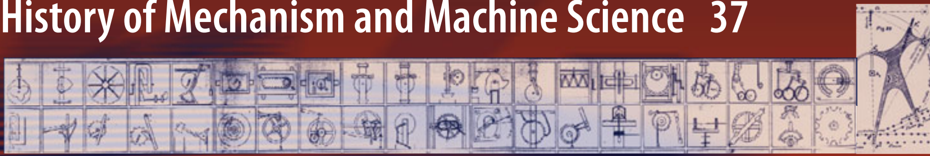
History of Mechanism and Machine Science 37



Baichun Zhang
Marco Ceccarelli *Editors*

# Explorations in the History and Heritage of Machines and Mechanisms

## Proceedings of the 2018 HMM IFToMM Symposium on History of Machines and Mechanisms

Springer

# History of Mechanism and Machine Science

Volume 37

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Baichun Zhang · Marco Ceccarelli
Editors

# Explorations in the History and Heritage of Machines and Mechanisms

## Proceedings of the 2018 HMM IFToMM Symposium on History of Machines and Mechanisms

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# Preface

History is full of exciting and entertaining stories. Historical investigations place our own present-day activities in a wider perspective. They help us define who we are. Moreover, history remains a source of ideas and of inspiration for future developments.

The organization of an international symposium on the History of Machines and Mechanisms (HMM) every four years is the main activity of the Permanent Commission (PC) for the History of Mechanism and Machine Science of IFToMM, the International Federation for the Promotion of Mechanism and Machine Science.

The first two symposia, HMM2000 and HMM2004, were held at the University of Cassino in Cassino, Italy. The third symposium, HMM2008, was held at the National Cheng Kung University in Tainan, Taiwan. The fourth symposium took place at the Vrije Universiteit in Amsterdam, The Netherlands, in 2012. The fifth symposium was at University of Queretaro in Queretaro, Mexico, in 2016.

The present volume contains the proceedings of HMM2018, the 6th International Symposium on the History of Machines and Mechanisms that was held at Chinese Academy of Sciences' Institute for the History of Natural Sciences (HINS) in Beijing, P.R. China, from September 26 to 28, 2018.

The mission of IFToMM is to promote research and development in the field of machines and mechanisms by theoretical and experimental methods, along with their practical applications. The aim of the international symposia on HMM is to maintain an international forum for the exploration of the history of machines and mechanism through study and presentation of historical achievements in MMS. The scope of the symposia is wide because they emphasize the history of technical systems and their applications. Relevant topics deal with the history of theories and design methods, biographies, the history of the institutions involved, the relations with other disciplines, the history of engineering education, and the social and cultural aspects of machines.

After the review process, 33 papers by authors representing 10 different countries were accepted for publication in the proceedings of HMM2018. A selection of them was evaluated for the Best Paper Awards according to IFToMM rules for regular and student papers. One glance at the table of contents is enough to see that we succeeded in bringing together an interesting group of scholars with a stimulating variety of subjects. We are very satisfied with this result and we thank the authors for their valuable contributions and for the efforts in submitting in time the final versions of the papers. Moreover, we would also like to thank the colleagues who helped us in the review process with timely feedbacks and careful evaluations.

This book shows the long-term development of machines and mechanisms in various contexts and reflects both the uniformity and diversity of knowledge evolution. It is meant for the inspiration and motivation of researchers, graduate students, engineers, and all others with an interest in the history of machines and mechanisms.

We would like to express our sincere gratitude to the members of the scientific committee:

M. Ceccarelli (Chair), University of Cassino, Italy
T. Chondros, University of Patras, Greece
O. Egorova, Bauman Moscow State Technical University, Russia
T. Koetsier, Vrije Universiteit, Netherlands
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Z. Lu, Beihang University, Beijing, China
H. S. Yan, National Cheng Kung University, Tainan, China-Taipei
B. Zhang, Chinese Academy of Sciences, Beijing, China

We also thank the sponsors of the symposium: the Institute for the History of Natural Sciences, CAS in Beijing, and IFToMM through the IFToMM Permanent Commission for History of MMS. Moreover, we are very grateful for the support we received from many friends and colleagues at IHNS and Springer, particularly Huang Xing and Yibing Fang. Without their support, we would not have been able to organize HMM2018.

We would also like to thank the funding of Chinese Academy of Sciences.

July 2018

Marco Ceccarelli
Baichun Zhang

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# Engineers and Their Stories

# Mechanics (Machines) in Ishaq Efendi, the Chief Instructor of Military School in the Ottomans

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**Abstract.** In this paper, it is studied the part of mechanics in the book entitled Compendium of Mathematical Sciences by Ishaq Efendi (1748?–1834) who was an eminent pioneer to transfer of modern sciences into the Ottomans. The treatise, which consists of four volumes, was published between 1831 and 1834 in Istanbul and in 1845 in Cairo as a second print. As far as is known the writer had been produced his work by drawing on Western sources, some of which we know, specifically the text books by Étienne Bézout (1730–1783) who was well-known French scholar.

I have studied the parts of mechanics by Ishaq Efendi and compared it with the work by Étienne Bézout in this paper, and concluded that Ishaq Efendi had been drawn to the mechanics from Bézout to a large extent as in other fields such as algebra, geometry, physics, etc. And I have gone into the reasons for this situation.

