Penny Boats

| **Subject:** Physics  **Related Subjects:** Marine Engineering, naval architecture | **Grade Level(s):** 3-5  **Length of Lesson:** 1 hr | **Type:** Project  **Keywords:** Buoyancy, density, weight distribution, displacement |
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# Lesson Overview

*Students will understand the concepts of buoyancy and water displacement to design a boat that must support a given amount of weight to pass the challenge. Also, students are going to explore the physics properties that allow boats to float in water.*

# Lesson Focus

What allows objects to float in water? What do marine engineers prioritize when building boats that hold weight? What is the optimal design for a boat in order for it to float?

| Lesson Objective(s) | By the end of this lesson, students will…   1. Build a successful boat that can hold a number of pennies without sinking. 2. Understand key terms like buoyancy, density, surface area, displacement. 3. Understand why some objects can float while others sink given enough weight. |
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# Lesson Timing

| 5 minutes | Intro |
| --- | --- |
| 25 minutes | Design and build boats |
| 10 minutes | Test boats |
| 5 minutes | Role models (you can too!) |
| 15 minutes | Wrap up (Explanation and Key Vocab) |

| Materials | * 2 square ft of aluminum foil (per group) * Masking tape (~1 ft per group) * Scissors (1 per group) * Large container of water * Pennies 30 pennies a group * Paper towel * Scratch paper and pencils for students to draw out designs * White Board (to keep score) and optional prizes |
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| Teacher Prep | 1. Fill up large container(s) with water for boat testing 2. Get paper towels in case of spills -- make sure technology separated from the water |
| Related Resources | * Khan Academy explains buoyancy well: [What is buoyant force? (article) | Fluids](https://www.khanacademy.org/science/physics/fluids/buoyant-force-and-archimedes-principle/a/buoyant-force-and-archimedes-principle-article) * Explains buoyancy through means of displacement and introduces the concept of density: [How Do Ships Float? | Things Explained: Buoyancy](https://youtu.be/06TFRgPlmxU) |

# Lesson Plan

## Introduction

1. Begin by making a connection to the students. Ask them about swimming:
   1. How many of you like swimming?
   2. Do you ever just float in the water? When you’re doing that, do you float with your arms out or your arms in?
   3. Have you ever thought about how the shape or position of your body impacts how well you can float? This is something that naval architects and marine engineers have to think about.
2. Ask students to guess what marine engineers and naval architects do.
   1. Marine engineers and naval architects together design giant metal ships that stay afloat and don’t tip over during thousand-mile journeys.
3. Watch video: [Why do big ships float? [Buoyancy and flotation explained] - YouTube](https://www.youtube.com/watch?v=Z3vgsp4vKQs)

## Optional: Warm-up demo

1. *Begin with a simple demonstration. Show the students two sheets of aluminum foil that are exactly the same size. Ask them if they think the aluminum foil will sink or float if you place it in the water. Give students an opportunity to explain their guesses.*
2. *Place one piece of aluminum foil on the top of the water. Ask them if they can think of any way to change the second sheet of aluminum foil so that it sinks rather than floats.*
3. *Crumple the second piece of aluminum foil into a ball and place it in the water. Ask students why they think the ball of foil sank when the sheet of paper floats.*
4. *Show a penny/marble to the students and ask them if they think it will float or sink and why. Put the penny/marble in the water to demonstrate that it sinks.*
5. *Discuss Steps 3 -4 (What does the aluminum ball have in common with the penny/marble? How are they different from the sheet of aluminum?) and explain the concept of water displacement and discuss.*

