

## *Density Determination and Archimedes' Ah-Ha Moment*



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# TOPIC<sup>tutor</sup> 1 (Density & Archimedes)

## GRADE LEVEL

This lesson is appropriate for grades 7-12. Parts of the lesson may be appropriate for grades 5-6.

## SUBJECTS

Science as inquiry, mathematical measurement, and data analysis.

## PURPOSES

1. To explain how to perform density determination.
2. To explain Archimedes' Principle and the measurement of mass and volume of irregularly shaped samples.
3. To expose students to common measuring instruments used in the lab.

## TIME NEEDED

One class period.

## ACTIVITY OVERVIEW (PLUS HELPFUL ADVICE)

This lesson is designed to easily and quickly integrate into existing curriculum. It comes complete with a high-interest reading passage, standards correlations, vocabulary lists, plus extensions and assessment tools with answer keys. This TOPIC<sup>tutor</sup> is appropriate for remedial, review, reinforcement, or extension purposes.

## CONNECTIONS TO NATIONAL SCIENCE AND MATH EDUCATION STANDARDS

### **SCIENCE CONTENT STANDARD A – SCIENCE AS INQUIRY**

- Develop descriptions, explanations, predictions, and models using evidence and explanations. (grades 5-8)
- Formulate scientific explanations and models using logic and evidence. (grades 9-12)
- Using mathematics in scientific inquiry. (grades 5-8 and 9-12)

### **SCIENCE CONTENT STANDARD G – HISTORY AND NATURE OF SCIENCE**

- Science as a human endeavor. (grades 5-8 and 9-12)
- Nature of science – scientists formulate and test their explanations using observation, experiments, and theoretical and mathematical models. (grades 5-8)
- History of science (grades 5-8) and historical perspectives. (grades 9-12)

### **MATH CONTENT STRAND 2 – DATA ANALYSIS, PROBABILITY AND DISCRETE MATHEMATICS**

- Concept 1 – Understand and apply data collection, organization and representation to analyze and sort data. (grades 5-12)

### **MATH CONTENT STRAND 4 – GEOMETRY AND MEASUREMENT**

- Concept 4 – Understand and apply appropriate units of measure, measurement techniques, and formulas to determine measurements. (grades 5-12)

# TOPIC<sup>tutor</sup> 1 (Density & Archimedes)

## KEY VOCABULARY

<i>ARCHIMEDES' PRINCIPLE</i>	An object that is immersed in a liquid will be buoyed up by a force equal to the mass of the displaced fluid.
<i>BUOY</i>	To float or to rise in a liquid or in air.
<i>DENSITY</i>	A characteristic property of matter that is equal to mass per unit volume (mass/volume.)
<i>DISPLACEMENT</i>	When one object/substance takes the place of another object/substance.
<i>GRAM</i>	A fundamental unit of mass used in the metric system (equal to the weight of one cubic centimeter of distilled water at 4°C.)
<i>IMMERSE</i>	To place into and cover completely with a liquid.
<i>LITER</i>	A fundamental unit of capacity/volume used in the metric system (equal to the volume of one kilogram of distilled water at 4°C.)
<i>MASS</i>	A measurement of the amount of matter (or more precisely, the sample's weight divided by acceleration due to gravity.)
<i>MILLIGRAM</i>	A fundamental unit of mass used in the metric system (equal to one thousandth of a gram.)
<i>MILLILITER</i>	A fundamental unit of capacity/volume used in the metric system (equal to one thousandth of a liter.)
<i>RELATIVE DENSITY</i>	The mass per unit of volume of an object compared to the mass per unit of volume of a liquid. If the object is less dense than the liquid, the object will float or rise. If it is more dense than the liquid, it will drop or sink.
<i>SPECIFIC GRAVITY</i>	The ratio of the density of an object/substance to the density of water.
<i>VOLUME</i>	The amount of space occupied by three dimensions (that is, cubic contents.)