**Keywords:** Ishaq Efendi · Mechanics · Ottoman Empire
Military engineering school · Étienne Bézout

## 1 Introduction

The science and technology in the Ottomans are studied by dividing into two periods as classical (traditional Islamic science) and modern ones. From the beginning the Ottomans followed the Islamic scientific tradition faithfully until eighteenth century when they realized the gulf between themselves and the Europeans due to military defeats. In the second period of the Ottoman Empire that entitled as Westernization or Modernization between 18th and first quarter of 20th centuries, modern sciences had been started to teach in the newly opened and having Western style schools in Istanbul, the capital city of the Ottomans. These schools were mostly engineering (both army and naval) schools, the first schools of higher education in the Ottoman Empire, and the text books to be followed in the courses had been translated or adapted from Western sources, and instructed by teachers who had been received their education in the Western countries [9].

Among these teachers Ishaq Efendi, the famous chief instructor of the Army Engineering School (established in 1795), was born in the town of Narta in Yanya (Janina) on today's border between Greece and Albania and a Jewish converted to


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Islam. We don't know his birth date and about his youth. It is known that he was a student at the Army Engineering School between 1806 and 1815. He has attracted Huseyin Rıfkı Tamani's (?-1817) attention who was then the chief instructor of the school during his student years. When Tamani was commissioned for the work of restoration of holy buildings in Medina in 1816, he took along Ishaq Efendi as his assistant. This was his first official job. Upon his return to Istanbul in 1823/24, Ishaq Efendi began to teach arithmetic and geometry at the Army Engineering School [2].

Ishaq Efendi knew several Western and Eastern languages, and in 1824 the work of translator of administration was assigned to him as his second official job. In 1829 the task of control and restoration of fortifications in the Balkans had been given to him. Upon his return to Istanbul in 1830, he became the director and chief instructor of the Army Engineering School. While he was on duty, he modernized the education system of the school and made some changes in curriculum. J. de Kay, an American, who come to Turkey and visited the School and met Ishaq Efendi at the time, gives some news about the school, students, and teachers in his book [7].

In 1834 Ishaq Efendi was sent to Medina with the task of restoration of holy buildings in there to stay on chief instructor at the Army School Engineering. He died on the way back in 1836. He had written eight books consisting of eleven volumes on mathematics, ballistics, fortifications, battle techniques, and general military issues [5].

He played an important role in the transmission of modern sciences to the Ottomans through his main treatise titled under the name of Mecmua-i Ulûm-ı Riyâziye (Compendium of Mathematical Sciences) which consists of four volumes. It was the first attempt to write a comprehensive textbook including a lot of modern scientific subjects such as mathematics, physics, chemistry, astronomy, biology, botanic, zoology, and mineralogy. Ishaq Efendi also created a new Turkish terminology for each of these sciences while he was preparing his treatise [6]. A part of the third volume (between the pages of 180 and 266) that titled under "dragging of inanimate bodies from the science of dragging of heavier weights", and consists of fifteen chapters which were devoted to mechanics of rigid bodies and machines have been described within these chapters. As far as known, it is the first treatise of such kind in the Ottomans.

## 2 Mechanics in Mecmua-i Ulûm-ı Riyâziye

At the introduction of the book [4], the science of dragging of heavier weights was described as a kind of knowledge about the principles on which forces and motions of bodies depend by means of skilful machines. Heavier weights have been dragged by light forces with these principles.

For example, the body of (A) weighs 1000 qiyya[1] and it is desired to lift up by 100 qiyya of force. It is taken a lever represented by (BC) and its end of (C) is placed under the body of (A). When it presses down on (B) by a force of 100 qiyya, (A) lifts up so that the distance of (EB) equals to 10 times of the distance of (EC) (Fig. 1).

[1] One qiyya equals to one kilogram (400 dirham, 1282 g in the older system of weights).

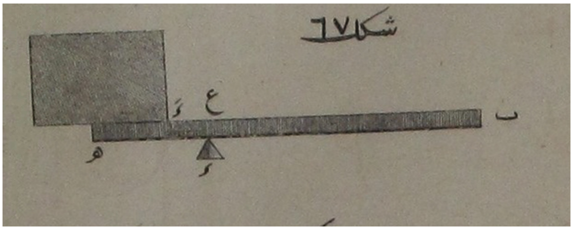


**Fig. 1.** Figure 67 in Ishaq Efendi.

With this machine it is possible also to move the heavier bodies by fewer forces in less time with the help of the science of dragging of heavier weights in comparison to the moving by various forces in a long time.

Then the skilful machines have been studied from the standpoint of the relationships between these machines and the effects of forces moving the bodies and elapsed time during the motion. The skilful machines were divided into two main categories as simple and complex machines. And simple ones also were divided into two sorts of which one includes lever, axle of wheel and horizontal and vertical capstan, pulley; the other consists of inclined plane, clamp and wedge. As to the complex machines, they composed of simple ones and had a wide variety of kinds and the same principles with that of simple ones. Thus the author arranged the chapters, which consists of the machines, as follows:

Chapter 1: Lever
Chapter 2: To make the levers most beneficial and improvement
Chapter 3: Balance
Chapter 4: Steelyard
Chapter 5: Axle of wheel and horizontal and vertical capstan
Chapter 6: Pulley
Chapter 7: Inclined plain
Chapter 8: Clamp
Chapter 9: Wedge
Chapter 10: Pulley systems
Chapter 11: Composition of Gearwheels
Chapter 12: Constitution of mechanical clocks
Chapter 13: The distance measuring device
Chapter 14: Mill and Crank Mallet
Chapter 15: Friction and Touch

Although these devices had been designed without weight and thickness, and thought that having no friction and touch, as they had been made of wooden or other materials, above mentioned conditions occur and it was required to give the principles accordingly.

The subjects included within these chapters have been explained by giving quantitative examples, theorems, results and warnings in great detail. All of the figures are given at the end of the book as that in book by Bézout [1].

