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# Air Swimmers

AIR-444

**Buoyancy:** The power to float or rise in a fluid. (Definition source: Dictionary.com)

Your Air Swimmer is a demonstration of buoyancy. Let's explore how buoyancy works!

Water is a fluid. We are used to the idea that things can float in water---maybe you are thinking of a boat, a block of wood, or a ball floating on top of the water. Things can also float below the surface of that water, such as a submarine. Air is also a fluid, and can allow some objects to float. We know that planes, birds, and helium balloons float in the air given the right conditions.

To understand buoyancy, you need to explore the concepts of density, volume, displacement, and equilibrium. You will also get the chance to show that you are as smart as two great scientists as you demonstrate Archimedes' Principal and Isaac Newton's Third Law!

## NGSS Correlations

Our Air Swimmers and these lesson ideas will support your students' understanding of these Next Generation Science Standards (NGSS):

**5-PS1-1** Develop a model to describe that matter is made of particles too small to be seen.
**5-PS2-1** Support an argument that the gravitational force exerted by Earth on objects is directed down.
**MS-PS2-5** Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.
**MS-PS3-5** Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

# Exploration Lab

**Rule: According to Archimedes, the buoyant force (the force pushing up in a fluid on an object) is equal to the weight of the displaced fluid.**

This means that an object will float if the force in the water pushing up is greater than or equal to the weight of the water that boat displaces as it sits in the water.

***Question: How would you figure out what that weight is? Boats can be pretty big things!***

**Open the lab with the statement and question above.**

This lab exploration can be done by a step-by-step process or by a full inquiry model. Student exploration will be more individually directed and knowledge gained should be better synthesized and absorbed if the inquiry model is used. Both versions are supplied here. This lesson is appropriate for middle grades or older.
Establishing the Relationship Between Volume and Mass as Related to Floating Level (step-by-step)

**Materials needed for each group:**

- Several sealable plastic containers of graduated sizes (film canister, small toiletry bottles of different sizes and shapes) Bottles should have watertight caps.
- Weights such as BBs (must be dense)
- 2-3 Sticks such as chopsticks
- Permanent Marker
- Metric scale
- A large graduated cylinder (metric measure) that the plastic containers will fit into submerged
- A small graduated cylinder
- Water to partially fill the basin and the cylinder
- One “mystery” container of a different size than the other containers used

**Rule: According to Archimedes, the buoyant force (the force pushing up in a fluid on an object) is equal to the weight of the displaced fluid.**

This means that an object will float if the force in the water pushing up is greater than or equal to the weight of the water that boat displaces as it sits in the water.

***Question: How would you figure out what that weight is? Boats can be pretty big things!***

**Use the Container Experiment Worksheet on page 5 to record your data.**

1. Establish the volume of your small plastic containers. Volume is the amount of 3-dimensional space occupied by the object. We are measuring the exterior volume, not the interior volume.
   - Make sure the cap is on the container. Mark the container with a number using the permanent marker.
   - Weigh each container and record its mass.
   - Fill the graduated cylinder with enough water to cover the containers when each is pushed below the surface.
   - Start with an easy to use measurement of water—such as an increment of 100 or 50.
   - Record the starting level of the water.
   - Push and hold the container so it is entirely just below the surface of the water. Use the chopsticks to hold it under (but try not to have the sticks in the water—you want to be measuring the container, not the sticks!)
   - Measure the volume of water in the graduated cylinder with the container submerged, record this number.
   - Subtract the starting water measurement from the submerged water measurement and record this number as the exterior volume of the container.
   - Measure the interior volume of one of your containers by pouring water into the container to fill it. Pour that water into a small graduated cylinder to measure the volume. Note the difference between that container's interior volume vs. its exterior volume. Why do you think there is a difference?

