NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE™

NEUTRAL BUOYANCY CHALLENGE

Students practice observation and math skills while learning about buoyancy and how it applies to astronaut training. Adapted from a lesson plan provided by NASA.

LESSON PLAN

Lesson Objective

In this lesson, students will learn about neutral buoyancy while experimenting with the buoyancy of various weights. Students will determine the volume and weight of their containers, adjusting the weights to achieve positive, negative and neutral buoyancy.

Learning Objectives

The students will:

- Work in teams
- Learn about density and neutral buoyancy
- Learn about Archimedes' Principle
- Learn how and why astronauts train for EVAs in neutral buoyancy
- Calculate the volume of the canister
- Investigate neutral buoyancy through experimentation

Introduction

Neutral buoyancy is the term used to describe an object that neither sinks to the bottom of a container of fluid nor floats to the top. Items that sink are *negatively* buoyant. Items that float are *positively* buoyant. Items that have an equal tendency to sink and float are configured to be neutrally buoyant (which is accomplished with a combination of weights and flotation devices) and seem to "hover" under water. Large, neutrally buoyant items can be easily manipulated much like in orbit. This is similar to how it feels to be in the microgravity environment of space. Astronauts train in NASA's huge Neutral Buoyancy Lab (NBL) to simulate working in space. Extra-vehicular Activities (EVAs) – or space walks – and many additional tasks related to living in space are rehearsed in the NBL.

Please note: there are two important differences between an actual spacewalk and training in the NBL. First, a suited astronaut in the NBL is not truly weightless. While it is true the suit/astronaut combination is neutrally buoyant, the astronauts feel their weight while in the suit (they are lying or standing in the suit depending on its orientation). Second, water drag acts to hinder motion making some things easier to do in the NBL than on orbit and some things more difficult.

Grade Level: 5—8

Ohio Learning Standards/Science (2018)

Expectations for Learning
Nature of Science
Cognitive Demands for Science

Physical Science
5.PS.1: Amount of change in movement of an object is based on mass and the amount of force exerted
6.PS.4: An object's motion can be described by its speed and the direction in which it is moving
8.PS.1: Objects can experience a force due to an outside field
8.PS.2: Forces can act to change the motion of objects

Materials Required:

- Large aquarium or other clear container filled about 2/3 with water
- Empty film canisters or other small air-tight plastic containers
- A number of a variety of small, waterproof or water resistant objects such as stainless steel or plastic nuts, bolts and washers
- Calculators
- Pencils
- Rulers
- Worksheets
- Digital scale
- Fish net
- Towels

Both effects are unlike the conditions of space and must be recognized during EVA training. However, even with these limitations, neutral buoyancy is currently the best available method for EVA training.

Fun fact: Our brains are neutrally buoyant! They are surrounded by cerebral fluid in which the brain neither floats (or it would hit the top of our skulls) nor sinks (or it would get squashed by its own weight)!

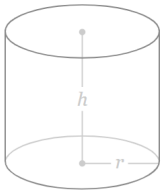
Procedures:

- In advance, prepare the aquarium/tank. Fill about 2/3rds full with tap water. Allow the water to reach room temperature. Determine, based on the size of the tank, how far below the surface of the water should the canister be hovering to be considered adequately neutrally buoyant. A depth of about 10 cm is common.
- Have the students work in teams of 2 to 3 students each.
- Depending on the students advance knowledge, either review or present information on the following:
  - What is volume? ***A measure of the amount of space enclosed by a shape or object; the amount of space a 3-d object occupies***
  - What is the formula for the volume of a rectangular 3-d object? The area of a circle? ***The volume of the rectangular shape is length times width times height and the area of a circle is πr^2***
  - What is π? ***The circumference of a circle divided by its diameter - regardless of the circle's size, this ratio will always equal π or approximately 3.14***
  - What is the formula for the volume of a cylinder? ***See below***

$$V = \pi r^2 h$$

r Radius

h Height



- What is density? ***The measure of how much mass is contained in a measured volume (don't forget to account for air)***
- What is the Archimedes Principle? ***An immersed object is buoyed up by a force equal to the weight of the fluid it displaces***
- What is buoyancy? ***An upward force acting on an immersed or floating body by the supporting fluid (e.g. water or air)***
- What two forces act on an object in the water? ***Gravity and buoyancy***

- What is negative buoyancy? ***An object's weight is greater than the weight of an equal volume of the displaced fluid – it sinks***

- What is positive buoyancy? ***An object's weight is less than the weight of an equal volume of the displaced fluid – it floats***

- What is neutral buoyancy? ***An object's weight is equal to the weight of an equal volume of the displaced fluid – it neither sinks nor floats but "hovers" in place (unless acted upon by an outside force)***

- Who or what needs to be neutrally buoyant? ***Submarines, some fish, hot air balloons, scuba divers, astronauts, etc.***

