Archimedes: The First Modern Type of Physicist in Ancient Time

ZHANG Yao[a],*; WU Wenliang[a]; XU Nan[a]

[a] Department of Physics, Zhaotong College, Zhaotong, China.
*Corresponding author.

Abstract

Archimedes is the greatest natural scientist before the modern scientific revolution and he introduced the mathematical methods to physics and is also a rare ancient scientist who can skillfully manipulate the experimentation confirmation method in physics, and used physics to technology firstly. These features are the basic characteristics of the development of modern physics. Therefore, he is the first modern type of physics in ancient world and we call him the physics pioneer.

Key words: Archimedes; Modern type; Physicist; Ancient Greek

From the history of science, we have known that the ancient Greeks in physics have a very few research results. But Archimedes has great contribution in physics and we call him the physics pioneer. In the history of science, he was the first scientists to observe, experiment and mathematical methods as one. Archimedes scientific researches opened the way for the modern scientists, or we can say that the pioneers of modern physics along the road which Archimedes opened up forward. Just as the well-known historian of science W. C. Dampier hailed Archimedes as "the first and the greatest physicists of the modern type in ancient world (Liu, 2006, p. 41)."

Archimedes was born in Syracuse, Sicily and died there in 212BC. His modern spirit shows in four principles. At first, Archimedes first introduced mathematical to physics, and made it become a quantitative science. Second, he took experiment as a important method of physics and developed the method of logical seasoning, which is called experimentation confirmation method he skillfully used it to physics. Futhermore, he was the first scientist to used physics to technology. At last, he applied Logical reasoning to physics, and improved the methodology of physics. The pioneers of modern scientist give Archimedes a high evaluation. For instance, Leonardo da Vinci and Galileo are the admirers of Archimedes, and their studies moved along with the path of Archimedes.

Archimedes was a great mathematician and physicist. However, few people know that he introduced the mathematical methods to physics. W.C. Dampier said: "Mechanics and fluid mechanics should be looked for in practical technology rather than in the writings of early philosophers. But when combined observing and the deductive method in the geometry, both of those sciences have a solid scientific basis. Archimedes of Syracuse combined these two disciplines on the solid foundation. His work is more than any other Greeks with the true modern spirit which combined mathematical and experimental study (Dampier, 2001, p. 41)." In his work *The Method of Mechanical Theorems*, Archimedes explicitly links the mechanics and mathematics. Archimedes wrote to his friends Eratosthenes: "I think it is appropriate: I wrote and explained a method of uniqueness in the same book in detail. In this way, this will likely to make you begin to start using mechanical means to study mathematics problems (HAN, p.22)." One of the Archimedes' modern type is introduced mathematical to mechanics, especially Statics. There is an example about it. When King Hieron asked Archimedes how great could be move by a small force, Archimedes demonstrates how he alone could pull a three-mastered ship which had been lugged ashore by a host of men. Archimedes designed a set of pulleys to pull a three-mast ship which had been lugged shored by a host of men. In this sense, Archimedes partly accepted Plato's

ideas. He used mathematics to solve a weight could be moved by a small forced, which is a mechanical problems. After did this, he famously said: "Give me a place to stand on and I will move the Earth," which underlines the principle of the lever (Ronan Colin A., 1983, p. 112).

As we know, Archimedes did not invent the lever, he just gave an explanation of the principle in his work on the Equilibrium of planes. Earlier descriptions of the lever are found in the Peripatetic school of the followers of Aristotle (Archimedes, p. 6). In his work On the Equilibrium of Plane, he explains the Law of the lever stating, "Magnitudes are in equilibrium at distances reciprocally proportional to their weights (Archimedes, p. 8)." He demonstrated the Law of the lever with the geometric method, and Newton still used geometric methods for his arguments.
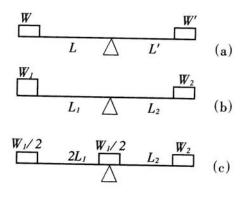

Figure 1
The Balance of Lever

Archimedes' argument about the Law of the lever is as follows: At first, he assumed balance lever, that is, $W=W'$, $L=L'$. (Figure 1(a)) Then Archimedes assumed the balance of lever as Figure 1(b), he draw the following equation:

$W_1/2=W_2$, $2L_1=L_2$.

Multiplying the two equations:

$W_1/2 \times 2 L_1 = W_2 \times L_2$,

That is

$W_1 \times L_1 = W_2 \times L_2$

At last Archimedes proved the balance of lever in Figure 1(c) by mathematical methods. This is a typical example that Archimedes introduced mathematical to physics. Whitehead commented: "Archimedes who combined the mathematical genius and physical insight has to compare with Newton who the founder of mathematical physics almost two thousand years ago (HUA, 2004, p. 1) ".

