Junior Engineering State Logo

Graduate Credit Workshop
Buoyancy

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Archimedes of Syracuse: The Father of Buoyancy

People have been aware of objects floating on water (or sinking) since before recorded history. It was not until Archimedes of Syracuse came along, that the theory of flotation and the buoyancy principle were defined.

Archimedes was born at Syracuse on the island of Sicily in 287 BC. His father is thought to have been an astronomer, and as a young boy, Archimedes developed a life-long interest in the study of the heavens. As a youth he traveled to Egypt where he studied at the great Library of Alexandria.

Archimedes is often described as being absentminded, self-absorbed, and somewhat eccentric. Despite these personal attributes, he was recognized in his own time as a genius, and is revered today as one of the greatest figures in the history of science and mathematics.

Archimedes' first love was mathematics. He would often spend days so intently fixed on solving a problem that he neglected both food and his person to the point that his friends would carry him kicking and fighting to the bath. He often stooped to the ground to work mathematical problems by drawing figures in the dirt. He is even said to have carried a small wooden tray filled with sand, which he used to draw his figures and work on his mathematical problems. This tray would have been Archimedes' version of the modern lap top computer. Of course, such a device is not without its problems: A strong wind could blow away a brilliant proof; a bully could kick a theorem into your face, and should a cat wander into the tray, the outcome could be too disgusting to contemplate.

Archimedes' accomplishments in mathematics are many, the most notable being:

1. The determination of circular area; he approximated more precisely than anyone to date.
2. The near development of the Calculus.
3. The quadrature of the parabola.
4. The sand-reckoner.
5. The determination of the surface area and volume of a sphere. His brilliant methods and proof for the sphere problem are described in his treatise *On the Sphere and the Cylinder.*

Archimedes and the Kings Crown

Despite his mathematical prowess, Archimedes is perhaps best remembered for an incident involving the crown of King Hiero.

As the story goes, the king of Syracuse had given a craftsman a certain amount of gold to be made into an exquisite crown. When the project was completed, a rumor surfaced that the craftsman had substituted a quantity of silver for an equivalent amount of gold, thereby devaluing the crown and defrauding the king. Archimedes was tasked with determining if the crown was pure gold or not. The Roman architect Vitruvious relates the story:

> While Archimedes was considering the matter, he happened to go to the baths. When he went down into the bathing pool he observed that the amount of water which flowed outside the pool was equal to the amount of his body that was immersed. Since this fact indicated the method of explaining the case, he did not linger, but moved with delight, he leapt out of the pool, and going home naked, cried aloud that he had found exactly what he was seeking. For as he ran he shouted in Greek: Eureka! Eureka! (eureka translated is "I have found it").

Although there is speculation as to the authenticity of this story, it remains famous. Probably no other tale in all of science combines the elements of brilliance and bareness quite so effectively. Whether the story is true or not, there is no doubt to the truth of Archimedes understanding of buoyancy.

Archimedes and the Principle of Buoyancy

Here is what Archimedes had found. Since an object immersed in a fluid displaces the same volume of fluid as the volume of the object, it was possible to determine the precise volume of the crown by immersing it in water. After determining the volume of water, a piece of pure gold could easily be made to match the volume of the water, and thus the volume of the crown. In theory, if the volume of the crown and the volume of the gold block are the same, they should also have the same mass. The only reason they would not have the same mass is if one of them was not pure gold. When the two objects were placed in a balance they did not have equal mass. Faced with this evidence the craftsman confessed to his crime.

Extending this idea further, if the mass of the water displaced is greater than the mass of the object, the object will float (Note: this calculation will require that the object be forcibly submerged). If the mass of the water is less than the mass of the object, the object will sink. If by chance the two masses are equal, the object will be suspended in the water at varying depths depending on the initial depth of the object and the water's temperature and turbidity. Every vessel that has ever sailed on water, every submarine that has ever launched, and in short, all objects that come in contact with a body of water, are governed by the principle of buoyancy defined by the great mind of Archimedes.