Chapter 1 deals with lever. In general, the conditions of balance in various situations are studied in this chapter. Lever is a machine that having no weight, density and any warp. It has five properties as force, weight, fulcrum, and distances from the fulcrum to the force and to the weight. (F) shows the force, (R) is being weight; (A) is fulcrum, (AR) and (AF) showing the distances (Fig. 2). The effect of the force on the weight results by a rope.

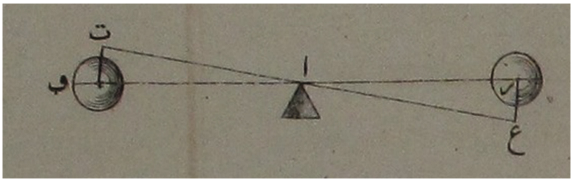

**Fig. 2.** Lever in Ishaq Efendi.

There were three kinds of levers according to the places of A (fulcrum), R (weight), and F (force). If (A) is placed between (R) and (F), it is a first kind of lever (Fig. 3). If (R) is placed between (A) and (F), it is the second kind of lever (Fig. 4). Finally if (F) is placed between (A) and (R), it is the third kind of lever (Fig. 5).

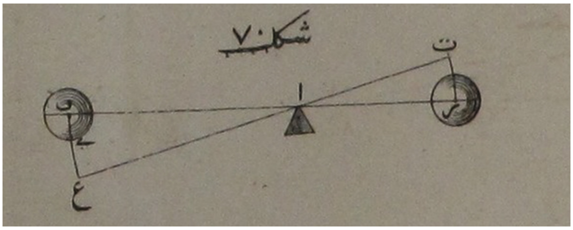


**Fig. 3.** A first kind of lever

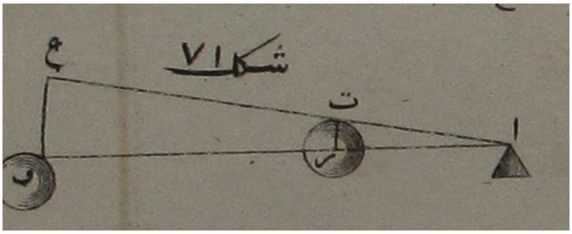


**Fig. 4.** A second kind of lever

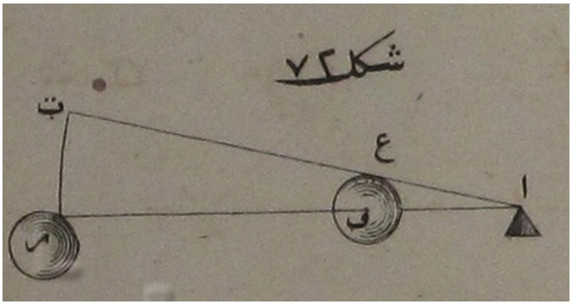


**Fig. 5.** A third kind of lever

Chapter 2 is on the various kinds of devices which depend on these three kinds of levers, and their using in the different places. For example, first kind of lever is included in some devices such as balances, clippers, jeweller's scissors, pliers and dental pliers, tongs, and pincers used by carpenters, and boat oars. The chopper knifes were examples of the second kind of levers. The third kind of levers is used in some mechanisms like table knifes and looms.

As a result, it was marked that all of solid motions carried out by means of levers.

Chapter 3 is about scale and balances. In this chapter it was studied the conditions of the accurate weighing and described the construction and use of balances, and the notions related to scale and balances (Fig. 6).

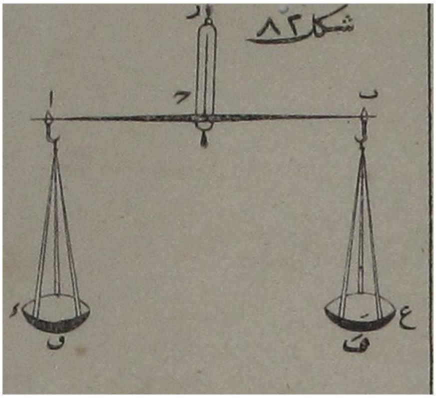


**Fig. 6.** A typical balance in Ishaq Efendi

Chapter 4 is on steel yard which a kind of balance having no equal arms, to weigh the very heavy loads. The heavy load to be weighed hangs the short arm of the device; the long arm has graduated notches for a standard weight (Fig. 7).

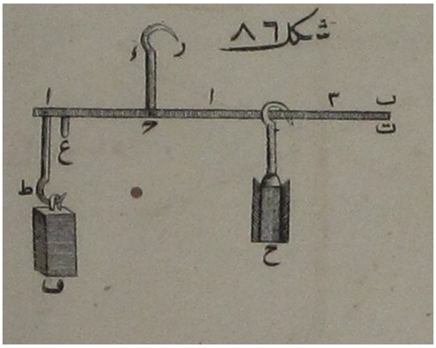


**Fig. 7.** Steelyard in Ishaq Efendi.

Chapter 5 is on axle of wheel and horizontal and vertical capstan. It is a machine for moving or raising heavy weights that consists of a vertical drum which can be rotated and around which cord is turned (Fig. 8).

