sank because it is *denser* than the water around it.

The empty water bottle floated because it was filled with air, making it less dense than the water around it.

***Note: Mass is different from weight. Mass will remain the same wherever we are, but weight has to do with the gravitational pull, so the weight would change if we were on the moon!*

ACTIVITY (25 MINUTES)

Pass out the *Sink or Float Challenge* Worksheet. Explain to students that they will continue testing different objects to see if they sink or float by working in groups to come up with a **hypothesis** (a prediction of what they think will happen) for what will happen when these items are placed in water.

Place materials at each table and have the students write the name or draw a picture of the object in the first column of the worksheet titled 'Object'. Afterwards, encourage students to feel the objects at their table and talk about the properties of the object (material, weight, etc.)

In small groups, have students use the worksheet to predict if the object will sink or float. Students will write their predictions in the second column. If students think the object will float, they will circle the word 'float'. If students think the object will sink, they will circle the word 'sink'. Encourage students to discuss why they think something will sink or float:

- I think _____ will float because....
- I think _____ will sink because....

Once their predictions are made, test their predictions at the bucket as a whole group. After testing each object, have students note if their predictions were correct or incorrect.

Wrap-Up (10 minutes)

Gather students together to discuss the experiment. Ask the students to make comparisons between the objects that floated, or were buoyant, and those items that sank:

- Which objects sank? Why do you think ____ sank?
- Which objects floated? Why do you think _____ floated?

Review buoyancy and density with students. From today's experiment, ask students:

- What made our objects float? [Buoyancy/having less density than water.]
- What made our objects sink? [Objects that sank had more density than water.]

Show students the picture of an underwater shipwreck again. Explain that this boat sank because its density increased as the water got inside it.

LINKS TO SUPPLEMENTAL MATERIALS
Want more explanation of density? Watch:
[Sink or Float? SciShow Kids]

Name:

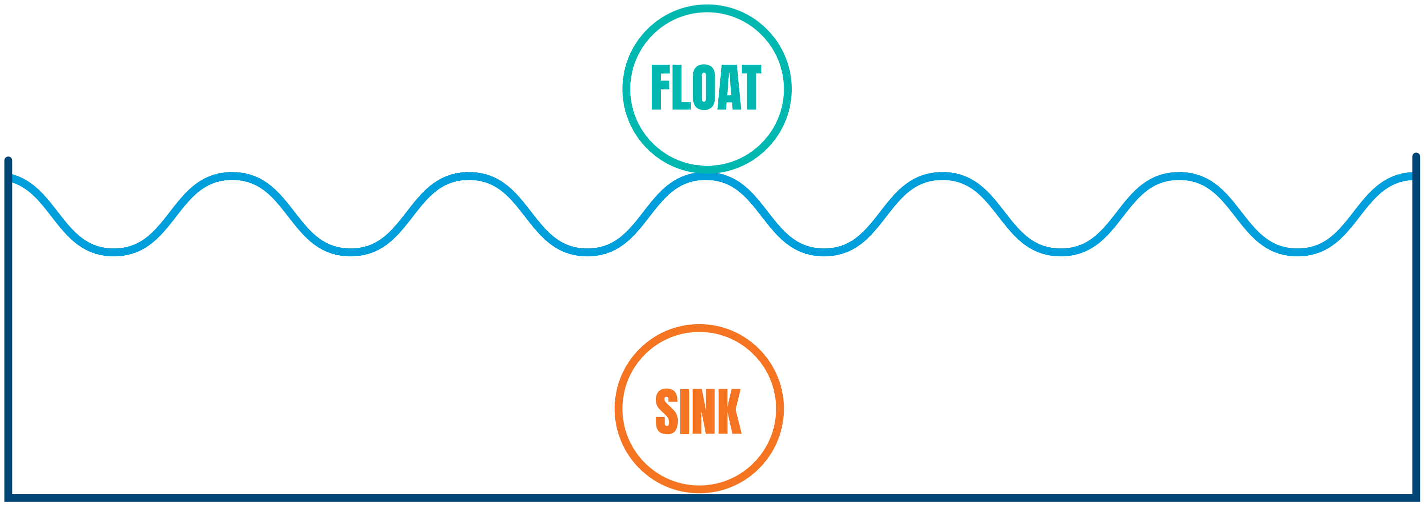
ACTIVITY: SINK OR FLOAT CHALLENGE

Directions: Write the object's name in the object column. Circle whether you think that object will sink or float when placed in water. Test to see if your guess was right and write down the answer.