## EXTENSION – CLASSROOM ACTIVITY TO ILLUSTRATE ARCHIMEDES' PRINCIPLE

### What You Need:

- Two steel cylinders, each about 1.5cm in diameter and 3.0cm long
- Cup, water, and weighing boat
- Balance with weigh-below hook (Adam TBB 2610S triple beam or Adam ACB<sup>plus</sup> 3000 electronic balance)

### Procedure:

1. Fill a plastic cup completely to the rim with water.
2. Place the filled cup onto the balance. Record the total mass of the water and the cup.
3. Suspend both cylinders from the weigh-below hook, and determine their total mass using a balance. (We got 138g.)
4. Place the weighing boat under the cup and lower the cylinders into the cup until they are completely submerged. Displaced water from the graduated cylinder will spill over into the weighing boat. Again measure the "apparent mass" of the cylinders while they are submerged. (We got 100g.)
5. Carefully remove the cylinders from the cup. Measure the total mass of the cup and the remaining water in the cup. (We got 38g.)
6. Determine the mass of the water displaced from the cup. (138g -100g = 38g) Eureka! Archimedes' Principle works!  
38g = 38mL H<sub>2</sub>O

# TOPIC<sup>tutor</sup> 1 (Density & Archimedes)

## ANSWER KEY FOR STUDENT ASSESSMENT SHEET

1. Mass = 20.7g
2. Aluminum Density =  $2.7\text{g/cm}^3$
3. Volume = 78.5mL
4. Copper Density =  $8.92\text{g/cm}^3$
5. Mass = 17.4g

## ADDITIONAL RESOURCES

Visit [www.adamequipment.com/education](http://www.adamequipment.com/education) regularly for new classroom resources.

## ABOUT ADAM EQUIPMENT

Adam Equipment's Americas Office is based in Danbury, Connecticut with its World Headquarters in Milton Keynes, England. The company's balances have been trusted by scientists worldwide for more than thirty years. Contact Adam Equipment by phone at either 888-355-3868 or 203-790-4774, by mail at 26 Commerce Drive, Danbury, CT 06810, or online at [www.adamequipment.com/education](http://www.adamequipment.com/education).

## ADAM EQUIPMENT BALANCES FOR DENSITY DETERMINATION

**MECHANICAL** - TBB Triple Beam Balance - The first triple beam developed specifically for educators (2610g capacity, 0.1g readability, available in two models: with or without tare)

Model recommended for this TOPIC<sup>tutor</sup> and its extension: TBB 2610S



The TBB offers the functions and durability that classrooms need plus an array of useful education features. Exclusive features include convenient weigh-below measuring with integrated weigh-below hook and stable, built-in tripod legs that lift the TBB up for better access and viewing. Other smart school features: integral security bracket to prevent theft; wider body for more stability; strong metal housing, easy-to-clean stainless steel pan; built-in mass holder; protractor, ruler, and conversion chart right on the balance's housing. The TBB delivers reliable center-point readings with well-defined notches, three graduated-tier beams, magnetic dampening, positive poise positioning, and a counterbalance knob for speedy zeroing. Five-year Adam Assurance Warranty.

**ELECTRONIC** - ACB<sup>plus</sup> Portable Balance - A rugged balance packed with smart classroom features (Fifteen weighing units & four weighing modes, available in seven models from 150g x 0.001g to 3000g x 0.1g)

Model recommended for this TOPIC<sup>tutor</sup> and its extension: ACB<sup>plus</sup> 3000



The ACB<sup>plus</sup> is a versatile precision balance for a wide range of students that delivers maximum performance with a weigh-below hook for specific gravity, a capacity tracker and audible overload protection to monitor overloads, plus removable draft shield, level bubble, and adjustable feet for better readings. The reliable ACB<sup>plus</sup> features the latest in weighing technology and is easy enough for novice students. Comes complete with RS232 interface, integral security bracket, both a rechargeable battery and an AC adaptor, auto-calibration from the keypad, low-battery indicator, and auto power-off. Two-year Adam Assurance Warranty.

For complete product details, visit [www.adamequipment.com/education](http://www.adamequipment.com/education).

# TOPIC<sup>tutor</sup> 1 (Density & Archimedes)

## GETTING INVOLVED IN ADAM EQUIPMENT'S TOPIC<sup>tutor</sup> and EXPERIMENT PROJECTS

### Feedback On This TOPIC<sup>tutor</sup>

If you have feedback on this TOPIC<sup>tutor</sup> that would be valuable to other teachers, we encourage you to share your thoughts. Please submit your comments to Adam's education division by email at [education@adamequipment.com](mailto:education@adamequipment.com).

### Submitting Your Own TOPIC<sup>tutor</sup> or Experiment

If you have an idea for a useful educational resource that you would like to share with other teachers, Adam Equipment is interested in hearing from you. Initial submissions need to include only a simple description of the activity with the activity's purpose, subject, and grade level.

Please contact Adam's education division by email at [education@adamequipment.com](mailto:education@adamequipment.com) to determine if your particular activity will fit into our experiment library. Adam Equipment will respond promptly to all inquiries.