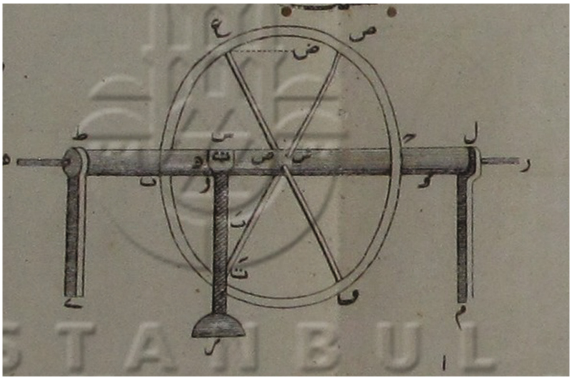

**Fig. 8.** Capstan in Ishaq Efendi

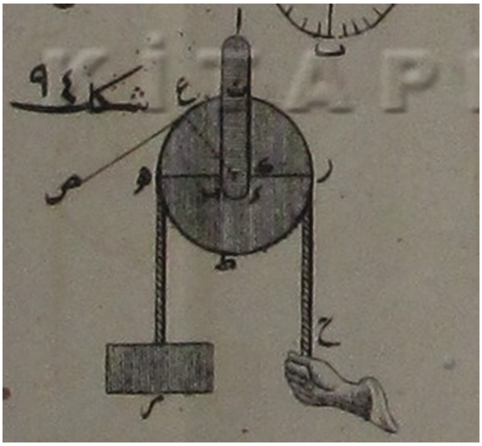


**Fig. 9.** A mechanism of a fixed pulley in Ishaq Efendi

In Chapter 6, it was explained the pulley which used for lifting weights. It is called "fixed" for the pulley no changing its place, and the pulley that changes its place and begins to act by a load is entitled "moveable" (Fig. 9). With a movable pulley we need less effort to lift a load (Fig. 10).

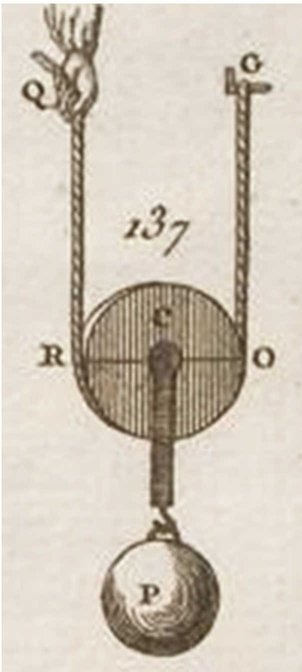


**Fig. 10.** A fixed pulley in Bézout.

Chapter 7 is on inclined plane and it is described the using of the device, and its application to the lifting loads (Fig. 11). If any two of them (magnitudes (literally essence) of force and load, and sine of inclination) were known, then the third one can be finding from the situation of balance (Fig. 12).

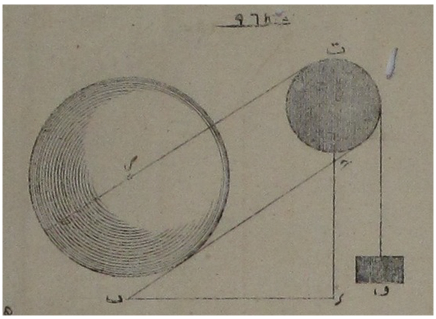

**Fig. 11.** Inclined plane in Ishaq Efendi

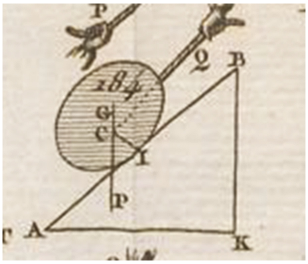


**Fig. 12.** Inclined plane in Bézout

Chapter 8 is on clamp which a device designed to bind or constrict or to press two or more parts together so as to hold them firmly. It was explained sorts and mechanisms of the device. A special use of clump had been shown in the (Fig. 13) and the same by Bézout in (Fig. 14).

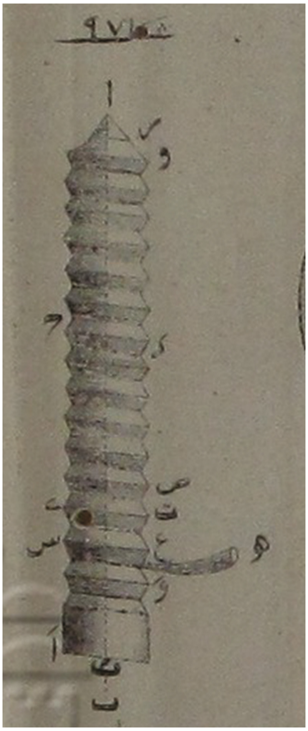

**Fig. 13.** Clamp in Ishaq Efendi

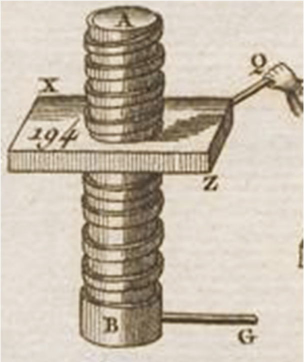


**Fig. 14.** Clamp in Bézout

Chapter 9 is about wedge which is a triangular shaped tool, and it is made up two inclined planes joint together. It is thick on one end and thins out to a sharp edge on the other end (Fig. 17). It can be used to separate two objects or portions of an object, lift up a load or hold an object in place (Figs. 15 and 16).