2. How many BBs are needed in your container to float it just below the water's surface?
   - Choose one of your small containers.
   - Make a guess about how many weights will be needed to float your container just below the surface of the water in graduated cylinder. Record your guess.
   - Place that number of weights in the container and try it out.
   - If your container does not float just below the surface, add or subtract weights until it does.
   - When you have established the correct number of weights that will keep your container just below the surface, take those weights out of the container and both count and mass them. Record this number for this container.
   - Repeat the floating with weights for each container, recording the number and mass of your weights.

3. Calculations: Complete your calculation table to establish the volume to weight ratios. Do you observe any correlation between this ratio calculation for your different containers?

4. Try to submerge your mystery container using the weight calculation to estimate the required weights. Were you successful?

5. Using the Definitions in Action, demonstrate the meaning of each of the terms using your container and water.

**Thought questions:**

- Is the interior volume the same as the exterior volume for the container you measured? Why or why not? Why do you think this experiment requires the exterior volume?
- Discuss the difference between your calculated average measure and the class average measure.
  Were there outliers (values less or more than expected) in any of your classmates' measures?
  Should any outliers be included to calculate a class value? Why or why not?
- Which should be more accurate---a value calculated from 3 trials, or from several times that number of trials? Why?
- If you had a container with an exterior volume of 4000 ml and a mass of 2000 g, what would the required weight be to float it just below the surface? Use the class average measure. Show your work.
- How big a basin might you need to float the container in question 3? How did you make that estimation?

**Optional:**
Explain how you demonstrated each of the terms on the Definitions in Action sheet using your container and water.

# Container Experiment Worksheet

Name/Group________________________________________________________________

| Container # | Exterior Volume Units ml (V) | Container Mass Units g ($M_1$) | Trial weights notes | Weights to Float Container | | Calculate $\frac{V}{(M_1 + M_2)}$ | Average Measure of $\frac{V}{(M_1 + M_2)}$ For your 3 containers |
|---|---|---|---|---|---|---|---|
| | | | | Number | Mass Units g ($M_2$) | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| "mystery" container | $V_m$ | $M_{1m}$ | | Calculate ($M_1 + M_2$) weights required | | | Use formula: Ave $\frac{V}{(M_1 + M_2)} = \frac{V_m}{X}$ (Isolate X for your total weight estimate and calculate $M_{2m}$ using the know $M_{1m}$ value) |
| Note the values here of your classmate's individual average measures. | | | | | | | Class Average Measure of $\frac{V}{(M_1 + M_2)}$ |

# Establishing the Relationship Between Volume and Mass as Related to Floating Level (Inquiry-style)

**Materials needed for each group:**

- Several sealable plastic containers of graduated sizes (film canister, small toiletry bottles of different sizes and shapes) Bottles should have watertight caps.
- Weights such as BBs (must be dense)
- Metric ruler
- 2-3 Sticks such as chopsticks
- Permanent Marker
- Metric scale
- A large graduated cylinder (metric measure) that the plastic containers will fit into submerged
- A small graduated cylinder
- Water to partially fill the basin and the cylinder
- Graph paper
- One "mystery" container of a different size than the other containers used

**Rule: According to Archimedes, the buoyant force (the force pushing up in a fluid on an object) is equal to the weight of the displaced fluid.**

This means that an object will float if the force in the water pushing up is greater than or equal to the weight of the water that boat displaces as it sits in the water.

***Question: How would you figure out what that weight is? Boats can be pretty big things!***

## Phase One

- Measure several containers to determine their exterior volume and mass. Total number of containers should be about 1 for each student. Use several different sizes. (i.e. film canisters, small food or cosmetic containers, all with water-tight caps)
- Materials: 1 container per student as above, graduated cylinder with water, metric scale, permanent marker for each group, instruction card for each group
- Volume- is the amount of 3-dimensional space occupied by the object. We are measuring the exterior volume, not the interior volume.