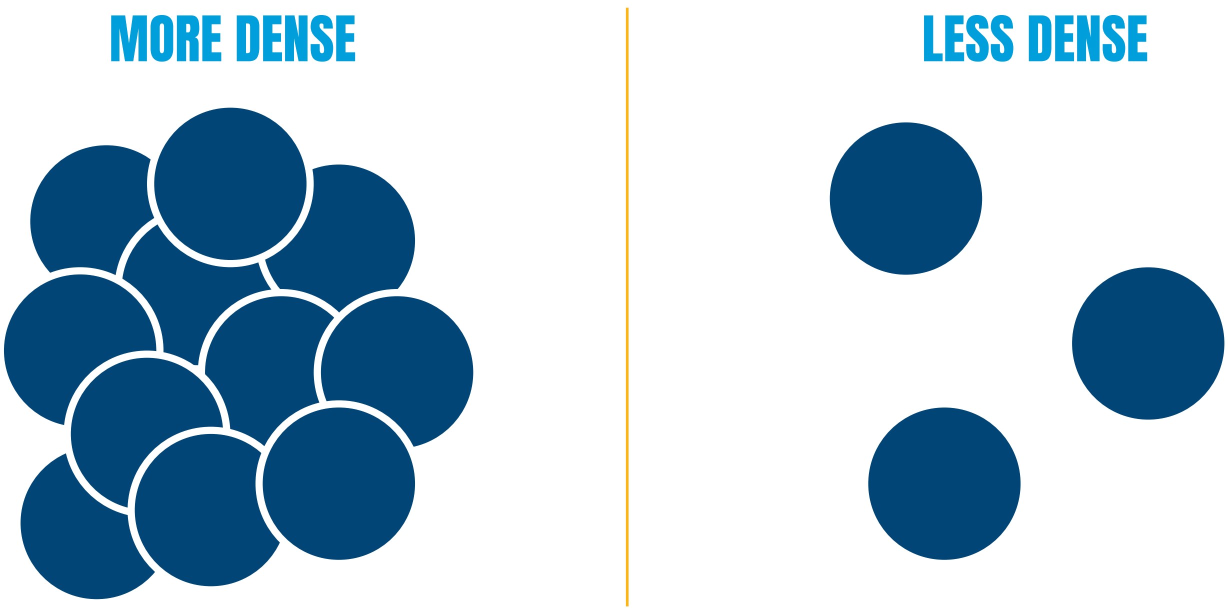
Object	Circle if you think the object will sink or float.	Was your guess correct? Yes or No.
Crayon	Float Sink	
	Float Sink	
	Float Sink	
	Float Sink	
	Float Sink	
	Float Sink	
	Float Sink	

Did anything surprise you?

BUOYANCY



DENSITY



UNCOVER THIS! UNDERWATER ARCHAEOLOGY DIG

Grades:
K-8

Program Length:
45 minutes

Next Generation Science Standards
Discipline(s): Engineering, Technology and the Applications of Science;
Cross *Cutting Concept(s)*: Interdependence of Science, Engineering and Technology
Practice(s): Obtaining, Evaluating and Communicating Information; Analyzing and Interpreting Data

C3 Framework for Social Studies State Standards
Dimension 3: Evaluating Sources and Using Evidence - Gathering and Evaluating Sources; Developing Claims and Using Evidence

Objective:
- Understand the detailed process of underwater archaeology
- Explore utilizing artifacts as a resource.

Assessment:
Students will produce a log (written or drawn) of their uncovered artifacts, including details about each artifact and their inferences about the "archaeological site."

Preparation:
Use masking tape to create a ship outline on the floor. Depending on the space available, divide the ship into 4-6 sections, designating each section as one part of the ship. Place a few artifacts (or, to save space, images of artifacts) in each section. Cover them with shredded paper, cotton, or newspaper. The ship will be a cargo ship, meaning it carried goods from place to place. Choose a type of cargo to put in the cargo hold.

Print Artifact Investigation Worksheet.

SUGGESTED ARTIFACTS

- Socks, t-shirts, diary, personal letters with the date indicated (berthing area/crew's quarters)
- Forks, plates, cans of food, trays (galley)
- Stethoscope, thermometer, bandaids (sick bay)
- Ship's log, compass, map with origin and destination indicated (bridge/pilot house)
- Cargo manifest/list and examples of cargo: could include clothing, furniture, food, machinery, vehicles (cargo hold)
- Rope, paint, chains, locks (bosun's locker)

Cover the artifacts in shredded paper. You may choose to rip things like maps, ship's logs and letters in multiple pieces so that they need to be put back together.