## Procedure

1. Remind students that of the Engineering Design Process and that we will be following this methodology:

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1. **Ask:** Today, you’re all going to be on a team of marine engineers and naval architects. Your task is to design and build a boat prototype out of tinfoil to hold the most shipping containers. Our prototypes will be made of tinfoil and the shipping containers will be represented by pennies (or paperclips)
2. **Research:** The intro video will serve as our research phase, recap the concepts highlighted in the video
3. **Imagine/Plan:** Give students 5 minutes to draw out some designs for their boats.
4. **Create:** Give students 15 minutes to create their boats. Encourage them to take their time shaping them and folding them. If they have extra time, have them sketch their final design again (the boat will get damaged during testing so want to remember their final design & then predict how their boat will sink)
5. **Test the boat:**
   1. Have each student place their boat in the container of water and wait 3 seconds to make sure it doesn’t sink initially.
   2. After waiting, start placing pennies in the boat one by one until the boat sinks.
   3. Write down the scores for each students boat
   4. When removing the boat, remove all the weights yourself, dry them off, then remove the boat and place it on a paper towel. Leave it with the group before going to the next one.
6. Have the top 3-5 scorers show and speak about their designs
7. **Improve:** Have students share why their boat failed and how they would improve their design if they were to build a new one -- list out these improvements to the whole class, also list out aspects of the most successful boats. Have the top 5 winners post drawings of their designs up front.
   1. As a class try to create the most successful boat by combining the winning designs and incorporating the suggested improvements -- have 1-2 students volunteer to do the actual building, but involve everyone in the process by taking maky suggestions

## Wrap-up

1. Let’s think about the activity we just completed! If your boat couldn’t hold all of the weight, why do you think that is?
   1. Examples: Used too much material (too heavy), weight wasn’t distributed well.
   2. One influence may have been the **weight distribution** of the boat. The weight distribution is how the weight is spread over the area of the boat. If one side of the boat was heavier than the other side, then that could’ve caused it to sink faster. Additionally, if you decided to place all of the 10g weights in one area, that could’ve made the weight distribution unbalanced as well.
   3. What would you do differently if you could build another boat?
2. Do any of you know what keeps boats afloat?
   1. Have you heard of the term **buoyancy**?
   2. Buoyancy is the force that keeps objects afloat. According to something called **Archimedes’ Principle**, the buoyancy force is related to the density and volume of the water displaced.
   3. Can anyone define **density** for me? (The mass of the material divided by the volume of the material.) Answers like: the thickness of an object will do but still mention D=m/v
   4. So, let’s break down Archimedes’ Principle. What are the two things that impact whether an object can stay afloat? (Have students answer and write on a board.)
      1. Low density of object
      2. High volume of water displaced

## Wrap-up

**Recap the broader theme “Physics” and how this lesson connects**

You’ve all done a great job today asking questions about the branch of science we call **physics**. Does anybody know what physics is?

* 1. Physics is the branch of science concerned with nature and the properties of matter and energy (mechanics, heat, light, sound, electricity, magnetism, structure of atoms).
  2. Many different types of engineering depend on physics! Students interested in these subjects could study physics alone, or related topics like math and specific types of engineering like astronautical or aerospace.
  3. If you’re interested in physics, you could do anything with it, from being a physics professor to being an astronaut to building skyscrapers.
  4. Opportunity to present a STEM role model

# Lesson Background for Teachers

## Explanation

* Marine engineers can somehow manage to design giant metal ships that stay afloat and do not tip over during thousand-mile journeys. They do this by keeping the overall density of the boat low relative to the water, and by evenly arranging the weight on the ship.
* Archimedes’ principle summarizes the important factors that keep a boat floating, namely the density of the boat and the volume of water that it displaces, which together create a buoyancy force pushing upwards on the boat.
* Students will have to consider this principle to create a successful design.

## Key Concepts and Vocabulary

* **Archimedes’ Principle**: Buoyancy force is related to the density and volume of the water displaced.
* **Buoyancy**: Force that keeps objects afloat in water.
* **Density**: The mass of the material divided by the volume of the material.
* **Physics**: Branch of science concerned with nature and properties of matter and energy (mechanics, heat, light, sound, electricity, magnetism, structure of atoms).
* **Weight distribution**: How weight is spread over the surface area of an object.