**Phase One Instructions:**

- Make sure the cap is on the container.
- Weigh the covered container on the scale and note the weight on the container (units "g" for grams)
- Fill the graduated cylinder with enough water to cover the containers when each is pushed below the surface.
- Record the starting level of the water.
- Push and hold the container so it is entirely just below the surface of the water. Use the chopsticks to hold it under (but trying not to have the sticks in the water—you want to be measuring the container, not the sticks!)
- Measure the volume of water in the graduated cylinder with the container submerged, record this number.
- Subtract the starting water measurement from the submerged water. This number as the exterior volume of the container. Mark it clearly on the bottom of the container. Units "ml" for milliliters.

**Teacher Questions to ask in the groups or as a class:**

- Will the volume number be the same if someone else were to measure it? Why/why not? What makes your procedure "standardized" for accuracy?
- Is the exterior volume the same as the interior volume? How would you determine that?
- We will be using displacement later in this experiment. It is defined as "The act of taking the place in space of one mass by another." If we were displacing water in a basin with the container you measured, would you need to know the interior volume or the exterior volume? Why?

## Phase Two

**Set up stations in the room for groups of 3-4 students. Include at each station:**

- 3 different containers from Phase One
- Weights such as BBs (must be dense)
- 2-3 Sticks such as chopsticks
- A basin that the plastic containers will fit into submerged
- Water to partially fill the basin (deep enough to float the largest container submerged)

Have available in the room or to be added later in the experiment:

- Metric scales
- Metric rulers
- Graduated cylinders
- 2-3 blank sentence strip papers for each group
- One “mystery” container of a different size than the other containers used

**Instruction Card at each station (plus copy of Definitions in Action Sheet)**

1. Try floating the containers in the basin. Make notes in your science notebook about your observations.
2. Add some of the BBs to one of the containers. How did this change your observations?
3. What do you expect to happen if you add more (or fewer) BBs to that container? Try it to see if you were correct. Note your observations.
4. Does the same number of BBs affect 2 different containers in the same way? Note your observations.
5. Does the mass of the weighted or unweighted container have any effect on what you observe? Note your measurements and observations.
6. Using the Definitions in Action Sheet and the materials at your station, demonstrate the definitions on the sheet

The teacher should circulate among the groups and ask questions if the group seems to be stuck. Discuss the Definitions in Action demonstrations for any that the students found challenging.

Share and discuss the investigation questions at the end of Phase Two. Is each question an investigable question with the time/materials/skills that the class has available? If not set that question aside. Is the question able to determine a set variable? If not rephrase the question or set it aside.

Have each group decide on which question their group will investigate. You may re-form groups based on individual desire to investigate a question. Establish reasonable sized groups as needed.

Discuss the concept of (or remind students about) “fair trial”. A fair trial uses a standardized procedure, several trials, and isolates the measurement of the one determined variable (i.e., time, weight, volume, etc). For instance “Does changing the mass affect submerging the container?”---requiring procedure to test with the same container different masses of weights. Weights are the variable being determined in this case.

Each investigation team should write out their procedure to investigate their question, and get the approval of the teacher on that procedure before beginning their experiment.

## Phase Three

Phase Three Directions

1) Write out your question and procedure for a fair test of that question in your science notebook. Plan to collect data on several trials to test your question.

Make notes about each of the following in your science notebooks:

2) What is the one variable that your experiment will measure?
3) Make sure to take notes on your observations and data collected.
4) Is there a mathematical correlation that your data shows?
5) There are forces that you can identify in your experiment.

Gravity—the force that attracts a body (your container) (or the water in the basin!) toward the center of the earth

Buoyancy—the buoyant force (that keeps the container floating) is equal to the weight of the displaced water in this experiment

## Synthesis of Knowledge

After completing the Phase Three Investigation, do a round-robin presentation/discussion of the findings of each group.

Collectively the teams probably investigated questions including:

- Affect of weight (container weight, BB mass needed to float)
- Affect of volume differences
- Relationships of volume/weight combinations

Teacher should direct this synthesis session to address each of the areas above, calling on groups and pointing out (or asking questions about) how one groups' data/discovery affects or could affect another's.