Notes about choosing artifacts:

- The items in the cargo hold should indicate what job the ship had.
- The map in the pilot's house should indicate where the ship was going. The ship's log should indicate the name of the ship.
- The diary or personal letters should indicate when the ship was sailing.
- The cause of the ship sinking could be indicated in the ship's log (notes about weather/ storms), the map (ship sailing toward icebergs or other frozen areas), and the cargo manifest (indicating that the ship is taking on more weight than permitted).

MATERIALS:

- Masking tape
- Measuring tapes (one per group)
- Notepad or clipboard with paper (one per group)
- Pencils
- Newspaper/shredded paper/cotton
- Shipwreck images

LESSON:

Introduction (5 minutes)

Ask the students what they remember about underwater archaeology from their visit to the exhibition. **Underwater archaeology is the careful study and recording of wrecks, crashes and cultural sites found underwater. This scientific practice helps us learn more about past cultures and people. Underwater archaeology requires collaboration between many different people with many different skills. These people include underwater archaeologists, artifact conservators, historians, biologists, photographers, oceanographers, and engineers.**

Ask students:

- What is an *artifact*?
- What kinds of artifacts might divers find at an underwater archaeological site?
- What is interpretation? What does it mean to interpret?
- What interpretations might the artifacts uncovered by divers let scientists make about the people who lived and/or worked at the site?

Archaeological Survey (20 minutes)

Tell students that they will be acting as underwater archaeologists and excavating artifacts from a shipwreck. Students will work in teams of 3-4. Assign each group one section of the ship. Along with making inferences about the artifacts they find and the kind of ship they are investigating, students must try to ascertain which part of the ship they are in. Introduce them to the possible parts of the ship they may be exploring:

- Galley: the kitchen or cooking area on board
- Berthing area: where the crew or passengers sleep
- Sick bay: the area of a ship where passengers can seek medical attention

- Bridge/Pilot house: the navigation center of the ship, where the captain and other crew maneuver the ship and oversee operations
- Cargo hold: the storage area on the ship; whatever the ship is carrying will be stored here
- Bosun's locker/Boatswain's locker: storage space for materials used by the ship's crew

Remind them of the steps the archaeologists take that they saw in the exhibition: grid for location; record the object by sketch or camera while it is in place; carefully remove, note layer, measure artifact, record or sketch recovered object, tag artifact with grid location. Collect and record their findings.

Once students are in groups and assigned a section of the ship, each group must assign an artifact recoverer, a measurer, and an artist. The groups must carefully uncover the artifacts in their section and measure and sketch them before moving them, then bring the artifacts back to their table to investigate them further. **Because students are underwater investigating the site, they may not speak to each other. Encourage students to fully plan out what they want to do prior to 'diving'. After they 'dive', they must communicate through writing, drawing, or hand gestures while excavating the site. A reference guide for some common scuba hand signals is provided!**

Artifact Investigation (20 minutes)

Students will use the attached worksheet to investigate their artifacts. Grades K-2 ask students to draw what they discover. Grades 3-8 ask them to describe the artifacts and think about how they might have been used on the ship. Ask students:

- What artifact(s) did you uncover in the shipwreck?
- How might that artifact have been used on board?
- What part of the ship were you excavating?

Wrap-Up (10 minutes)

Ask students to share their ideas about the following questions:

- What was the ship's job?
- What was the ship called?
- Where was the ship going?
- When did the ship sink?
- How did the ship sink?

Ask students:

- How do you know?
- What clues did you find to help you answer these questions?
- What other evidence do you wish you had in order to be 100% sure you are correct?

ARTIFACT INVESTIGATION

1. Describe your artifact:

Shape: ______________________________

Size (measurement): ______________________________

Material: ______________________________

Color: ______________________________

2. What does your artifact look like? Sketch it in the box below.

3. Reflection Starters. How do you think this artifact was used?

This reminds me of ______________________________

____

I am thinking ______________________________

____

I wonder about ______________________________

____

4. What information can we learn about a shipwreck or other underwater archaeological site by looking at artifacts?

____

____

(Grades 3-8)

ARTIFACT INVESTIGATION

(Grades K-2)

SCUBA DIVING HAND SIGNALS

It is challenging to communicate underwater. Divers communicate using the language of scuba diver hand signals. Practice these simple signals for your underwater archaeology excavation.