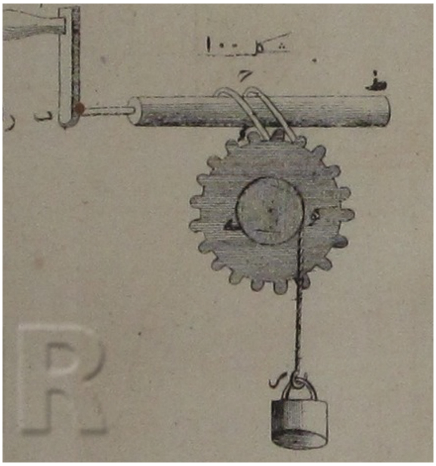

**Fig. 15.** A special use of clamp in Ishaq Efendi

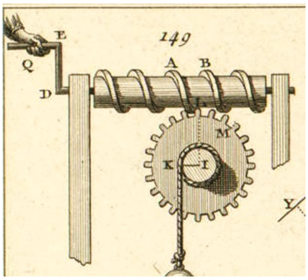


**Fig. 16.** Clump in Étienne Bézout

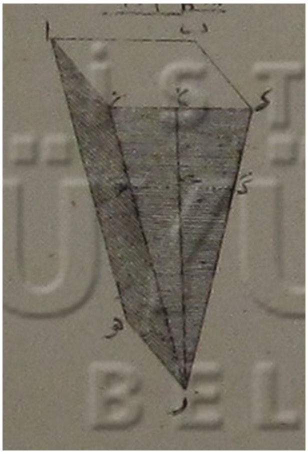

**Fig. 17.** Wedge in Ishaq Efendi

Chapter 10 is about the various systems of pulleys among complex machines which compose of simple pulleys (Fig. 18). With this system it is possible to move heavy loads very easily (Fig. 19).

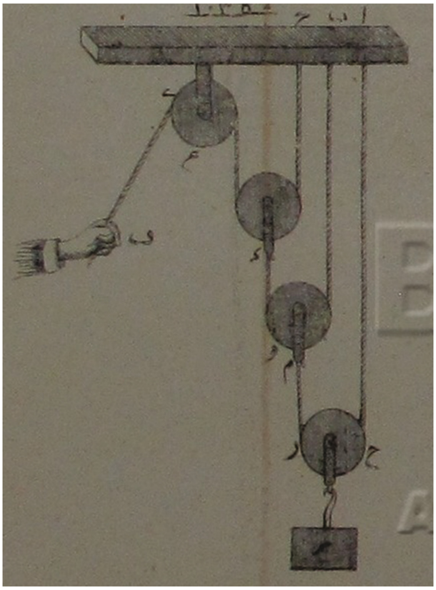

**Fig. 18.** A system of pulleys in Ishaq Efendi

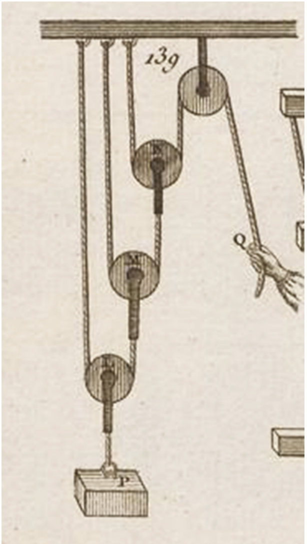


**Fig. 19.** A system of pulleys in Bézout

Chapter 11 is on the gear wheels that consisting of a tooth wheel which engages another toothed mechanism in order to change the speed or direction of transmitted motion today. A force of (F) is applied to tooth of ($T^1$) on the gear wheel of ($AT^1$), and the weight of (T) is not hanged on (A), and some little tooth wheels pass to each other by their tooth and to the endmost one (A) is hanged. That system of tooth wheels is used to lift heavy weights and for some other works (Fig. 20).

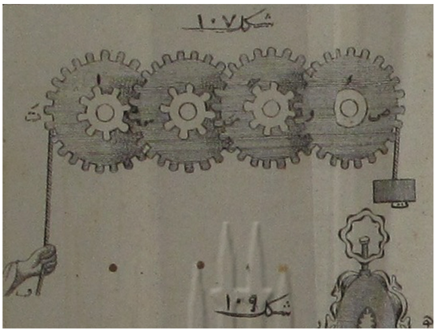


**Fig. 20.** A toothed wheel in Ishaq Efendi

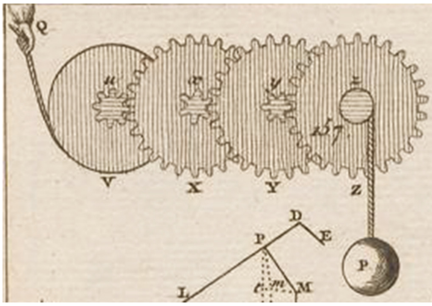


**Fig. 21.** Toothed wheel in Bezout

Chapter 12 is on the construction mechanical clocks by using the wheels. According to the author, the mechanical clock (with wheels) was made for telling time more accurately than water and sun clocks. He classifies mechanical clocks as hangklok of which power source is weight, table clock of which power source is spring and its moving from a place to another place is difficult, and pocket clock which is portable and its power source is again spring. It is mentioned that making correct clocks needs some principals such as less wheels, lack of friction and touch, sturdy material, and stability between warm and cold (Fig. 21).

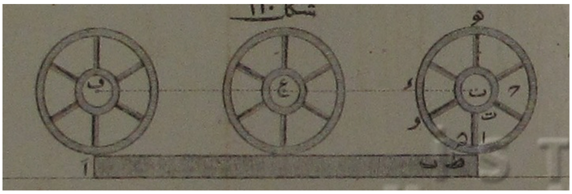

**Fig. 22.** A device for measuring a land.

Chapter 13 is about a distance measuring device by which it is possible to measure on a rough terrain (Fig. 22). It needs to find the true distance between two points on a rough terrain, because that distance does not coincidence to the straight line between the points. In this device, circumference of the wheel is equalized to the straight line.

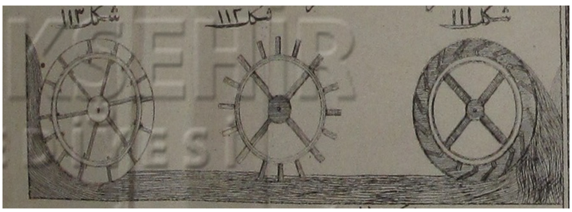

**Fig. 23.** Mill and crank mallet in Ishaq Efendi

Chapter 14 is on mill and crank mallet which is used to grind wheat, crush minerals, and turn flax seed to paper by the means of water or wind (Fig. 23). It is divided into three kinds consisting of vertical, inclined and parallel according to the direction of water driving the first mill.