- What is NASA's Neutral Buoyancy Laboratory (NBL)? ***Where astronauts train for spacewalks – see resource section below***

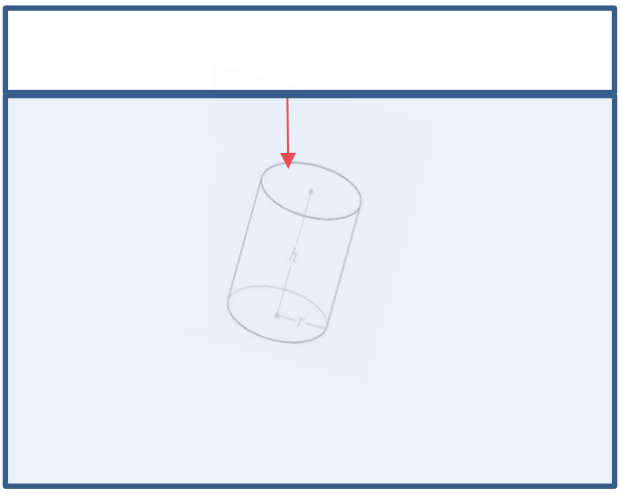
- What is the advantage of working in a neutrally buoyant environment?
  How does training in this environment prepare astronauts for working in space? Does the NBL duplicate the working environment of space? ***See background information above***

- Next, explain to the students that each team will be investigating neutral buoyancy using a film canister or small plastic container with the various nuts, bolts and washers as the weights.

- When testing the buoyancy of the canisters, students should make sure the lid is on tight. The canisters should be lowered gently into the water. After observing the buoyancy level, the canister should be removed with the fish net and placed on a towel. Care should be taken that students do not reach into the water. Besides allowing for a less messy process, this also helps to keep the water cleaner for the duration of the experiment.

- First, students should calculate the volume and weight (with lid) of their empty canister. Annotate their answers on the worksheet.

- Next the students should test the buoyancy of the empty canister and annotate their worksheets (Trial 1). Students should measure the distance of the highest point of the canister from the top level of the water (see red arrow below). In the case of the floating, empty canister, the distance will be 0 cm.



- As a team, students should attempt to achieve neutral buoyancy by adding items to the canister, weighing it, and testing it in the aquarium/tank. They should measure its distance from the surface of the water and annotate all observations on their worksheets. This process should be continued, adding or subtracting weight, until the students achieve neutral buoyancy with their canister.

- Allow as much or as little time as class permits. Allow enough time to have the class come together as a whole to discuss their experimentation. Did anyone achieve neutral buoyancy? If so, how much did the cylinder weigh? How many trials did it take? What issues/problems did they encounter?

- For older students, you may want to introduce the discussion about the temperature of the water and how it affects the experiment [*low temperature makes the water more dense and objects float easier*]. What if salt is added to the water? [*salty water is more dense and also makes objects float easier*]

Resources:

Neutral Buoyancy Lab:

https://youtu.be/BRPb0J8lZcY

https://youtu.be/3Pcas0pQw5U

https://youtu.be/tTU8U7y0CUI

https://www.nasa.gov/johnson/HWHAP/neutral-buoyancy

https://arstechnica.com/science/2013/03/swimming-with-spacemen/

Buoyancy:

http://hyperphysics.phy-astr.gsu.edu/hbase/pbuoy.html#:~:text=The%20buoyant%20force%20on%20a,then%20to%20determine%20its%20density

http://hyperphysics.phy-astr.gsu.edu/hbase/pbuoy.html#:~:text=The%20buoyant%20force%20on%20a,then%20to%20determine%20its%20density

http://physics.bu.edu/~duffy/sc527_notes01/buoyant.html

https://www.khanacademy.org/science/physics/fluids/buoyant-force-and-archimedes-principle/a/buoyant-force-and-archimedes-principle-article

https://adventure.howstuffworks.com/outdoor-activities/water-sports/life-jacket1.htm#:~:text=Buoyancy%20is%20the%20upward%20force,and%20it's%20measured%20by%20weight.&text=The%20trapped%20air%20weighs%20much,to%20remain%20buoyant%20and%20float.

https://www.ck12.org/physics/buoyancy/lesson/Buoyancy-MS-PS/

http://www.scienceclarified.com/everyday/Real-Life-Chemistry-Vol-3-Physics-Vol-1/Buoyancy-How-it-works.html

https://www.seaperch.org/article?article_id=313

Interactive: http://phet.colorado.edu/sims/density-and-buoyancy/buoyancy_en.html

How submarines work: https://science.howstuffworks.com/transport/engines-equipment/submarine.htm

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NAME: _____

VOLUME OF CANISTER: _____

WEIGHT OF EMPPTY CANISTER: _____

NEUTRAL BUOYANCY WORKSHEET

TRIAL NUMBER	WEIGHT IN GRAMS	FLOAT, SINK OR NEUTRAL	NUMBER OF CM BELOW WATER LEVEL