# TOPIC<sup>tutor</sup> 1

## Density Determination and Archimedes' Ah-Ha Moment

The development of scientific principles may seem like a dry subject but over 2000 years ago Archimedes demonstrated how scientific discovery can be entertaining, if not even a bit racy, by today's standards. As you know, all matter occupies space and has mass. One characteristic property of matter shows the relationship between the mass of a pure sample and the volume of the sample. Density expresses the mass per unit volume of the sample.

Measurement of density is one of the least complex of all laboratory procedures. First, the mass of a sample is measured using a balance and then the sample's volume is determined by any one of several available methods. Once these two measurements are obtained, the sample's density can be calculated by:

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (mL or cm}^3\text{)}}$$

Describing a piece of lead as "heavy" refers to the density of the lead. The density of water is 1g/mL or 1g/cm<sup>3</sup>. Compared to water, lead is approximately eleven times denser and a sample of lead will sink in water. Substances with densities less than 1g/ml will float in water. Solids tend to be denser than water and thus will sink in water.

Back in the 3rd Century B.C., it was not known how to calculate the density of most objects because no one knew how to determine the volume of a sample if it wasn't in the shape of a sphere or a cube. Archimedes, a noted Greek mathematician and natural philosopher, figured out how to determine an irregular object's volume when commissioned by a king to resolve a problem he had with his crown. If you think Archimedes worked this out in an early day lab, then you're all wet!

The story begins when King Hiero of Syracuse (on the island of modern day Sicily) began to wonder if his crown was really made from pure gold. At the same time, Hiero started to realize that his goldsmith was living a lifestyle beyond his means. The goldsmith was rumored to be preparing the crowns with a cheaper alloy, using a silver-gold mixture, instead of pure gold. No one at this point in history knew how to prove or disprove the speculation that the goldsmith was stealing from the king.

The king asked Archimedes to determine if one of his crowns was pure gold without destroying the crown in the process. Needless to say, this was not a trivial problem! Archimedes knew that silver was less dense than gold, but he did not know of a way to determine the relative density (mass/volume) of an irregularly shaped crown. The mass could be determined using a balance or scale, but the only method known to determine volume, using the geometry of the day, was to beat the crown into a solid sphere or cube, something Hiero would not allow.

A short time later, while in the public baths, Archimedes observed that the level of water rose in the tub when he entered the bath. Ah-ha, this was the solution to his problem! The crown should not only weigh the right amount, it should displace the same volume of water as an equal weight of pure gold. Supposedly, Archimedes leaped up and ran naked through the streets screaming "Eureka, Eureka!" (I've got it!) Later, he demonstrated to Hiero and his court how the amount of water overflowing a tub could be used to measure a volume. His calculations indicated the goldsmith was, indeed, an embezzler.

Archimedes' observation has been formalized into Archimedes' Principle: "An object partially or wholly immersed in a liquid is buoyed up by a force equal to the weight of the liquid displaced by the object." People often say they do some of their best thinking in the tub and if Archimedes were here today, he would surely agree.



### **ARCHIMEDES OF SYRACUSE**

*A Greek mathematician and engineer who lived from circa 287 to 212 BC. He is often considered to be the greatest mathematician of ancient times and he excelled especially in computing areas and volumes.*

# TOPIC<sup>tutor</sup> 1

## Density Determination and Archimedes' Ah-Ha Moment

### ASSIGNMENT

Using Archimedes' Principle and the metal densities shown here, answer the following problems. Show your work.

<i>Metal</i>	<i>Density (g/cm<sup>3</sup>)</i>
Aluminum	2.699
Copper	8.92
Gold	19.32
Iron	7.874
Lead	11.43
Nickel	8.908
Silver	10.49
Tin	7.265
Zinc	7.14

$$\text{Density} = \frac{\text{Mass (grams)}}{\text{Volume ( mL or cm}^3\text{)}}$$

**STEP-BY-STEP:** Read each problem to identify two of the equation's values and solve for the third value.

1. A zinc bar has a volume of 2.90cm<sup>3</sup>. What is the mass of the bar?
2. A metal block, 2.0cm x 2.5cm x 3.0cm, has a mass of 40.5g. What is the density of the sample? Can you identify the sample using the above chart?
3. A lead fishing weight of 39.7g is submerged in a graduated cylinder of water containing 75.0mL of water. The water level will increase to what volume in the cylinder?
4. Ten coins with a total mass of 26.76g will displace 3.00mL of water in a graduated cylinder. What is the density and the identity of the coins?
5. A nickel cube has a side length of 1.25cm. What is the mass of the cube?

NAME: \_\_\_\_\_

CLASS: \_\_\_\_\_

DATE: \_\_\_\_\_