Archimedes and simple Machines

Archimedes was also well recognized for his mastery of simple machines. Though he appears to have considered machines as a lesser discipline to mathematics, he used them to serve his purposes when needed.

The first example of his engineering ability came when King Hiero's ship could not be launched. Though usually modest, Archimedes is claimed to have said "Give me a place to stand on and I will move the world". The case of the king's ship was soon to prove he was correct. All the men in Syracuse had tried to launch the ship, but their combined strength and ingenuity had not been equal to the task. Archimedes set about building a system of levers and pulleys into a compound machine. When he was done he had the ship fully loaded with cargo and crew, put the end of a rope in Hiero's hand and told him to pull. The king did so, and the ship steadily eased into the water. The king, previously being somewhat skeptical of such machinery, immediately issued a proclamation stating: "From this day forth Archimedes is to be believed in everything that he may say". There is no evidence that he took unfair advantage of this edict, and it probably gave him no further authority with his wife.

As the years went on king Hiero died and Hieronymus took his place. Hieronymus joined forces with Carthage against Rome. Marcellus, the Roman leader, soon blocked the harbor with Roman ships and led his army to the gates of the city. It is easy to believe that Archimedes had little interest in military matters, but with a Roman army threatening the city he drew upon his genius to help his countrymen. And help he did. Almost singlehanded he kept Marcellus at bay. He first project was to design and built cranes, similar to the ones used today. With his cranes he grappled the Roman ships, raised them high in the air, and let them fall to smash against the water; or he swung them over the wall of the city and lowered the ship and crew to the waiting Syracusians.

He next built catapults that would hurl huge stones against the ships that were out of his cranes' reach. He also used these catapults to shower metal and small rocks at the Roman soldiers who patrolled outside the city walls. His machines and contraptions were so effective that simply throwing a rope over the city wall was enough to send the Roman soldiers running in panic. Marcellus did the only wise thing; he withdrew his assault and settled down to starve out the enemy. Even the great Archimedes could not solve this problem. He quietly went back to his home and to his beloved mathematics.

The Death of Archimedes

In 212 BC Syracuse surrendered to Rome. Before sending his men to sack the city Marcellus told them "Spare that mathematician". Plutarch records what happened next:

> As fate would have it, intent upon working out some problem by a diagram, and having fixed his mind alike and his eyes upon the subject of his speculation, he [Archimedes] never noticed the incursion of the Romans, nor that the city was taken. In this transport of study and contemplation, a soldier, unexpectedly coming up to him, commanded him to follow Marcellus; which he declining to do before he had worked out his problem to a demonstration, the soldier, enraged, drew his sword and ran him through.

As much as anyone, Marcellus lamented the death of Archimedes. In the midst of his triumph he provided Archimedes with an honorable burial and befriended his surviving relatives.

Thus ended the life of Archimedes. For all of his great weapons, for all of his practical invention, his true love was pure mathematics. His levers and pulleys and catapults were mere trifles compared with the beautiful theorems he discovered. It was his mathematics that would be his greatest legacy. In this arena, Archimedes stands unchallenged as the greatest mathematician of antiquity. It would take some 2000 years to produce his equal in the form of Isaac Newton.

In accordance with the expressed desire of Archimedes, his family and friends inscribed on his tomb the figure of his favorite theorem; the sphere and the circumscribed cylinder, and the ratio of the containing solid to the contained. When Cicero was in Sicily at Quaestor in 75 BC, he discovered the neglected and forgotten tomb of Archimedes near the Agrigentine Gate. Realizing what he had found, he piously restored the burial site.

Hands on activity

Objective: Given the stated materials, build a vessel that will hold the most pennies and still float

Materials needed:

- aluminum foil (10 x 10 cm)
- Scotch tape (30 x 1.9 cm)
- water container
- pennies (50)

Rules: Using the aluminum foil and tape,construct a vessel that will float on water and hold a load of pennies. You do not have to use all the materials, but you may not use any more than listed . The boat that holds the most pennies wins, and the penny that causes boat to sink, does **not** count

Links for additional study

- **Study this link for the test**
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