NOVA

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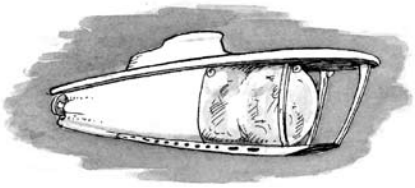
Underwater Dream Machine

PROGRAM OVERVIEW



NOVA follows the journey of Peter Robbins, a man who staked everything he owned to build his own submarine with the world's largest acrylic dome.

The program:

- reviews the sub's design, which combines a conventional steel aft section with a forward transparent acrylic plastic hull.
- explains that the sub is powered by a long-range diesel engine.
- notes that the submarine's budget is $1.5 million, which means that many of its parts will need to be off-the-shelf components from ordinary hardware stores and auto suppliers.
- presents Robbins' idea to turn the vehicle (named Alicia after his daughter) into a profit-making enterprise by taking tourists and researchers to shipwrecks lying off England's south coast.
- chronicles the construction of the submarine's components, including its batteries, ballast, dive control mechanisms, acrylic sphere, air filtering system, and fail-safe mechanism.
- points out the setbacks involved in building the sub's never-before-made acrylic sphere.
- explains Robbins' fascination with German U-boats and reveals his efforts to track down a surviving member from a World War II U-boat involved in the war's last major U-boat action.
- recounts the survivor's account of that English Channel battle and his escape from the U-boat.
- shows Robbins' submarine undergoing pressure testing at Britain's largest pressure chamber and presents its first test dives.
- recounts Robbins' voyage with the U-boat survivor to the wreck of the supply ship torpedoed by his U-boat.

BEFORE WATCHING

1 In the program, Peter Robbins was inspired by Jules Verne's *20,000 Leagues Under the Sea,* a science-fiction novel. List on the board titles of science-fiction books or movies students have read or seen. Have students share aspects of each book or movie related to real-world science and aspects that are fictional.

2 Organize students into three groups. Have one group take notes on the people involved in building and designing the vehicle and the different skills each person brought to the project. Ask the second group to track each of the steps taken to design and build the vehicle. Have them note which components had already been created and could be used off the shelf and which had to be fabricated. Have the final group track the obstacles encountered during the vehicle's construction.

AFTER WATCHING

1 Have students who took notes on the same topic meet and share what they learned. What skills did Robbins and his crew possess? What expertise did each person contribute to the project? What obstacles did Robbins have to overcome in order to turn his dream into a reality? How did he overcome them?

2 Robbins was inspired by Jules Verne's *20,000 Leagues under the Sea.* Have students consider the underwater exploration that might be possible with a deep-sea vehicle like that featured in the program. If students could choose, what would they want to investigate? Use a student-generated idea to discuss how to move from an idea to a scientific investigation.

CLASSROOM ACTIVITY

Activity Summary

Students prepare a diving tank and a submarine and make the submarine neutrally buoyant in the tank.

Materials for Teacher

- kitchen utility scissors

Materials for Each Team

- copy of "Build Your Own Submarine" student handout
- 2-liter plastic soda bottle, rinsed, label removed, and cut to specifications
- package of 3-ounce drinking cups, plastic preferred
- large needle
- large paper clips
- kitchen utility scissors
- waterproof markers
- water, room temperature
- dishwashing liquid
- for ballast: paper clips and metal washers

Background

Submarines are important to military operations and to undersea exploration because they can function entirely underwater. Military submarines are usually much larger than scientific submarines, and they often carry weapons. Scientific submarines carry a small number of crew members and are usually designed for specific exploration missions. The submarine featured in this program is a recreational submarine used to transport passengers to underwater wrecks.

Submarines usually have two hulls, an outer and inner, and both are often made of steel. How deep a submarine is able to dive is limited by the strength of the hulls. The ballast is the part of the submarine that is between the hulls. Ballasts are filled with air or water: filling the ballast with water sinks a submarine, filling it with air causes a submarine to float. Neutral buoyancy occurs when the submarine's density is about equal to the density of the surrounding water.

In this activity, students will make a diving tank and a submarine and then investigate how weight and buoyant forces apply to the submarine.

