

Archimedes of Syracuse (Greek: Ἀρχιμήδης) (c. 287 BC – c. 212 BC) was a [Greek mathematician](#), [physicist](#), [engineer](#), [inventor](#), and [astronomer](#). Although few details of his life are known, he is regarded as one of the leading [scientists](#) in [classical antiquity](#). Among his advances in [physics](#) are the foundations of [hydrostatics](#), [statics](#) and the explanation of the principle of the [lever](#). He is credited with designing innovative [machines](#), including siege engines and the [screw pump](#) that bears his name. Modern experiments have tested claims that Archimedes designed machines capable of lifting attacking ships out of the water and setting ships on fire using an array of mirrors.^[1]

Archimedes is generally considered to be the greatest [mathematician](#) of antiquity and one of the greatest of all time.^{[2][3]} He used the [method of exhaustion](#) to calculate the [area](#) under the arc of a [parabola](#) with the [summation of an infinite series](#), and gave a remarkably accurate approximation of [Pi](#).^[4] He also defined the [spiral](#) bearing his name, formulas for the [volumes](#) of [surfaces of revolution](#) and an ingenious system for expressing very large numbers.

Archimedes died during the [Siege of Syracuse](#) when he was killed by a [Roman](#) soldier despite orders that he should not be harmed. [Cicero](#) describes visiting the tomb of Archimedes, which was surmounted by a [sphere inscribed](#) within a [cylinder](#). Archimedes had proved that the sphere has two thirds of the volume and surface area of the cylinder (including the bases of the latter), and regarded this as the greatest of his mathematical achievements.

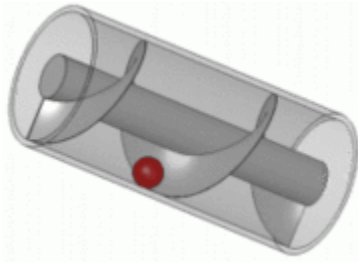
Unlike his inventions, the mathematical writings of Archimedes were little known in antiquity. Mathematicians from [Alexandria](#) read and quoted him, but the first comprehensive compilation was made only by [Isidore of Miletus](#) (c. 530 AD), while commentaries on the works of Archimedes written by [Eutocius](#) in the sixth century AD opened them to wider readership for the first time. The relatively few copies of Archimedes' written work that survived through the [Middle Ages](#) were an influential source of ideas for scientists during the [Renaissance](#),^[5] while the discovery in 1906 of previously unknown works by Archimedes in the [Archimedes Palimpsest](#) has provided new insights into how he obtained mathematical results.^[6]

The Golden Crown

The most widely known [anecdote](#) about Archimedes tells how he invented a method for determining the volume of an object with an irregular shape. According to [Vitruvius](#), a new crown in the shape of a [laurel wreath](#) had been made for [King Hiero II](#), and Archimedes was asked to determine whether it was of solid [gold](#), or whether [silver](#) had been added by a dishonest goldsmith.^[13] Archimedes had to solve the problem without damaging the crown, so he could not melt it down into a regularly shaped body in order to calculate its [density](#). While taking a bath, he noticed that the level of the water in the tub rose as he got in, and realized that this effect could be used to determine the [volume](#) of the crown. For practical purposes water is incompressible,^[14] so the submerged crown would displace an amount of water equal to its own volume. By dividing the weight of the crown by the volume of water displaced, the density of the crown could be obtained. The density of the crown would be lower than that of gold if cheaper and less dense metals had been added. Archimedes then took to the streets naked, so excited by his discovery that he had forgotten to dress, crying "[Eureka!](#)" (Greek: "εὕρηκα!", meaning "I have found it!")^[15]

The story about the golden crown does not appear in the known works of Archimedes, but in his treatise *On Floating Bodies* he gives the principle known in [hydrostatics](#) as [Archimedes' Principle](#). This states that a body immersed in a fluid experiences a buoyant force equal to the weight of the displaced fluid.^[16]