OK	
CHECK IT OUT	
FOLLOW ME	
STOP	
TIME TO TURNAROUND	

[Basic Scuba Hand Signals (Illustrated Guide)]

CREATE AN UNDERWATER ARCHAEOLOGICAL SITE

Grades:
3rd - 12th grade

Program Length:
75 minutes

Next Generation Science Standards
Discipline(s): Engineering, Technology and the Applications of Science;
Cross *Cutting Concept(s)*: Interdependence of Science, Engineering and Technology
Practice(s): Obtaining, Evaluating and Communicating Information

C3 Framework for Social Studies State Standards
Dimension 3: Evaluating Sources and Using Evidence - Developing Claims and Using Evidence

Objective:
Students will be able to show their understanding of how the underwater environment impacts our investigation of the past through archaeology.

Assessment:
Students will be able to compare "underwater" sites with different parameters. Discuss or write down what the differences were in types of artifacts and challenges that they noticed. What are the similarities?

Preparation:

1. Print and copy the Underwater Site Parameter page. Cut into strips.
2. Fold strips and put them into four different containers, one for each parameter (one for age, one for type of water, etc.).
3. Optional Modification: For those students who may need extra support, print the worksheet "MY UNDERWATER SITE."
4. Gather remaining materials.

MATERIALS:

- Paper (at least 3 sheets per student)
- Pencils (1 per student)
- Crayons/Markers/Colored pencils/Oil pastels (1 set per group/pairing)
- Scissors
- Model magic (optional)
- Stickers
- Foam shapes
- Other various crafting supplies
- Containers for the site parameters

- Site characteristics and parameters on slips of paper or other methods of randomly choosing.
- Optional: Journals (1 per student)

LESSON:

Introduction (10 minutes)

Ask the students what they remember about underwater archaeology from their visit to the exhibition.

Underwater archaeology is **the careful study and recording of wrecks, crashes and cultural sites found underwater. This scientific practice helps us learn more about past cultures and people. Thousands of underwater archaeological sites have been located and studied. However, there are still millions of shipwrecks, plane wrecks, sunken cities, and submerged cultural sites around the world that have not been located or identified yet.**

Ask students:

- What artifacts do you think a researcher would find in a certain underwater site?
- What information about people do you think we can learn from the artifacts found at underwater sites?
- What types of materials do you think you could find at an underwater site? (Organic vs. inorganic)
- What are some underwater sites that have been discovered by researchers? (Pull on prior knowledge from the exhibit if appropriate.)

Virtual Exploration Example (10 minutes)

Use Visual Thinking Strategies with the group of students to analyze the 3D model of an archaeological underwater site, using some of the guiding questions from the intro above.

Ask students: What do you see? What makes you say that? What more can you find?

Virtual Archaeology Museum

ACTIVITY (40 MINUTES)

With some understanding and prior knowledge of different types of underwater sites, students will design their own.

1. Divide students into pairs or small groups (3-4 students)
2. One person from each pair/group will pick one slip of paper from each Underwater Site Parameter, while someone else in the group writes it down. ***Students should not share the characteristics their pair/group has chosen with others who are not in their pair/group. This is to allow more investigation opportunities from the other pairs/groups.**
3. The student who picked the slip of paper will fold it back and place it back in the container. Do this with all your pre-made parameter containers. ***Optional Modification: Students who need more support may circle the specific parameters for their underwater site on the worksheet, MY UNDERWATER SITE.**
4. After all pairs/groups have chosen their parameters, each pair/group will use their creativity to collectively create what the site might look like and what artifacts could be found there with their parameters in mind. They should include the objects, artifacts, and other organic matter (plants, animals, bones) they think could be found at their sites. They should use prior knowledge from the exhibition and virtual underwater site exploration. Have students think of the physical effects that time and being underwater would have on their site. They can then write a label about what the challenges to exploring and excavating the site would be based on their parameters.

Gallery Walk and Wrap-Up (15 minutes)

After all pairs/groups have completed their projects, lead students on a gallery walk of all the sites (with optional notetaking journals) to reflect on, discuss, and analyze what they see in each pair's/group's underwater sites.

For each site, ask students to think about:
- What kind of underwater site do you think it is?
- What objects or artifacts do they notice?
- What kinds of organic matter do they notice/ (plants, animals, bones)
- What excavation challenges were there?

Sum it up: whole group discussion
- What were the differences in types of artifacts and excavation challenges that they noticed between sites with different parameters? What are the similarities?