Chapter 15 deals with friction and touch and it is said that friction and touch hinder the motion. When bodies were in moving from a place to another place, or in turning around an axis, it appears a resistance of friction. According to the given information, the resistance of friction increases depending on the weight and the solidity of bodies. Sliding or rolling of a body on another body increase the touch. Because, a wheel of a going down cart is fastened to slow down and thus it is obliged to slide and stop it's wheeling. It appears that the increase of touch retards the motion of the cart.

## 3 Conclusion

Spurred on by increasing military, political and economic needs, when the Ottomans had begun to adopt Western science and technology in the eighteenth and nineteenth centuries, they wanted to transfer and teach Western knowledge and technology related to war and military techniques primarily. As a first step, military engineering schools were established so as to better prepare the Ottoman Empire against future military attacks. Text books for the schools were prepared with translations and adaptations from European (especially from French, but not only French) sources. Occasionally professors from abroad had given courses in these schools, for example French scholars taught the practical courses in the Naval Engineering School. These practical courses were terminated after teacher's leaving for home, however theoretical courses were continued to be taught by Ottoman teachers. Ishaq Efendi, among the professors of these schools, was a pioneer in this transferring process and wrote some text books for the students of these military schools.

Among his treatises, Mecmua-i Ulûm-u Riyâziye was a monumental work consisting of four volumes and total of 2221 pages and played an important role in transferring modern science into the Ottomans. The author was devoted a part of the third volume to applications of mechanics. It was one of the successful examples in teaching the mechanism of machines theoretically. It is interesting enough to see that the machines and devices included in the book of Ishaq Efendi were not just about the war arts, but at the same time were concerned with the practical need to be faced in everyday life. This situation conforms to the pragmatic approach of the Ottomans.

It was known that Ishaq Efendi draw on the books by Étienne Bézout (1730–1783), who was a famous French mathematician, for first and second volumes of Mecmua and for his other books, but there was a silence about the source of mechanics in the third volume. It appears now that Ishaq Efendi had followed up also Bézout for his mechanics. The figures of the machines in both of the books by Bézout and Ishaq Efendi show a great analogy. The crucial question is, then, why did İshaq Efendi prefer to draw on Bézout's book in writing his Mecmua?

I think Bézout's academic and educational achievement would be him a major choice. Bézout was appointed adjoint in mechanics to the Académie des Sciences in 1758, and teacher and examiner in mathematical sciences for young would be naval officers in 1763. He took up similar duties for the “Corps d’Artillerie” in 1768. He was also a member of Académie de Marine and among his published works were the courses of lectures he gave to his students.

As a very popular and active scholar in education and mathematical sciences, his textbooks were translated into English for use in American schools. According to J.V. Grabines, “These translations considerably influenced the form and content of American education in the nineteenth century” [3]. Besides, Bézout was very influential also on the reform of the Portuguese university [8]. Books of Bézout apparently were preferred by the intellectuals of periphery to improve their science education systems. In that case it is not surprising that Bézout’s textbooks were also used in the Ottomans during the military education reforms.

Moreover, relations between the Ottoman Empire and France were initiated from the late fifteenth century, and Ottoman military reforms of the eighteenth and nineteenth centuries were dominated by French experts and French books were included in the curriculum of the military engineering schools where French was taught as a main foreign language. Students were sent to Paris to further improve their language skills. French influence over this reform period was ubiquitous. French culture had impact in diverse areas such as government structure, the legal system, clothing, the press, the financial system, daily life and the arts. So, here we see another example of French domination in the scientific modernization of the Ottomans on the occasion of the mechanics by Ishaq Efendi. On the contrary we see the German influence on the Ottomans towards to the end of nineteenth and the first quarter of twentieth centuries.

## References

1. Bézout É (1772) Cours de mathématiques à l’usage du corps royal de l’artillerie. (4) Tome quatrième, concernant l’application des principles généraux de la Mécanique, à différens cas de movement and d’équilibre
2. Tahir BM Osmanlı Müellifleri, İstanbul (1342 H). (in Ottoman Turkish)
3. Grabiner J, Bezout, É Dictionary of scientific biography, vol. 2. Charles Scribner’s Sons, New York
4. Efendi I (1845) Mecmûa-i Ulûm-i Riyâziye (Compendium of Mathematical Sciences), vol 3. Bulak Matbaası, Cairo (in Ottoman Turkish)
5. Ihsanoglu E (1996) Büyük Cihad’dan Frenk Fodulluğuna (in Turkish). İstanbul
6. Ihsanoglu E (1989) Başhoca Ishak Efendi. Türkiye’de Modern Bilimin Öncüsü, İstanbul (in Turkish)
7. De Kay J (1833) Sketches of Turkey in 1831 and 1832. J. & J. Harper, New York
8. Saraiva LMR (2015) Étienne Bézout in Portugal. Historia Mathematica 42(1):14–46
9. Esad, M.: Mirât-I Mühendishâne-i Berrî-i Humâyûn, İstanbul (1312 H). (in Ottoman Turkish)

# Giuseppe Ceredi. A Hydraulic Engineer in 16th-Century Italy

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**Abstract.** The main objective of this contribution is to reconstruct Ceredi's work by analyzing the hydraulic machines he redesigned, starting from rediscovered ancient and early Renaissance models that, in some cases, are known and in others, completely unknown.

With his 1567 work, *Tre discorsi sopra il modo d'alzar acque da' luoghi bassi* as a point of departure, this research has brought to light some biographical information on the author, completely unknown in the scientific literature, as well as the *Philosophia Naturalis* model that influenced his work as a proto-engineer.

