

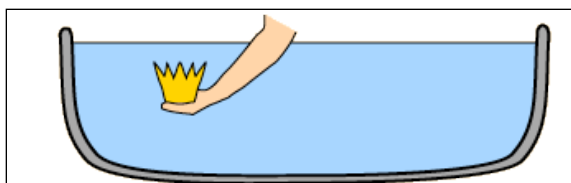
## ARCHIMEDES' PRINCIPLE



**Archimedes running naked through the streets of Syracuse, all in the name of physics.**

### INTRODUCTION

In a story you probably heard first in a grade school science class, Archimedes ran naked through the streets of Syracuse (in ancient Greece, not New York), shouting “Eureka!” (“I have found it!”, not the Sci-Fi channel series). The reason for all the excitement? Fluid displacement. What Archimedes realized was that when you submerge an object in water, the water has to get out of the way. How much water has to get out of the way? Exactly the volume of the submerged object. In the cartoon shown, Archimedes is clutching what appears to be a golden crown. This is important, because what he also realized was that measuring volume by fluid displacement made it easy to calculate the density of the object. According to the legend, he was able to show that the crown of the king was not pure gold, by finding its density and comparing it with known gold. While we don't have any valuable gold crowns lying around, we do have many different samples of different metals that we can test in exactly the same way as Archimedes did over 2000 years ago.



$$\text{Mass of object} - \text{Apparent mass when submerged} = \text{Density of water} \times \text{Volume of object}$$

$$440 \text{ grams} - 409 \text{ grams} = 1 \text{ gram/cm}^3 \times \text{volume}$$

$$\text{So the volume must be } 31 \text{ cm}^3!$$

$$\frac{440 \text{ grams}}{31 \text{ cm}^3} = 14.2 \text{ grams/cm}^3$$

Wait a minute! The density of solid gold is 19.3 gm/cm<sup>3</sup>!!

**Use this method to calculate the density, but keep all extremities out of the beaker of water.**

### ACTIVITY 1: DENSITY TWO WAYS

- Choose two different sample cubes from the selection provided.
- Measure and record the mass of each cube in air.
- One at a time, submerge the cube. Measure and record the apparent mass of the submerged cube.
- When under water, the cube has the same mass as in air, but it seems to weigh less because of the buoyant force of the water supporting it. The difference between the actual and apparent masses is buoyant force due to the displaced water. The volume of water displaced is equal to the volume of the submerged object.
- Measure the volume of each cube by directly measuring the volume of water displaced. Fill the overflow cup precisely to the point where it is ready to overflow. Place the graduated cylinder below the spout to catch the displaced water, then lower the cube into the cup until it is submerged. When the overflow has run out into the cylinder, measure the volume of the displacement directly from the cylinder. Repeat for the second cube.

CUBE	MASS OF CUBE m <sub>1</sub> (g)	APPARENT MASS m <sub>2</sub> (g)	MASS OF DISPLACED WATER m <sub>w</sub> = m <sub>1</sub> - m <sub>2</sub> (g)	VOLUME OF DISPLACED WATER V = (m <sub>w</sub> )/(1g/cm <sup>3</sup> )	DENSITY OF CUBE ρ = m <sub>1</sub> /V (g/cm <sup>3</sup> )
A	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
B	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____

### QUESTIONS

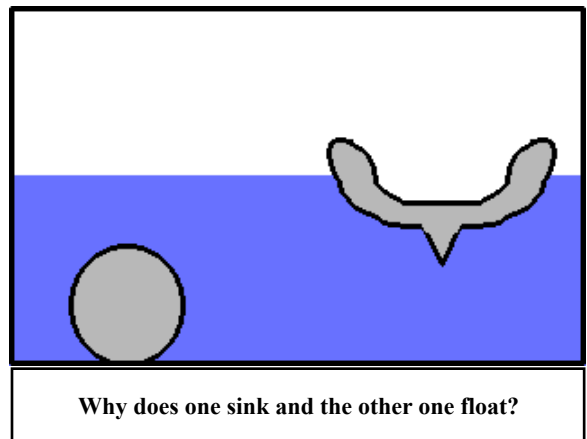
1. Calculate the density of each cube.
2. Do the cubes have the same volume? Do they have the same density?
3. Check the density table in your text. Identify what each cube is made of. Is one method more accurate for finding density? If so, why do you think that is?
4. Sketch the cube and illustrate the forces acting on it. What is the direction of the buoyant force?
5. What is the buoyant force on each cube? Does the water provide the same amount of buoyant force on each? Why?
6. Does the buoyant force change if you submerge the cube in deeper water?
7. If you had a cube of styrofoam (less dense than water), how could you use this method to determine its density?

**ACTIVITY 2: SINK OR SWIM**

- Two squares of aluminum foil have the same size and mass. Crumple one square into a small ball and place it in the water. You will need to compress all of the air out of the crumpled foil ball!
- Shape the second square of foil into a cup or bowl shape, and place it in the water.

**QUESTIONS**

8. If the squares of foil have the same size, same density, and same mass, how can one sink and the other one float? Which piece of foil displaces more water?
9. Compare the buoyant force on the crumpled square with the buoyant force on the aluminum bowl. Same buoyant force on each? Why or why not?
10. If you had a lump of clay that weighed 50g, would it sink or float? Why?
11. If you reshaped the lump into a bowl, could you make it float? Why? What is the minimum volume that your bowl must have in order to float?



**Sand barges on Vietnam's Mekong River. These are loaded to just about the limit: one more grain of sand, and they are going under!**

**ACTIVITY 3: BEAN BOAT**

- Measure and record the mass of the empty boat.
- Figure out how many aluminum "beans" your boat can safely transport without sinking. Add beans to your empty boat until it just barely floats. (Don't count the *number* of beans, just *weigh* the total.)
- Measure and record the mass of the fully loaded, bean-filled boat.

**QUESTIONS**

12. What is the buoyant force on the empty boat? The full boat? Same buoyant force on each? Why or why not?
13. How is the mass of the almost submerged boat, related to the volume of the boat? What is the volume of your boat?
14. If you had lead pellets instead of aluminum, would you be able to transport as many? What would the mass of the lead-filled boat be, compared to the aluminum-filled boat? How do you know?
15. A famous physics puzzle asks the question: Will a battleship float in a bathtub? Aside from the obvious (that a real battleship doesn't fit in a real bathtub), can an object float in a vessel only slightly larger than it is? Explain.