Differentiation:
- Students may create a diorama for their underwater sites, incorporating modeling clay, sculpture, painting or collage for a more detailed and three-dimensional effect.
- Students may use a web design platform to create a 3D rendering of their underwater site.

UNDERWATER SITE PARAMETERS

Cut the strips below for each underwater site parameter. Put in containers from which students will choose randomly for the creation of their site.

AGE OF SITE	100 YEARS
AGE OF SITE	250 YEARS
AGE OF SITE	1,000 YEARS

BODY OF WATER	DEEP OCEAN
BODY OF WATER	RIVER
BODY OF WATER	LAKE
BODY OF WATER	SHALLOW SHORELINE

TYPE OF WATER	SALTWATER
TYPE OF WATER	FRESHWATER
TYPE OF WATER	BRACKISH

WATER TEMPERATURE	MODERATE
WATER TEMPERATURE	WARM/TROPICAL
WATER TEMPERATURE	COLD/POLAR

TYPE OF SITE	SHIPWRECK
TYPE OF SITE	SUBMERGED LANDSCAPE
TYPE OF SITE	CITY OR HARBOR
TYPE OF SITE	HUMAN-MADE STRUCTURE

MY UNDERWATER SITE

CIRCLE ONE OF EACH

Age of site:

100 YEARS	250 YEARS	1,000 YEARS

Body of water:

DEEP OCEAN	RIVER	LAKE	SHALLOW SHORELINE

Type of Water:

SALTWATER	FRESHWATER	BRAKISH WATER

Water Temperature:

MODERATE/TEMPERATE	TROPICAL	COLD/POLAR

Type of Site:

SHIPWRECK	SUBMERGED LANDSCAPE	CITY/HARBOR	HUMAN-MADE STRUCTURE

“ROBOTIC” HANDS

Grades:
3-12

Program Length:
45 minutes

Next Generation Science Standards
Discipline(s): Engineering, Technology and the Applications of Science;
Cross *Cutting Concept(s)*: Interdependence of Science, Engineering and Technology; Structure and Function
Practice(s): Asking Questions and Defining Problems; Constructing Explanations and Designing Solutions

Objective:
Students will understand how robotic hands (end-effectors) function and how they can assist underwater archaeology exploration and excavation.

Assessment:
Students will demonstrate engineering skills through the construction and manipulation of a model robotic hand and reflect on the design.

Preparation:
- Review the materials and suggestions from NOAA for an overview of underwater robots. (Note: This lesson is a simple concept idea for how robotic hands assist in underwater archaeology exploration and excavation, rather than a complete robotics lesson.)
- Print Visual Instructions for each group.
- Prepare some materials in advance if desired.

MATERIALS:

- 2 cardboard coffee cups per group
- 3 rubber bands per group
- 1 pair of scissors per group
- 1 roll of tape per group
- Yarn or Koosh balls
- Disposable water bottles
- The student’s science notebooks and pencils

LESSON:

Introduction (10 minutes)

Ask the students what they remember about underwater archaeology from their visit to the exhibition. **Underwater archaeology is the careful study and recording of wrecks, crashes and cultural sites found underwater. This scientific practice helps us learn more about past cultures**

and people. Underwater archaeological sites can be found at all water depths.

Ask students: What challenges do underwater archaeologists face when exploring sites? What tools assist in their exploration and excavation? What functions would you want in a robot that assists in underwater exploration?

Mobile robots help humans explore hard-to-reach places like space, disaster zones, and deep oceans. Underwater robots, including remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs), play a vital role in exploring the ocean. They can reach places that are too risky or challenging for humans. These robots come in different shapes and sizes and can be equipped with various sensors and tools to gather large amounts of data from deep-sea environments. They often work using tools like hands or grippers, called ***end-effectors.***

Review vocabulary from the exhibit:

- **ROVs (Remotely Operated Vehicles):** ROVs are unoccupied, highly maneuverable underwater machines that can be used to explore ocean depths while being operated by someone at the water's surface.
- **AUVs (Autonomous Underwater Vehicles):** uncrewed, untethered vehicles used to conduct underwater research.

Kinesthetic Learning (5 minutes)

Pass out water bottles and have students describe what it is like to pick up objects with their hands. What do their muscles do? How do the fingers work together? Try some coordination challenges:

- Hold a plastic bottle in one hand and grab it with your other hand.
  - Explain that nerve endings in your hands and fingers tell your brain if you are grasping the bottle correctly. What could be a challenge that arises when using a robotic arm to grasp something like this bottle?
- Do the same thing, but use just two fingers at a time. Try different combinations of fingers (e.g., index finger + thumb). What feels different? What is most effective?
- Hold a plastic bottle in one hand and grab the bottle again. This time, knock the bottle onto the floor.
  - If we do not grab an object on dry land successfully, what happens to it? (drops to the ground, rolls away, etc.)
  - If we do the same thing underwater, what happens to it? Why does that happen? (might float away, get swept away by current, be harder to grab, etc.) What does that tell us about challenges in exploring underwater archaeological sites?

