

Archimedes, the Greek mathematician, lived in Syracuse in the third century B.C. He was known for contributions such as the invention of the lever and the "Archimedes screw" (which is still used in Egypt to raise the waters of the Nile for irrigation); and the law hydrostatics, sometimes called Archimedes Principle. It was he who ran naked from the public baths through the streets of Syracuse shouting "Eureka, eureka!" "I found it".

What had Archimedes found! What so excited him that he forgot to put on his clothes before dashing home? To answer this question we need to learn what Archimedes had on his mind as he stepped into the baths that day. Hiero, the king of Syracuse and a close friend and perhaps even a relative of Archimedes, had commissioned a goldsmith to make a crown for him from pure gold. Upon receiving the finished crown, the king had doubts about whether the goldsmith had put all the gold into it. Couldn't the goldsmith have substituted a less valuable metal, silver or copper, for some of the gold and kept the gold that was not used!

It was known how to mix gold with silver and copper. These mixtures, or alloys, retain the rich color of gold even when significant amounts of the other metals are incorporated. Pure gold is called 24-carat gold. The alloy 14-carat gold is 58% gold and 48% other metals; it is commonly used for jewelry and looks almost exactly like pure gold.

King Hiero called in his friend Archimedes and presented the famous mathematician with the job of finding out whether the crown was indeed pure gold and contained all of the precious metal the king had given to the goldsmith without of course destroying the crown. Chemical analysis was not nearly so far advanced in the third century B.C. as was mathematics, and Archimedes was, after all, a very clever mathematician and engineer.

Archimedes had previously worked out mathematical formulas for the volumes of regular solids such as spheres and cylinders. He realized that if he could determine the volume of Hiero's crown, he would be able to tell whether the crown was made of pure gold or of a mixture of gold with other metals. When he saw water run over the top of the tub as he stepped into the water, he realized that the volume of the overflow water was exactly equal to the bulk of the part of his body that he had placed in the water. Now he saw a way to calculate the volume of any irregular solid object, whether it was his foot or a crown. So if he put the crown into a container filled with water, he could measure the volume of the water that overflowed. This would be equal to the volume of the crown.

Suppose Hiero had given the goldsmith a cube of pure gold that weighed exactly 5 pounds. The edges of such a cube would measure 4.9 cm (cm = centimeter; one centimeter = 0.394 inch) and the volume of the cube would be 118 cubic cm. If the goldsmith made the crown with all of this gold and no other metal, the crown would weigh 5 pounds, and

its volume would be the same as that of the original cube, 118 cm³, although in a different shape. If the goldsmith made the crown with only half of the gold and substituted an equal weight of silver, for example, for the other 2.5 pounds, the alloy crown would weigh 5 pounds, but its volume would be different.

If one could measure the volume of the crown, it would be found to be more than 118 cm³ because silver is only about half as dense as gold. Density is a measure of the weight per unit volume of a substance. Gold has a density greater than that of any other common metal; its density is 19.3 grams per cm³; the density of silver is 10.5 grams per cm³, and that of copper is even less, 8.9 grams per cm³. A 5pound crown made of 50% gold and 50% silver would have a volume of 167 cm³.

After Archimedes made his accidental discovery at the public baths, it was a simple matter to measure the volume of Hiero's new crown by placing it in water and measuring the volume of the displaced water. When the king found out that the volume was considerably greater than it should have been for a crown made of pure gold, the dishonest goldsmith received swift justice in the form of execution. What was a fortuitous discovery for Archimedes (serendipity!) was not so fortuitous for the goldsmith.

So this serendipitous discovery of a way to measure the volume of any solid object was the cause of the excitement that led Archimedes to dash out of the bath unaware that he had left his clothes behind.

Check out the cartoon on the Chapter 2 homepage that goes with this story.