## Capstone Question:

- Archimedes' Principal states that "The buoyancy force is equal to the weight of the displaced fluid." End synthesis with how the groups identified that this principal was demonstrated in their investigations.

- Optional: Complete the "Container Experiment Worksheet" in groups, creating a classroom data sheet about the different types of containers used by the groups. Present one "mystery" container and discuss how students could determine how many BBs would be required to submerge it.

- With the Air Swimmer—if Air is a fluid (which it is) how does the Swimmer float? What forces do you think are affecting it? Are they the same or different from forces you identified in your experiments? How do the weights used on the Swimmer affect its movements? Could you make it sink or rise by making any changes?

# Definitions in Action

Demonstrate the meaning of the following words using the water basin and practice containers.

| |
|---|
| **Buoyancy:** The power to float or rise in a fluid. (Definition source: Dictionary.com) |
| **Displacement:** The act of taking the place in space of one mass by another. |
| **Equilibrium:** A state of rest or balance due to equal action of opposing forces. (Definition source: Dictionary.com) |
| **Archimedes' Principal:** An object wholly or partially immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object. (Text from Wikipedia.com) |
| **Newton's Third Law:** When a body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in directions to that of the first body. (Definition source: Wikipedia.com) |
| **Density:** the compactness or closeness of molecules defined as mass per unit volume. |

Sources and Extensions

A great submarine lab can be found at
http://teachers.oregon.k12.wi.us/sundstrom/Physical%20Science/Measurement/Buoyancy%20Submarine%20Lab.pdf

Physics Interactive Science Simulation for Density and Buoyancy can be found at
http://phet.colorado.edu/sims/density-and-buoyancy/buoyancy_en.html

# Take Your Lesson Further

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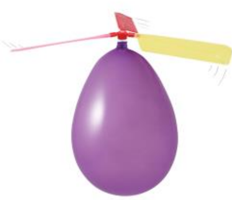
**http://blog.TeacherSource.com**

To extend your lesson, consider these Educational Innovations products:

**Solar Tube** (SLR-222)

Watch this amazing tube gently lift into the air. At 60 feet long with a 72 inch circumference, this is the largest Solar Tube available. Run to fill with cool air, tie off the end, and move it into the sun. As the bag heats, the 240 cubic feet of air expands, becomes less dense, and floats. A great demo of density, thermodynamics, solar energy and more. Hold onto the string!



**Balloon Helicopter** (AIR-610)

These balloon-powered helicopters are great for outdoor or indoor fun (if you have high ceilings). Simply snap the blades on the hub, place the balloon on the collar, inflate the balloon, and you're ready for lift off! When you release, air travels through the blades, causing them to spin. Lift is created and off it goes! We've gotten these to fly over 20 feet high.

**Paper Balloon Paradox** (AIR-160)

A balloon made out of paper? Yes! Start out by unfolding it, and then blow into the reinforced opening just a bit - until it's about half way inflated. Once you've done that, spend a few minutes bouncing it in your hand and watch science do the rest! You won't believe your eyes as this crunchy, colorful balloon slowly fills with air. The balloon's deceptively simple design conceals an intricate process that includes elastic waves, fluid motion, and the plasticity of the paper itself. The result? An inflated balloon with an uncovered hole at one end.

**Air Pressure Bundle** (AIR-900)

Six air pressure demo goodies will certainly prove that science never sucks! Start with a Tornado Tube or Fountain Connection for hours of water play (and learning). Learn about lift with a balloon-powered helicopter. Your Harbottle is the perfect tool to demonstrate atmospheric pressure. How does that balloon stay inflated without being tied shut? The Pressure Pullers and Atmospheric Mat are guaranteed to baffle anyone who doesn't (yet) know about the pushing force of the air around us.