ACTIVITY: BUILD THE ROBOTIC HAND AND TEST

Phase 1: Free Engineering (5 minutes)

- Break students up into groups of four or five.
- Supply each group with 2 paper cups, 3 rubber bands, scissors, and a strip of duct tape
- Ask each group to think of a design that could be used to pick up a bottle and move it from one spot on the table to another using only those materials.

Phase 2: Following Visual Instructions (20 minutes)
Students will construct an "end-effector" or robotic hand to successfully pick up an empty water bottle and a koosh ball or ball of yarn (or other soft, round object).

- Using the instruction cards, have students build and test their effectors.
- Students should practice using their effectors to pick up the water bottle and move it from one end of the table to the other. Try with the Koosh ball/yarn ball.
- Ask students to write a reflection. Do they believe their robotic arm's effector is a good design for use underwater? What might work better? If they had all the materials they could want to work with, what would their design look like? (They can sketch it if they like.)

Wrap Up (5 minutes)
Students will construct an "end-effector" or robotic hand to successfully pick up an empty water bottle and a koosh ball or ball of yarn (or other soft, round object).

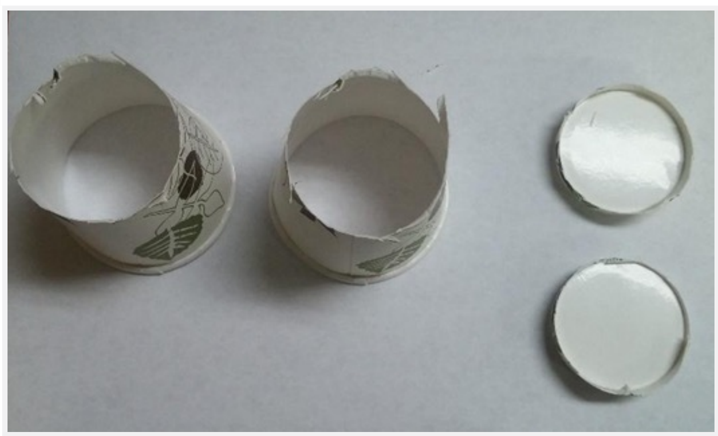
- Bring groups back together and discuss what groups learned during the process.
  - What worked? What didn't work?
  - Ask students to share their reflections on the effector's design and some of their design ideas.

VISUAL INSTRUCTIONS: ROBOTIC HAND

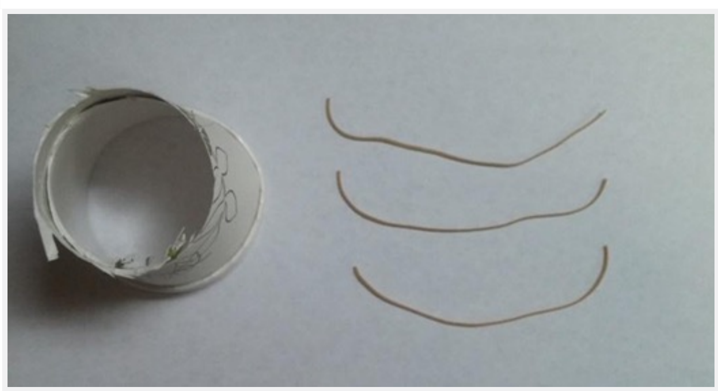
Materials:
Two disposable cups
3 rubber bands (or can try heavy string/yarn)
Duct tape (or you can use masking or painter's as well)
Scissors

Remove the bottom end of each cup by cutting along the curved wall of the cup.