**Keywords:** History of hydraulic technology · Giuseppe ceredi
History of cochlea · Italian renaissance machines

## 1 Introduction

Recalling the progress in the 16th-century construction techniques of machines, Usher [1] highlighted the difficulties historians have encountered in reconstructing these innovations due to the limited availability of descriptive sources. In fact, given the many easily available drawings and projects of the time, there are very few documents, apart from a couple of exceptions, with details on the workings of the mechanisms and tools. The availability of such sources would allow a complete history of Renaissance machines to be written for the first time. Yet, alongside the two main exceptions identified by Usher – Agricola's *De re metallica* (1556) [2] and Bélidor's *Architecture hydraulique* [3] – mention must be made of the Italian Giuseppe Ceredi's work *Tre discorsi sopra il modo d'alzar acque da' luoghi bassi*, published in 1567 in Italian [4].

While Agricola's work has been studied in depth and Bélidor's works are less known, Ceredi's *Tre discorsi* are still almost completely unknown, written at a particularly complicated time from a cultural point of view as the Scientific Revolution was also beginning to have an impact on the field of mechanics. Nevertheless, the comparison to ancient thinkers continued to maintain a predominant role.

Consequently, the main objective of this contribution is to reconstruct Ceredi's work by analyzing the hydraulic machines he redesigned, starting from the rediscovered ancient and early Renaissance models – known in some cases, completely unknown in others. Nevertheless, this research introduces some biographical information on this author, completely unknown in scientific literature, as well as the *Philosophia Naturalis* model that influenced his work as a proto-engineer.


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https://doi.org/10.1007/978-3-030-03538-9_2

## 2 Ceredi, 16th-Century *Mechanician, Philosopher* and *Historian*

In the *Dizionario biografico piacentino*, published in 1899, the very brief note dedicated to Ceredi reads: "Ceredi Giuseppe; highly regarded pharmacist, physician, and mathematician in the sixteenth century, known as the perfecter of Vitruvius's cochlea thanks to the teachings of Pappus and Dionysodorus. In 1567, he published a work entitled *Tre discorsi sopra il modo di alzare acqua da' luoghi bassi;* said work was discussed with great praise in his time. He wrote but did not publish on how to divide floods and river islands. He was a student of Benedetto Labadini" [5].

This is essentially the most substantial evidence currently available for a biography of Ceredi, apart from a very few other references that he himself made in his work as, for example, the confirmation of his medical training; his friendship with Benedetto Labadini, a "very famous professor" in Piacenza [6]; and a visit to Giorgio Valla's private library. By chance, this latter episode allowed him to come into the possession of "some writings by Hero, Pappus, and Dionysodorus […]– never printed or translated, as far as is known" [7] – in which were contained elements that, in his opinion, were essential to learning about hydraulic science and complemented the "classic" descriptions by Euclid, Archimedes, and Apollonius of Perga.

Indeed, hydraulic science is the central theme around which all of Ceredi's work revolved. In fact, it is a "science" because, in this case, machines represent the natural fulfillment of the theoretical assumptions traced by the author in the natural philosophy of his times. As highlighted in the dedication to Alessandro Farnese, prince of Piacenza and Parma, hydraulics are of great importance in daily life, for the "wonderful mathematical effects" [8] as well as its practical applications to architecture and military structures. Ceredi wrote, "Making [each hydraulic machine] according to mathematical and physical models [is fundamental] to almost all men, and to all territories, [both because] it is suitable for bringing nourishing moisture, where lacking, to meadow grasses, fodder, and all plants [and because] it can lift water to armies, and to walled towns for drinking and various other uses" [9].

Moreover, as a staunch supporter of the theory of Thales of Miletus as well as consistent with his profession as a doctor, Ceredi believed that water was the fundamental element for life as every living being draws from moisture "the nourishment of its own vital heat, from which all processes of generation, growth, and maintenance derive" [8].

Human history is essentially associated with the evolution of transport techniques for water, as demonstrated by the major hydraulic works constructed until that time. They include the particularly large aqueduct, for its time, in the city of Ecbatana and "a high hill drilled a distance of twenty-five stadia" [10], whose operation was replicated by that city's army in the form of foldable and transportable cowhide pipes, indispensable for transporting water from rivers to military camps; the approximately 14-km long "canal of Samÿ" in ancient Greece, able to move water up a hill more than 11 meters high; and the majestic aqueducts, baths, and fountains in ancient Rome.

Nonetheless, these works were able to move and lift water with "only the effects of our mother nature" [11]. Rather, machines capable of lifting quantities of water that could justify the expense necessary their construction and maintenance did not exist. Not surprisingly, water projects for “civil” – and not private – use only also existed in the major Italian and European cities that rose near large rivers. Inhabitants with the economic possibility had water transported by men or animals to the cisterns in their dwellings. Both the German populations and the ancient Romans were very skilled at moving huge amounts of water from one place to another – the former, to drain mines and the latter, to build bridges and ports.

At this point, Ceredi made a brief but earnest epistemological digression on the possibility of verifying “many times with various clearly successful experiments” the mechanical effects of the scientific theories, especially in the field of the science “of moving weights”, where it is necessary to control “with one’s own hands” and with “artificial instruments” the laws “known only in the abstract by men of science”. In short, the “beautiful mathematical arguments” in a mechanistic model of nature interpreted by Ceredi as a sort of factory of the world, capable of producing the “most artificial organs” by itself, had perforce to be accompanied by their “honest execution”, just as “discourse” and “hands” must contribute with equal dignity to make humans more suitable for survival [12].