While Archimedes did not invent the [lever](#), he wrote the earliest known rigorous explanation of the principle involved. According to [Pappus of Alexandria](#), his work on levers caused him to remark: "Give me a place to stand on, and I will move the Earth." ([Greek](#): "δῶς μοι πᾶ στῶ καὶ τὰν γᾶν κινάσω")^[17] Plutarch describes how Archimedes designed [block and tackle pulley](#) systems, allowing sailors to use the principle of [leverage](#) to lift objects that would otherwise have been too heavy to move.^[18]



The [Archimedes' screw](#) can raise water efficiently.

A large part of Archimedes' work in engineering arose from fulfilling the needs of his home city of Syracuse. The Greek writer [Athenaeus of Naucratis](#) described how King Hieron II commissioned Archimedes to design a huge ship, the *Syracusia*, which could be used for luxury travel, carrying supplies, and as a naval warship. The *Syracusia* is said to have been the largest ship built in classical antiquity.^[19] According to Athenaeus, it was capable of carrying 600 people and included garden decorations, a [gymnasium](#) and a temple dedicated to the goddess [Aphrodite](#) among its facilities. Since a ship of this size would leak a considerable amount of water through the hull, the [Archimedes screw](#) was purportedly developed in order to remove the bilge water. Archimedes' machine was a device with a revolving screw-shaped blade inside a cylinder. It was turned by hand, and could also be used to transfer water from a low-lying body of water into irrigation canals. The Archimedes screw is still in use today for pumping liquids and semifluid solids such as coal and grain.

The Archimedes Screw

The Archimedes screw described in Roman times by [Vitruvius](#) may have been an improvement on a screw pump that was used to irrigate the [Hanging Gardens of Babylon](#).^{[20][21][22]}

The Claw of Archimedes

The [Claw of Archimedes](#) is another weapon that he is said to have designed in order to defend the city of Syracuse. Also known as "the ship shaker", the claw consisted of a crane-like arm from which a large metal grappling hook was suspended. When the claw was dropped on to an attacking ship the arm would swing upwards, lifting the ship out of the water and possibly sinking it. There have been modern experiments to test the feasibility of the claw, and in 2005 a

television documentary entitled *Superweapons of the Ancient World* built a version of the claw and concluded that it was a workable device.^{[23][24]}

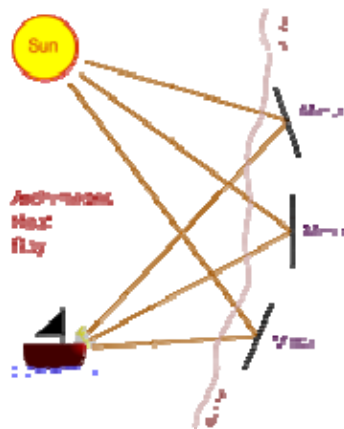
Archimedes has also been credited with improving the power and accuracy of the [catapult](#), and with inventing the [odometer](#) during the [First Punic War](#). The odometer was described as a cart with a gear mechanism that dropped a ball into a container after each mile traveled.^[25]

[Cicero](#) (106 BC–43 BC) mentions Archimedes briefly in his [dialogue *De re publica*](#), which portrays a fictional conversation taking place in 129 BC. After the capture of Syracuse c. 212 BC, General [Marcus Claudius Marcellus](#) is said to have taken back to Rome two mechanisms used as aids in astronomy, which showed the motion of the Sun, Moon and five planets. Cicero mentions similar mechanisms designed by [Thales of Miletus](#) and [Eudoxus of Cnidus](#). The dialogue says that Marcellus kept one of the devices as his only personal loot from Syracuse, and donated the other to the Temple of Virtue in Rome. Marcellus' mechanism was demonstrated, according to Cicero, by [Gaius Sulpicius Gallus](#) to [Lucius Furius Philus](#), who described it thus:

“ Hanc sphaeram Gallus cum moveret, fiebat ut soli luna totidem conversionibus in aere illo quot diebus in ipso caelo succederet, ex quo et in caelo sphaera solis fieret eadem illa defectio, et incideret luna tum in eam metam quae esset umbra terrae, cum sol e regione. — When Gallus moved the globe, it happened that the Moon followed the Sun by as many turns on that bronze contrivance as in the sky itself, from which also in the sky the Sun's globe became to have that same eclipse, and the Moon came then to that position which was its shadow on the Earth, when the Sun was in line.^{[26][27]} ”

This is a description of a [planetarium](#) or [orrery](#). [Pappus of Alexandria](#) stated that Archimedes had written a manuscript (now lost) on the construction of these mechanisms entitled [On Sphere-Making](#). Modern research in this area has been focused on the [Antikythera mechanism](#), another device from classical antiquity that was probably designed for the same purpose. Constructing mechanisms of this kind would have required a sophisticated knowledge of [differential gearing](#). This was once thought to have been beyond the range of the technology available in ancient times, but the discovery of the Antikythera mechanism in 1902 has confirmed that devices of this kind were known to the ancient Greeks.^{[28][29]}

The Archimedes Heat Ray - myth or reality?





Archimedes may have used mirrors acting as a [parabolic reflector](#) to burn ships attacking [Syracuse](#)

The 2nd century AD historian [Lucian](#) wrote that during the [Siege of Syracuse](#) (c. 214–212 BC), Archimedes repelled an attack by Roman soldiers with a [burning-glass](#).^[30] The device was used to focus sunlight on to the approaching ships, causing them to catch fire. This claim, sometimes called the "Archimedes heat ray", has been the subject of ongoing debate about its credibility since the Renaissance. [René Descartes](#) rejected it as false, while modern researchers have attempted to recreate the effect using only the means that would have been available to Archimedes.^[31] It has been suggested that a large array of highly polished [bronze](#) or [copper](#) shields acting as mirrors could have been employed to focus sunlight on to a ship. This would have used the principle of the [parabolic reflector](#) in a manner similar to a [solar furnace](#).

A test of the Archimedes heat ray was carried out in 1973 by the Greek scientist Ioannis Sakkas. The experiment took place at the [Skaramagas](#) naval base outside [Athens](#). On this occasion 70 mirrors were used, each with a copper coating and a size of around five by three feet (1.5 by 1 m). The mirrors were pointed at a plywood mock-up of a Roman warship at a distance of around 160 feet (50 m). When the mirrors were focused accurately, the ship burst into flames within a few seconds. The plywood ship had a coating of [tar](#) paint, which may have aided combustion.^[32]

In October 2005 a group of students from the [Massachusetts Institute of Technology](#) carried out an experiment with 127 one-foot (30 cm) square mirror tiles, focused on a mocked-up wooden ship at a range of around 100 feet (30 m). Flames broke out on a patch of the ship, but only after the sky had been cloudless and the ship had remained stationary for around ten minutes. It was concluded that the weapon was a feasible device under these conditions. The MIT group repeated the experiment for the television show [MythBusters](#), using a wooden fishing boat in [San Francisco](#) as the target. Again some charring occurred, along with a small amount of flame. In order to catch fire, wood needs to reach its [flash point](#), which is around 300 degrees Celsius (570 °F).^[33]

When *MythBusters* broadcast the result of the San Francisco experiment in January 2006, the claim was placed in the category of "busted" (or failed) because of the length of time and the ideal weather conditions required for combustion to occur. It was also pointed out that since Syracuse faces the sea towards the east, the Roman fleet would have had to attack during the morning for optimal gathering of light by the mirrors. *MythBusters* also pointed out that conventional weaponry, such as flaming arrows or bolts from a catapult, would have been a far easier way of setting a ship on fire at short distances. ^[1]