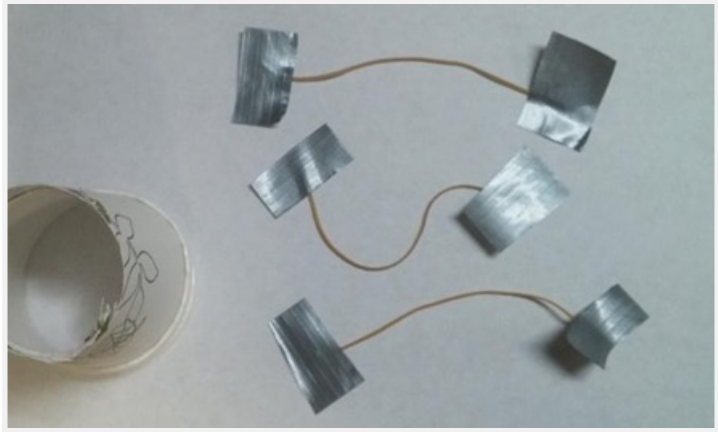
Discard the cup bottoms and place one cup inside the other.



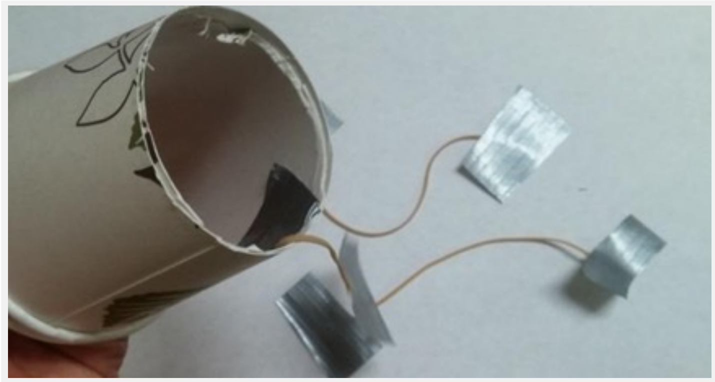
Take three rubber bands and cut them so they no longer make loops.



Place a strip of tape on each end of the rubber band.

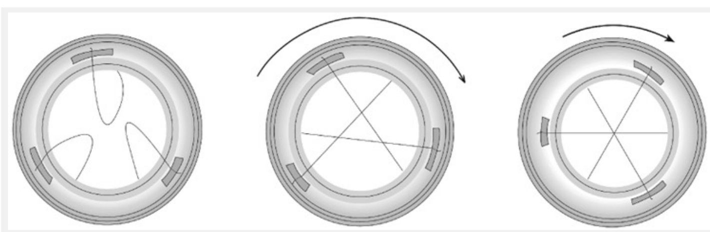


Tape one end of a rubber band to the inside of the inner cup. Repeat this process with the other two rubber bands. Space each rubber band out evenly.



Tape the other ends of the rubber bands to the outside of the outer cup so that the rubber bands make a small loop over the cut edges of the cups.

Position the cup so the rubber bands are facing down. Twist the inside cup clockwise while holding the outside cup in place. The motion should be similar to using a pepper grinder. The rubber bands should all intersect in the middle of the cups. This is your snare.
Adjust rubber bands as needed to make them even.
Turn the opposite way to make the rubber bands go back to their starting positions.



(Image credit: NASA)

BUOYANCY CONTROL: MAKING CARTESIAN DIVERS

Grades:
5-12

Program Length:
50 minutes

Next Generation Science Standards
Discipline(s): Engineering, Technology and the Applications of Science; Physical Sciences,
Cross Cutting Concept(s): Energy and Matter; Interdependence of Science, Engineering and Technology.
Practice(s): Planning and Carrying Out Investigations

Objective:
Students will be able to define *buoyancy* and apply it to the study of underwater archaeology.

Assessment:
Students will understand and be able to explain how the Cartesian diver models the effect of buoyancy and density.

Preparation:
- Fill one plastic water bottle per student (or pair of students)
- To reduce steps, cut plastic drinking straws to 14 cm each.

MATERIALS:

Per student:
- 1 or 2-liter clear plastic bottle with cap (recycled water or soda bottles work best)
- Plastic drinking straw
- Small hair elastic or rubber band
- Small paper clips
- Scissors
- Ruler
- Water (bottles can be filled beforehand)
- Tall cup of water
- Key Terms list (or cards for vocabulary wall. etc)

LESSON:

Introduction (10 minutes)

Ask the students what they remember about underwater archaeology from their visit to the exhibition. ***Underwater archaeology is the careful study and recording of wrecks, crashes***

and cultural sites found underwater. This scientific practice helps us learn more about past cultures and people. Underwater archaeological sites can be found at all water depths. Divers may survey sites up to 300 feet under the surface.

Ask students:

- What challenges might divers face while surveying an underwater site?
- What tools might be important for divers spending extended time under the water exploring a site?
- How do divers move around under the water?