LEARNING OBJECTIVES

Students will be able to:

- make an object neutrally buoyant in water.
- understand buoyancy forces.

KEY TERMS

ballast: Something that gives stability. In a submarine, it is the space between the hulls that is filled with either water or air.

buoyancy: The upward force a fluid puts on an object less dense than itself.

hull: The main body of a boat or casing of a submarine.

negative buoyancy: A boat or submarine has negative buoyancy if it weighs more than water.

neutral buoyancy: A boat or submarine has neutral buoyancy if it weighs about the same as water.

positive buoyancy: A boat or submarine has positive buoyancy if it weighs less than water.

submarine: A ship that can operate completely underwater.

CLASSROOM ACTIVITY (CONT.)

Procedure

1. Before class, prepare diving tanks for each team by cutting around the shoulder of a soda bottle so that the remaining base is tall and straight-sided. For safety, use kitchen utility scissors. This activity involves working with these "tanks" filled with water. Work in a wet lab, outdoors, or place them in plastic dishpans.
2. Organize students into teams and distribute copies of the "Build Your Own Submarine" student handout. Demonstrate for students the construction of a submarine (see the student handout for an illustration of the final product):
   - **a** Poke two holes with a large needle on opposite sides of the drinking cup's rim.
   - **b** Bend a large paper clip into a U-shape and attach to the cup through the holes.
   - **c** Neatly cut a bean-shape hole in the side of the cup about a quarter of an inch (6.35 millimeters) from the bottom. The submarine will be easier to control if the edge of the hole nearest the cup bottom is straight and parallel to the cup bottom.
3. Supervise students as they build their submarines and prepare their diving tanks. (If students have difficulty making their submarines neutrally buoyant, add some dishwashing liquid to the diving tank. This will reduce the surface tension, making the size of the escaping bubbles smaller and thus making it easier to achieve neutral buoyancy.)
4. Once students have gotten their submarines to be neutrally buoyant, conduct a class discussion about buoyancy using the scenarios listed in the questions section of the student handout.
5. As an extension, change the density of the water and repeat the experiment. First have students predict what might happen, then retest the submarine in dissolved sugar or salt water.

STANDARDS CONNECTION

The "Build Your Own Submarine" activity aligns with the following National Science Education Standards (see books.nap.edu/html/nses).

GRADES 5–8
Science Standard B
Physical Science
- Motions and forces

GRADES 9–12
Science Standard B
Physical Science
- Motions and forces

Video is not required for this activity.

Classroom Activity Author
James Sammons taught middle and high school science in Rhode Island for 30 years. His teaching practices have been recognized by the National Science Teachers Association, the Soil Conservation Service, and the National Association of Geoscience Teachers. This activity originally appeared in a slightly different form on NOVA's "Hitler's Lost Sub" Web site.

ACTIVITY ANSWER

A submarine rises because the weight of water pushing up on the submarine, known as the buoyant force, is greater than the downward force, the weight of the submarine. If the submarine weighs more than the buoyant force, it sinks. If it weighs less than the buoyant force, it will rise. If the buoyant force and the weight are about equal it will drift (either on or beneath the surface). At this point, the submarine is neutrally buoyant. That is, there is no tendency for it to rise or sink so the submarine should remain at about whatever level it was placed.

Divers use this same principle when they add or let air out of their buoyancy vests in order to control their position in the water. Bony fishes use a swim bladder to maintain neutral buoyancy. Like the diver's buoyancy vest, this saves energy that would otherwise be spent maintaining vertical position.

Student Handout Questions

1. You are piloting a new research submarine among stony towers rising from the center of the Mid-Pacific Rise. Your guest scientist points to a two-meter-tall tower and asks if you can break it off to take back to the surface. Although the mechanical arm can do that, and you have a forward sample basket big enough to hold the piece, you are doubtful for two reasons. What are they? *The first reason is that the pilot can't know whether it can be lifted safely because she doesn't know the weight of the sample. If it is more than the weight of the sub's releasable iron pellets, taking it threatens the sub's ability to surface. The second reason concerns where the sample is situated; placing a large weight near the front end of a submarine will cause the sub to be off-balance and could result in it pitching forward into an unsafe head-down attitude.*
2. On the forward surface of your submarine are six large floodlight bulbs. These bulbs are like regular light bulbs, except for their large size. Imagine that something bumps the floodlight rack, breaking the bulbs. How will this affect your submarine? What will you have to do? *Because they contain air but don't have much weight, the bulbs add to the buoyancy of the sub. If the bulbs break, that buoyancy is lost. To remain neutrally buoyant, the sub will have to drop some iron pellet ballast.*

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LINKS AND BOOKS

Links

NOVA—Underwater Dream Machine
www.pbs.org/nova/alicia
Find articles, interviews, slide shows, and resources in this companion Web site to the program.

