Eureka! Or Buoyancy and Archimedes' Principle

Learning Objectives

After this activity, you should be able to:

- Measure masses and volumes of known and unknown substances.
- Calculate density using given measurements.
- Predict physical behaviors by employing a numerical model.
- Apply predictions to an engineering design challenge.

Introduction

Most of us know that steel feels heavier than plastic, but why? How do we know what an object is made of? How do large ships made of metal float on water? How are these two questions related? And why do engineers care about the properties of materials? Let's start with the first question.

A long time ago in ancient Greece, a man named Archimedes was trying to solve a problem. He wanted to know how to tell if a crown was made of real gold. You might know that different materials have different densities (mass per volume). Archimedes reasoned that if he could figure out the density of the crown, he could determine whether it was gold or not. Density = mass / volume, so if you had a regular shape like a cube, it would be easy to measure and calculate the volume. But how could he calculate the volume of the crown? He decided to have a nice bath to think about this. When he got into the bath, the water level rose, and he realized that he could measure the volume of water displaced by the crown, and so discover the volume of the crown, then calculate the density of the crown. Eureka!

Do you know why large ships made of steel can float on water? It is related to what Archimedes noticed when he got in the bath. The displacement of water is what keeps ships afloat and we call it the buoyancy effect. In order for a ship to float on water, it needs to displace its own weight in water. This might be hard to understand right now, but we will do some experiments to prove that this is true.

So, why is this important to engineers? Engineers apply mathematical equations to determine the properties of materials. By predicting how a material will behave in a certain situation, under certain constraints, engineers can determine which material to choose for a given design project. For example, in order to design a boat that will float, engineers must understand buoyancy to determine how objects behave in a fluid (liquid or gas). Differences in densities determine whether an object sinks or floats in a liquid, or how much liquid the object displaces when floating. Engineers must consider material densities and the resulting buoyant forces when designing boats, submarines, underwater pipelines and cables, and aircraft.

Vocabulary

buoyant force: The force exerted by water due to displacement of the water. Because water has a density of 1 g/cm3, for each cubic centimeter (or milliliter) displaced, 1 g of water has been displaced. This means that by measuring the change in volume in milliliters, we have found the mass of the object in grams.

density: The ratio of mass per volume of a material. Mass is an intensive property (as opposed to extensive), which means that it is a characteristic of the material and independent of the size of the object. Density of water is 1 g/cm3. density = mass / volume.

displacement: The volume of water that is moved away or replaced by an object. This is viewed as a change in apparent volume and we measure it in milliliters (ml).

mass: The property of an object that gives it weight. We will be using metric unit of gram (g) as the unit of mass and equating it to the weight measured by a scale under classroom conditions.

volume: The space an object takes up. We will use both the metric unit cubic centimeter (cm3) for solids and milliliters (mL) for liquids. It is convenient that 1 cm3 = 1 ml.

volume equations: Volume of a block = l * w * h or length * width * height; volume of a sphere = 4/3 * π * r3, where r is the radius; volume of a cylinder = h * π * r2, where h is the height.

weight: How heavy an object is. What a scale reads when it is weighed in a given setting. Weight is a measure of both mass and gravitational pull, so an object's weight would be different on the moon than on Earth.