Breathing, water pressure, temperature and visibility are all challenges for divers surveying underwater sites. Another challenge is the ability of a diver to move up and down in the water, as well as maintain one depth.

In addition to SCUBA (Self-Contained Underwater Breathing Apparatus) equipment, divers exploring an underwater site must have tools to control their position in the water. Divers wear buoyancy control devices (BCDs), also known as buoyancy compensators (BCs), to control their buoyancy. By controlling the amount of gas being added to or removed from the BCD, divers are able to establish positive, negative, or neutral buoyancy.

Explain Key Terms: Introduce the concepts of mass, density, volume, and buoyancy.

Mass: Mass is different from weight. Mass is the measurement of how much of any one thing there is. It is the same no matter where the object is, whether it is on Earth, Jupiter, or in the vacuum of space. Weight is the force of gravity pulling down on the mass of an object. Generally, something that is more massive is heavier.

Density: How much mass is packed into the space an object takes up. Density = Mass divided by Volume. The density of any substance can be found by using this formula.

Volume: The amount of three-dimensional space a shape or object occupies. Different shapes have different volumes.

Buoyancy: The upward push of fluid on an object (buoyant force). Buoyancy is what we call the force of the water that opposes gravity's pull on an object.

Positive buoyancy: An object is less dense than the water it displaces. If an object floats, it is positively buoyant.

Negative buoyancy: An object is denser than the water it displaces. If an object sinks, it is negatively buoyant.

Neutral buoyancy: An object has the same density as the water it displaces. An object is neutrally buoyant if it neither floats nor sinks.

To demonstrate buoyancy, students will be making Cartesian Divers. The Cartesian Diver is an experiment named after French scientist René Decartes. A Cartesian diver is a simple physics demonstration that illustrates the principles of buoyancy and pressure in a closed system. It involves a small, partially water-filled object (representing the diver) inside a larger container of water that can be squeezed, causing the diver to rise and fall. In a Cartesian diver, there is air trapped.

The experiment demonstrates the principle of buoyancy, where an object floats if it's less dense than the surrounding fluid (water).

The experiment illustrates Boyle's Law, which states that for a fixed amount of gas, the pressure and volume are inversely related (i.e., if pressure increases, volume decreases and vice versa).

The experiment highlights how density (mass/volume) plays a crucial role in whether an object floats or sinks inside, making it less dense than the water around it so it will initially float.

Wrap-Up (10 minutes)

Ask students:

- What happened when you *squeezed* your bottle?
- What happened when you *released* your bottle?
- How does the Cartesian diver experiment demonstrate the principles of buoyancy and density?
- How can we use the Cartesian diver to understand how divers at archaeological sites control their depth with the buoyancy control devices?

ACTIVITY (30 MINUTES)

Building the Cartesian Diver - Visual Instructions

1. Cut the drinking straw to 14cm.

2. Fold the straw in half by pinching the middle, making it easier to bend.

3. Wrap a small rubber band or hair elastic around the open ends of the straw several times. This will be your “diver”. [See image]

4. Add weight to the diver by opening a small paper clip slightly and hooking it around the elastic. Direct the prong of the paper clip up toward the elastic. [See image]

a. Test the diver by putting it in a glass of water, making sure that it is almost entirely submerged. If it needs more weight, add another paper clip.

5. Fill the water bottle up to the top with room temperature water. Avoid extreme temperatures.

6. Put the diver inside the bottle and screw the top on. [See image]

7. Squeeze the bottle and observe what happens.
8. Release the bottle and observe what happens.

The Cartesian diver goes to the bottom of the bottle when the bottle is squeezed. Water is forced into the diver - the only place it can go - and the tiny space of air in the diver is compressed so that the volume of the air decreases and the density of the air in the diver increases, making it sink. When the bottle is released, the pressure is released from the air bubble inside the diver, which becomes less dense again, so buoyancy pushes the diver to the top. The air bubble has a constant mass. We did not add or subtract any matter. We are only altering its volume. In a closed system like this, where no air is being added or taken away, as volume decreases, density increases. As volume increases, density decreases.

$$density = \frac{mass}{volume}$$

Tips for adjusting the diver:

- If it does not dive, squeeze the bottle harder. If that does not work, add weight (paper clips) to the diver.
- If the diver sinks but does not rise, try removing a paper clip or replacing it with a half-paper clip. In rare cases, the straw could be cracked and leaking air. Replace it with a new one.
- If the bottle is dropped, the diver likely will not rise. The pressure shock will have allowed too much water to get into the diver. Fish out the diver, shake up the bottle, and try again.