How Submarines Work
people.howstuffworks.com/submarine.htm/printable
Discusses many aspects of submarines, including diving and surfacing, life support, power supply, and navigation.

Submarines
unmuseum.mus.pa.us/sub.htm
Reviews the parts of a sub and explains the differences between military and scientific submarines.

Submarines: How They Work
ww.onr.navy.mil/focus/blowballast/sub/work1.htm
Addresses the concept of buoyancy, the relationship between pressure and volume, and methods of propulsion.

Books

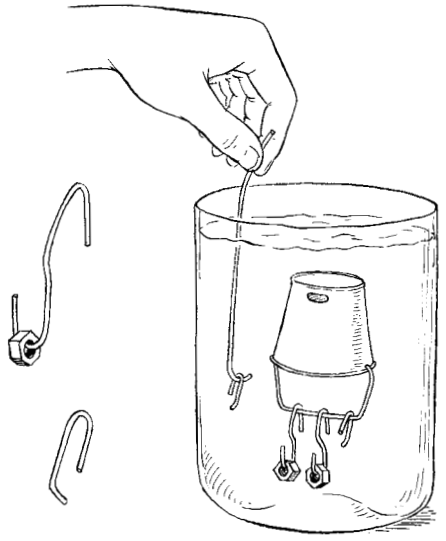
DK Eyewitness Guides: Force and Motion
by Peter Lafferty.
Dorling Kindersely, 1992.
Discusses the principles behind several different kinds of force and motion, including buoyancy.

DK Eyewitness Guides: Submarine
by Neil Mallard.
Dorling Kindersley, 2003.
Describes how submarines work, their role in wars, and how submarines are detected in the water.

Submarines (History Series)
by J.J. Tall.
Barrons, 1998.
Shows submarine development, with emphasis on the vessels of WWI, WWII, and modern nuclear submarines.

Build Your Own Submarine

A submarine is not just a silent shape gliding smoothly along under the sea. The submarine's crew is constantly making adjustments to keep it from bobbing to the surface or sinking below its safe depth. Here's an activity that lets you be the submarine captain.



Procedure

1. Your teacher will demonstrate how to make your submarine. Use markers to name your submarine.
2. Fill your soda bottle "diving tank" to within a half-inch (12.7 mm) of the top and stir in a few drops of dishwashing liquid. Use the plastic cup and paper clip to make your submarine. Place your submarine bottom-side up in the tank where it will float like an actual submarine floats on the surface.
3. Sink the submarine by pushing lightly with your finger. What happens when you release it?
4. Carefully add ballast by hanging pieces of paper-clip wire and metal washers to the paper clip hanging from your submarine until it starts to dive. What happens to the submarine as you add more ballast?
5. Now for the challenging part. Can you make your submarine behave like a real submarine? Can you get the ballast just right so that it is neutrally buoyant, that is, its weight is equal to the water's buoyant force? You'll know you have succeeded if your submarine goes neither up nor down—it stays at the depth it is at.

Questions

Write your answers on a separate sheet of paper.

1. You are piloting a new research submarine among stony towers rising from the center of the Mid-Pacific Rise. Your guest scientist points to a two-meter-tall tower and asks if you can break it off to take back to the surface. Although the mechanical arm can do that, and you have a forward sample basket big enough to hold the piece, you are doubtful for two reasons. What are they?
2. On the forward surface of your submarine are six large floodlight bulbs. These bulbs are like regular light bulbs, except for their large size. Imagine that something bumps the floodlight rack, breaking the bulbs. How will this affect your submarine? What will you have to do?