We have known Chinese people also discovered the principle of the Lever. The method of discovering the principle is quite different. The Chinese people based on a lot of practical work but Archimedes proved this Statics problem through mathematical method. This is unprecedented. The Field Medal for outstanding achievement in mathematic carries a portrait of Archimedes, along with his proof concerning the sphere and cylinder. The

inscription around the head of Archimedes is a quote attributed to him which reads in Latin: "Transire suum pectus mundoque potiri", in English, it means Rise above oneself and grasp the word (Archimedes, p. 11).

Archimedes was both a mathematician and a practical man. Precisely, Archimedes should be called as a mathematician and experimental scientist. As we known that Aristotle also paid attention to observation and experiment in his scientific research, especially in biological research, however, his scientific method only lead scientific research to the correct path. Archimedes was a great man who leads a correct path for scientific research firstly, the path is the correct method of experiment.

He paid attention to the experiment. Early ancient Greek experiments do not know experimental method, until Archimedes had experimental work of signs. He is not only use mathematical methods to physics but make experiment as an important method.

A famous story about Archimedes is his discovery of Archimedes' principle; we also call the laws of buoyancy, which describes in his treatise on Floating Bodies. This principle states that a body immersed in a fluid experiences a buoyant force equal to the weight of the fluid displaces (HUA, 2004). The principle from the story of King Hierons's golden crown show that whether some silver had been substituted by dishonest goldsmith. The king asked Archimedes to determine whether or not the gold had been adulterated without damaging the crown. Archimedes solved this problem by experiment. He balanced gold on a scale with the equal weight of the crown, then immersing them respectively in water. If the crown was less dense than gold, it would displace more water due to its larger volume. Through the experiment and accurate calculation, Archimedes found that the crown had some silver. This marks the birth of mathematical experimental science. Galileo consider it "probable that this method is the same that Archimedes followed, since, besides being very accurate, it is on demonstration found by Archimedes himself (Archimedes)."

Archimedes' principle had affected the idea of Galileo. He were inspired from Archimedes' experiments of inspection kings crown. He applied the law of buoyancy, and overthrew Aristotle' theory from theory. Galileo hypothesized that the same size of the golden ball, shot and cricket were placed in mercury and water. From Archimedes' law showed that only the golden fall, shot and the cricket floated in mercury surface and put them in the water, wood ball floated on the water, Golden Globe and shot would fall. Galileo said: "In view of this, if we completely exclude air resistance, all objects fell as fast." Galileo certificated it by slope experiment (ZHAO, p. 43). Finally, Galileo correctly summarized the law of inertia. Form this, we can clearly see that Archimedes is the first modern type of physics in ancient times.

Another important contribution of Archimedes was that he firstly used physics to technology. He was the first scientist to link science and technology. Archimedes made his contemporary and future science to recognize knowledge was useful. However, until the industrial revolution science and technology generally linked together in the history of science. Therefore, Archimedes can demonstrated that science was useful in ancient time. It is showed that he is the modern type of scientists indeed.

When Roman forces captured the city of Syracuse. Archimedes had invented a weapon called The Claw of Archimedes for the purpose of defending the city of Syracuse. Archimedes used the principles of mechanics to designed the weapon. The claw consisted of a crane-like arm form which a large metal grappling hook was suspended. The claw can be dropped onto an attacking ship and the arm would lift the ship out of the water. There have been modern experiments of the 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 (Archimedes, p.5).

Archimedes also used the principles of optics to designed a device called Archimedes heat ray. He used mirrors acting collectively as a parabolic reflector to burn ship in the Roman fleet. As Archimedes made scientific principles into a useful weapon attacked the Roman army, which was forced the Roman General Marcus Claudius Marcellus were forced to change the attack to siege tactics. The people of Syracuse resisted the Roman army outside for three years.

Plutarch in the book of *The Life of Marcellus* very described the war vividly:

> "When the Romans from the sea and land attack on the Syracuse, the people were all stunned. They were simply no way to resist the Romans such a terrible attack. However, at this time Archimedes began to use its machines. He attacked the enemy on land to a variety of stones and a large number of boulders poured down with Amazing speed. The enemy cannot resist at all, they were knocked on the ground, the queue has been beaten to disorder. Meanwhile, the huge wooden beams suddenly fell from the walls and hit a part of the enemy ships. Some ships were seized the bow suspended by the claw and a crane-like arm hanging in the air, then the stern sunk deep down in the water. Moreover, Some ships were turned round by the machine in town, others were crashed by the protruding cliffs, which caused great casualties on board (HUA, 2004, p. 50)."

From above, we can clearly see that the invention of Archimedes play the power in the defensive battle of Syracuse.

Archimedes' famous mechanical inventions is The Archimedes Screw. This is a labor-saving machines for lifting water. Details will be described on the following article, so it is not repeated here.

