

Our last two emails have discussed many of the concepts and principles involved with density. This week, we have a related topic:

The Story of Archimedes

In the history of human thinking, the notion of **density** is new. This idea was not available to the earliest scientists. *Archimedes* couldn't look up the density of gold in a table, so he had to reason through the problem posed to him:



Was the king's crown pure gold?

Here is his traditional story:

Hiero, king of Syracuse in the third century B.C., gave a jeweler a bar of gold and ordered the jeweler to make it into a crown. When the jeweler delivered the crown to the king, the king measured the mass of the crown and found that the crown had the same mass as the gold he had given the jeweler. Even so, Hiero was suspicious. He believed that the jeweler had cheated him and substituted some less precious metal for the gold. Hiero asked Archimedes, a natural philosopher, to find a way to demonstrate that the crown was not pure gold.

According to legend, Archimedes struggled with the problem for a very long time. Then, one day, as he stepped into a bathtub filled with water, he saw that the water overflowed. He "noticed that the amount of water that overflowed the tub was proportional to the amount of his body that was submerged."¹ He had found the answer and ran from the bathhouse crying, "Eureka!" ("I have found it!")

Remembering that Archimedes knew nothing of density, let us see if we can figure out how water splashing out of a bath tub lead Archimedes to a solution of his problem: testing whether or not the jeweler had cheated the king.

Archimedes' Reasoning

Archimedes reasoned that (1) if the gold bar and the crown had the same mass and (2) if both had the same volume, then the crown was pure gold. Archimedes reasoned that the volume of water displaced by the crown should be the same as the volume of water displaced by the bar of gold. However, if the gold bar and the crown were the same mass but had different volumes, then he reasoned the crown was not pure gold, and the jeweler was a fraud.

What Archimedes Measured

- Mass of the gold that Hiero had given the jeweler 1000 gm (Greek mass units)
- Volume of water the gold displaced 50 gvu (Greek volume units)
- Mass of the crown 1000 gm
- Volume of the water the crown displaced 100 gvu

	Mass	Volume of Displaced Water
Gold Block	1000 gm	50 gvu
Jeweler's Crown	1000 gm	100 gvu

What Archimedes Assumed

The gold crown should displace the same volume of water as the gold Hiero had given the jeweler.

What Archimedes Found

Archimedes found that the jeweler's crown displaced more water than the gold block.

Archimedes' Argument (Explanation)

Archimedes reasoned that a gold crown should displace the same volume of water as the as the gold Hiero had given the jeweler. However, if it was not pure gold, but a silver alloy as the king suspected, that would increase the **volume** of the crown and displace more water. He observed that the jeweler's crown displaced twice the volume of water displaced by the gold and concluded that the jeweler's crown was not made from gold.

Thus, Archimedes showed that water displacement was a good method for measuring the volume of irregular objects (as Archimedes certainly was!). An object immersed in water will displace a volume of water equal to the volume of that object.

On to Floating and Sinking

We have only touched on a part of how Archimedes thinking was influenced by his experiences in the bath. Our next e-mail will go on to the Archimedes principle and floating and sinking.

Meanwhile, a question to ponder:

Think about the push of your bottom on a chair and on the bottom of the bathtub when a large part of your body is immersed in the water. How do the pushes compare?

¹ <http://www.shu.edu/projects/reals/history/archimed.html>