Archimedes

Archimedes was a Greek mathematician, scientist and inventor who could well be said to be the founder of theoretical mechanics. Somewhat unusual for a Greek, he also pioneered in deducing mathematical laws from experimental observations. The Greeks, who greatly valued pure thought, normally disdained observations.

Archimedes was born in the city-state of Syracuse, in modern Sicily, around 287 BC. His father, Phidias, was an astronomer. It appears that he was closely associated with, and possibly related to, Heiron II the king of Syracuse and his son Gelon. Archimedes had his education in Alexandria in Egypt, which had by this time become a great centre of learning. He then returned to his native city to a life of mathematical and scientific research and invention.

The range and depth of Archimedes' work is quite remarkable. We are fortunate to have still available about ten of his treatises in geometry and mechanics; there are references in the literature to about seven more which appear to have been lost over these millennia. In order to give some idea of the scope of his work we will here describe just four of his important contributions:

a. ***The geometry of three-dimensional objects:*** The Books of Euclid, the source of our school geometry, deal only with plane figures like triangles and circles. In his treatise *On the Sphere and Cylinder*, Archimedes dealt with the geometry of three-dimensional objects such as spheres, cylinders and cones. The books *On Conoids and Spheroids* and *On Spirals* further deal with solids of revolution generated by conic sections and with spirals.

b. ***An approximation for π:*** In the short book *Measurement of the Circle*, Archimedes shows that the circumference of a circle is less than $3^1/_7$ and greater than $3^{10}/_{71}$ of its diameter, thus putting narrow limits to what we now call π.

c. ***The method of exhaustion – ancient calculus:*** This method is credited to Eudoxus of Cnidius (*c.* 390—*c.* 340 BC) and was used by Euclid. The idea is to find the area of an irregular figure by filling it with smaller regular figures of known area, filling in the spaces with smaller figures of known area and so on until the given figure is approximated to the desired degree. Archimedes ingeniously extended the method of exhaustion so that in some cases, e.g. for the volume of a sphere and of a paraboloid of revolution, it was *actually equivalent to integration*. These remarkable results are given in *Quadrature of the Parabola* and *The Method*.

d. ***The foundations of theoretical mechanics:*** The treatise *On the Equilibrium of Planes or Centres of Gravity of Planes* consists of two books that demonstrate ways of determining the centres of gravity of various geometrical objects. The general principles of hydrostatics and their applications to hydrostatic stability are dealt with in the two books that make up *On Floating Bodies*. It would be fair to say that these two treatises, dealing with solid and fluid mechanics respectively, are the bedrock of theoretical mechanics.

We would urge every reader who has not yet done so to have a look at Archimedes' derivation of the volume of a sphere, $V = {}^{4}/_{3}\,\pi r^3$. Students today only get a derivation of this result after they have been introduced to calculus and integration. Archimedes, who did not have the advantage of knowing calculus (remember this is around 250 BC!), obtained the exact result using a combination of geometry and mechanics. His miraculous derivation is even now a source of wonder and inspiration.

Archimedes was not just a mathematician and scientist – he was also an engineer and an inventor. He played an active role in the defense of his city when it was invaded by the Romans. He devised engines of war which held the enemy at bay for three years when they laid siege to Syracuse. It is also said that he constructed an apparatus of convex glass mirrors that reflected the heat of the sun and set the Roman ships on fire. The story should probably be taken with a pinch of salt but it is more than likely that Archimedes constructed some such burning instrument. The story that is universally known is the one where Heiron asks whether Archimedes can tell whether a crown made for him, and supposedly of gold, contains some silver or not. The great man is initially puzzled. However, one day when he steps into his bath he notices the water running over. It then occurs to him that the excess of bulk introduced by the silver could be measured by putting the crown and an equal weight of gold into a vessel of water in turn and measuring the overflows. If the crown were of pure gold it would displace the same amount as the piece of gold; if not, the overflow would be more. The well known story tells that he was so thrilled by his discovery that he ran naked through the streets crying "eureka, eureka" ("I have found it, I have found it"). Archimedes also discovered the lever principle in mechanics – a small force can move a large weight if a long lever arm is available. He is said to have claimed "Give me a place to stand on and I will move the earth". Among his other inventions we will only mention the water screw, a device using a corkscrew shaped tube in a cylinder to pump water for irrigation.

The Romans finally captured Syracuse in 212 BC. The Roman general Marcellus, apparently a civilized man, had issued orders that the house and person of the sage be spared. Unfortunately at the time of the sack, the aged Archimedes was so deep in thought drawing geometrical figures in the sand that he paid no attention to the Roman soldier who accosted him. Thus it was that this great scientist was stabbed to death even as he was doing what was so natural to him. Marcellus mourned his death and buried him with all honours.

It would be more than one and a half millennia before another scientist was born whose work could be said to be comparable in scope and creativity to that of Archimedes of Syracuse.

P N Shankar
33/1 Kasturba Road Cross
Bangalore 560 001, India.
Email:pn_shankar55@rediffmail.com

We are glorious accidents of an unpredictable process with no drive to complexity, not the expected results of evolutionary principles that yearn to produce a creature capable of understanding the mode of its own necessary construction.

Stephen Jay Gould