As an ancient Greek scientist, Archimedes also attention to logical thinking, which often be used in modern scientists in physics. He first proposed the hypothesis, and obtained by logical inference, then be verified by observation and experiment. At last, he summed up some of his observations of the phenomenon to the principle. After the age of Archimedes, the ancient Greek' science began to take the path of logical thinking. A good example is that Archimedes solved the problem of crown, then he summarized this the phenomenon to Archimedes' principle. We also take an example of China's history. There are many similar applications on the laws of buoyancy. Unfortunately, they are not recorded it (ZHANG, 2008, p. 37). A typical example is Cao Chong weighted the elephant. He applied the laws of buoyancy successfully, however, Cao Chong couldn't summary this technical to scientific principles. Also, we know the story of Huai Bing Fishing cattle. Huai Bing takes the buoyancy as the driving force, which ingenious applicator the law of buoyancy, then pulled each 4 tons of heavy tractor to ashore form river. He also couldn't take this to theory. Because Archimedes could use logical thinking, he could combine experiment and theory in his science researches.

Solved the problem of king Hieron' crown, Archimedes was taken as his inspiration. While taking a bath. In fact, he solved this problem by his logic thinking constantly. He was puzzled by the problem of golden crown a long time, and hit upon the answer while having a bath. Archimedes noticed that the amount of water in the tub overflowed as he entered it. Then he quickly realized that this effect would be used to determine the volume of the crown. Archimedes also used logical thinking to invent the Archimedes screw when he saw the snails on the beach. This machine can raise water efficiently and was turned by hand. A pipe in the form of a helix is rotated with one end in water; the water moves up the pipe as it rotates (Ronan, 1983, p. 111). The Archimedes screw is still in use today in agriculture.

When Archimedes used the science experiment, he combined Plato' idea to his ideas. Idealize is a significant feature of Plato' idea and it is a very important method in the experiment of physics. Archimedes success used the idealizer to his scientific experiments. For instance, Archimedes settled the principle of lever, he ignored its own weight, the fulcrum of friction and air resistance factor, and took the object as a particle, dealt the location of the lever as idealized mathematical point (LU, 2005, p. 41).

Today we call Archimedes a mathematician and hydrostatics, and not forget to his great contribution in practical experiment and philosopher. Archimedes love science in his whole life. Plutarch wrote about Archimedes: "He placed his whole affection and ambition in those purer speculations where there can be no reference to the vulgar needs of life (Archimedes, p. 7)." We know that his last words are "Do not disturb my circles", as he was supposedly studying in the mathematical drawing, then he was disturbed by a Roman soldier. Archimedes

was angered and said "Do not disturb my circles." The soldier was enraged and killed Archimedes. When General Marcellus knew the death of Archimedes, he was angered. Because he considered Archimedes a valuable scientific asset and had ordered that he not be harmed, he killed the soldier.

In order to adorned Archimedes, his tombstone with one of his geometrical triumphs: A cylinder insider which a sphere fitted exactly, together with an inscription giving the ratio by which the volume of the cylinder exceeded that of the sphere (Ronan, 1983, p. 113).

Just as Mr. Wu Guosheng pointed, Archimedes is an outstanding representative of Hellenistic science, he sets an example for the modern science that is not only pay attention to mathematics and interpretation but also operation and efficiency (WU, 2002, p.88).

From the above we can see that Archimedes already has the characteristics of modern scientists, also has the ancient prototype of the modern scientists. Therefore, we call him the modern physicist is suitable.

REFERENCES

[1] LIU, Kui (2006). *Western Civilization in the Scientific -- New Theory of Western Science and Culture*. Beijing: Science Press.

[2] Dampier, W. C. (2001). *A History of Science and Relations with Philosophy and Religion*. Guilin: Guangxi Normal University Press.

[3] HAN, Cai-ying (--). Archimedes: The Ancient Model of the Combination of the Spirit of Reason with the Spirit of Experimentation-confirmation. *Studies in Philosophy of Science and Technology*.

[4] Ronan, Colin A. (1983). *The Cambridge Illustrated History of the World's Science*. New York: Cambridge University Press.

[5] Archimedes. Retrieved from http://en.wikipedia.org/wiki/Archimedes

[6] HUA, Guoji (2004). *Ancient Greek physicist Archimedes Physics and Engineering,* (6). Carroll Bradley W "Archimedes" http: //www.physics.weber.edu/carroll/Archimedes/principle.htm Weber State University.

[7] ZHAO, Zheng (--). *Sixteen Lectures of Physics and Human Civilization*. Beijing: Higher Education Press.

[8] ZHANG, Yao (2008). An Insight into the Backward Development of Science and Technoloy of Modern China Based on the Principle of Buoyancy. *Journal of Zhaotong Teacher's College*, (5).

[9] LU, Yongqiang (2005). *Science Tour*. Shenyang: Liaoning Education Press.

[10] WU, Guosheng (2002). *The History of Science* (2nd ed.). Peking University Press.