During the 16$^{th}$ century, particularly in Italy, the growing role of technology and its progressive expansion of theoretical and mathematical aspects tended to make the figure of the “anonymous craftsman” gradually disappear in favor of the “artist-engineer, builder of fortresses, dams, canals, and councilors in service to princes and republics” [13].

Not surprisingly, the *Tre discorsi sopra il modo di alzar l’acque da’ luoghi bassi* focused on the *cochlea* (Italian: *coclea* or *chiocciola*) or *Archimedean screw*, comparing it to other hydraulic machines and describing in detail its moving parts as well as its relation to the “science of moving weights” [14]. There is no lack of detailed considerations on the economic aspects, agricultural applications, and a true sanitary revolution resulting from the use of the cochlea. In this sense, Ceredi indeed embodies the typical 16$^{th}$-century inventor, capable of rediscovering and improving an old mechanical device [15], yet also taking on the guise of historian, able to let the evidence of a technological past to be discovered, one that would otherwise have been lost.

For example, this was the case of the hydraulic machine that fed the cloister fountain in Venice’s Basilica of San Giorgio Maggiore. The system had two cisterns: one lower than the fountain, the second higher. The latter collected the water coming from the first and sent it to fall into the fountain. The peculiarity of the machine consisted in the principle according to which the water was lifted from the first tank. A lid as large as the mouth of the cistern was connected to a counterweight that gradually descended, thus pushing on the liquid that regularly re-ascended. Ceredi explained its operation by referring to the theory developed by Pliny the Elder [16], who claimed that waters rise on mountains because of the earth’s weight that presses so hard as to make it flow out. However, this hydraulic machine had two major limitations. The first was due to the different pressure that the counterweight managed to exert with the varying depth of the water in the cistern. Ceredi erroneously attributed the cause of this phenomenon to Archimedes’s principle and gave as an example the case of a ship that, with the same weight, sank more on the surface of a river compared to the sea, due to the greater depth of the latter with regard to the former [17]. Here too he was mistaken, as the variable linked to the higher density of salt water was not considered. The formulation of the hydrostatic law, developed by Simon Stevin in 1568 – hence, the year after the *Tre discorsi* was published – would have clarified the importance of the depth factor to explain the pressure increases in fluids.

Ceredi then went on to examine Ctesibius's famous machine, described by Vitruvius. It was able to raise water higher than the others, as "it needs a strong engine and a year rarely goes by without it breaking down" [18]. (p.15). Although the bellows machines, described by Roberto Valturio [19] in his *De Re Militari*, were also able to lift water to great heights, there were obvious limits to their efficiency (Fig. 1).

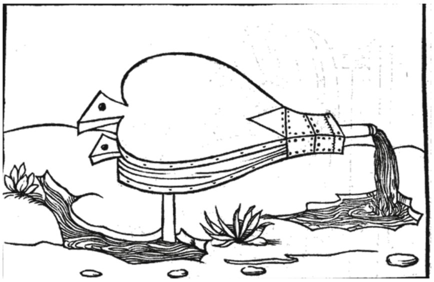

**Fig. 1.** Bellows machine described by Valturio

Like other machines common at the time, these particular machines generally "force nature and are violent" [20]. Consequently, they had two major defects: one due to the demand of elevated propelling forces compared to the amount of water lifted and the other to the intrinsic fragility of these mechanisms.

## 3 The Cochlea: Ceredi's Patent?

The cochlea is a machine that can lift considerable quantities of water with relatively little effort (Fig. 2). Composed of a helical surface formed around a central cylinder (and hence the screw analogy) positioned inside a tube, the cochlea was submerged in water at an angle. By turning the shaft, the lower part of the spiral draws water and conducts it through the pipe up to the top.

According to some sources, one fundamental mechanism in the Renaissance economy [21] can undoubtedly be attributed [22] to a design by Archimedes that continues to bear his name still today. According to other interpretations, the cochlea dates back to the mechanics of pre-Hellenistic Egypt, as Archimedes would simply have improved the mechanism [23]. Beyond the debate on the invention's paternity, Ceredi was fully acquainted with the operation of the cochlea, to the point of improving a series of construction details that made it more efficient mechanically and, consequently, more useful for public health and in so doing, acquired a kind of patent [24]. Indeed, Popplow noted that "even if Ceredi claimed that the publication of his treatise

**Fig. 2.** An example of a cochlea

served only the public welfare and that he did not wish to draw any personal benefit from it, the calculation mentioned above also included the license fee the investor had to pay him for the employment of his invention" [25].

However, especially in the second discourse, the detailed reconstruction of the various technical advances that, over the centuries, had established a truly standardized design for use in constructing the cochlea, testifies primarily to the existence in the 16$^{th}$ century of a heated debate on the proto-concept of hydraulic machine efficiency. Nevertheless, Ceredi's digression also bears witness to the turning point, also typical of the 16$^{th}$ century, which would determine the dawn of technology as an autonomous science and not subordinate in the least to the mathematics and physics.

Nevertheless, on the subject of 16$^{th}$-century "mechanical arts", Rossi observed, "Some of the processes used by men to produce everyday objects or build machines [...], benefited from a proper knowledge of the natural world, substantially more than those intellectual constructions or philosophical systems that end up preventing or limiting man's active exploration of natural matters" [26]. This consideration appears entirely consistent with Ceredi's intent in the *Tre discorsi*. In fact, he did not fail to underscore, in more than one passage, how much he had departed from a theoretical epistemological model, compared to most of the debates that also existed on machines and their ability to subdue the forces of nature. Yet again, the rich iconography in the text confirms Ceredi's desire to show, even with his own drawings and designs – according to a requirement that was spreading in the field of technical knowledge [27] – how the complex calculation of the forces involved in the movement of machines was