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A Simplified Replica of the Antikythera Mechanism as a Tool to Astronomy Teaching

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Authors' contributions

This work was carried out in collaboration between both authors. Author WG designed the study, reconstructing the replica of Antikythera Mechanism and wrote the first draft of the manuscript. Author MCDN is the supervisor of the original Master Dissertation and managed the final composition of the study. Both authors read and approved the final manuscript.

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ABSTRACT

The Antikythera Mechanism is a machine made up of bronze gears capable of predicting celestial positions, moon phases, eclipses and calculating calendars. Its construction is estimated to be 205 BCE. Studies on the functioning of the mechanism revealed great technical sophistication. From the principle of operation of the Antikythera Mechanism, a simplified didactic replica of the device was developed to be used as an educational instrument.

Keywords: Antikythera mechanism; astronomy; astronomy teaching.

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1. INTRODUCTION

1.1 The Antikythera Mechanism

The 82 fragments of the Antikythera Mechanism were found in 1901 on a Roman shipwreck alongside numerous archaeological artifacts that are currently found in the National Archaeological Museum in Athens (Fig. 1) [1] [2] [3] [4].

Today it is known that the mechanism had two metallic plates containing internally its complex system of approximately 60 gears. This set is in a wooden casing of 515x190x100 mm [2]. The front panel presents dates and times of birth and sunset of some stars called Parapegma. In the central region is the planetarium, within two concentric circles. The outer circle marks the Egyptian year of 365 days. The inner circle contains the 12 zodiacal constellations. From the center of the panel there are pointers that indicate the position, in relation to the constellations, of the Sun, the Moon and the five planets known in antiquity: Mercury, Venus, Mars, Jupiter and Saturn. [5] [6] [7] [8]

The irregular movements of the Moon (lunar anomaly), of the planets (epicycles) and probably of the Sun, were reproduced. There could be a longer hand indicating the graduated date on the outer circle. The Moon hand has a phase indicator by means of a semi-silver rotating sphere. The main gear train was composed in such a way that every 254 turns of the Moon pointer corresponded to 19 turns of the Sun pointer, that is, it reproduced the natural cycle of 254 sidereal months[1] every 19 years. The rear of the machine includes two calendars arranged in a spiral and texts with operating instructions.

The upper dial was a Metonic calendar, with 5 spiral loops representing 19 years of 235 synodic months[2]. There are two auxiliary clocks on the inside of the Metonic calendar: The Calyptic, which indicates when a day should be compensated for reading every 76 years and the Olympic, which indicates the location of the Pan-hellenic games. The lower calendar is an eclipse prediction called Saros, distributed in a spiral of 4 turns that concentrates 18 years with 223 synodic months that constitutes a cycle of occurrence of solar and lunar eclipses. Inside there is an auxiliary clock (Exeligmos) that indicates whether or not there is a need to add 8 h or 16 h at the time of the eclipse. Both calendars have a pointer whose outer end is fitted in the groove of the spirals and the inner end can slide on the axis that connects it to the gear inside the Mechanism. Thus the hand follows the correct reading at each turn [9] [10] [11].

[1] *Period when the Moon returns to its initial position in relation to the bottom of the fixed stars; approximately 27 days.*

[2] *Period when the phases of the Moon are repeated; approximately 29.5 days.*

1.2 A Simplified Replica of the Antikythera Mechanism as a Teaching Tool

The sophistication of the Antikythera Mechanism makes it a resource of great educational potential, of interdisciplinary scope, and can be used as a means of engaging students and the general public for Science and Technology [12] [13]. Thus, it is proposed to build replicas of the Mechanism to be used as didactic instruments. Due to the technical sophistication of the original Mechanism, the construction of replicas contains simplifications. Only the front panel of the planetarium was reproduced, with an indicator hand of the Sun and Moon, without considering the movement of the lunar anomaly. A Mercury pointer on the panel was included in one of the proposed models. The gears and panels were made with laser cutting system, respectively in wood (MDF) and acrylic.

1.3 Simplified Didactic Replica of Sol-lua of Separate Panels (R1)

It is an ultra-simplified model, composed of just 3 gears: The solar with 254 teeth and the lunar with 19 teeth. Thus the cycle of 254/19 is respected. One intermediate gear connects the other two and does not interfere with the cycle. A fourth gear (optional) is the driving gear, where the user rotates the system. The panels with pointer from the Sun (above) and the Moon are separated. Fig. 3 shows a photograph of the replica R1.

1.4 Simplified Didactic Replica of Single-panel Sun-moon (R2)

The simplified didactic replica R2 was designed so that its layout is similar to that of the Antikythera Mechanism. That is why the planetarium panel that contains the Sun and Moon hands is unique. It also uses the main gear train identical to that of the original mechanism. Fig. 4 illustrates the gear train of replica R2. In figure 5 are the photos of the assembled and functional replica R2.

Fig. 1. The 82 fragments of the Antikythera Mechanism
Source: Nature. https://www.nature.com/articles/nature05357/figures/1

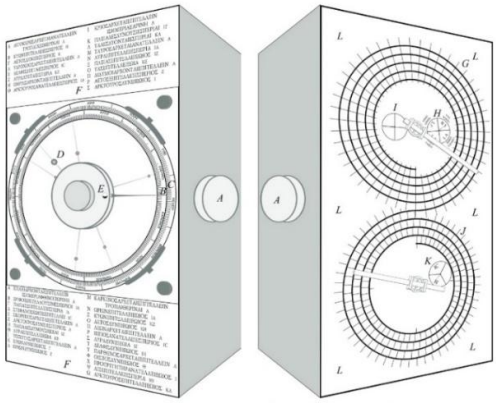

Fig. 2. The external aspect of the Antikythera Mechanism according to the most current research
Source: JONES [11]

Fig. 3. Replica R1: front (left) and rear (right) face. The replica and the major fragmente found in the shiwreck. Authors' design and images

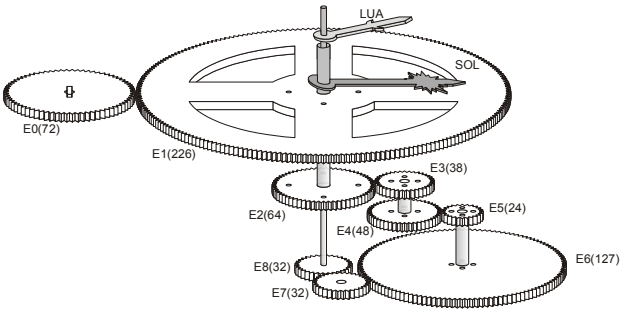

Fig. 4. Replica R2 gear train. In parentheses are the number of gear teeth. Author's design and illustration

Fig. 5. Replica R2: front (left) and rear (right) face. Author's design and images

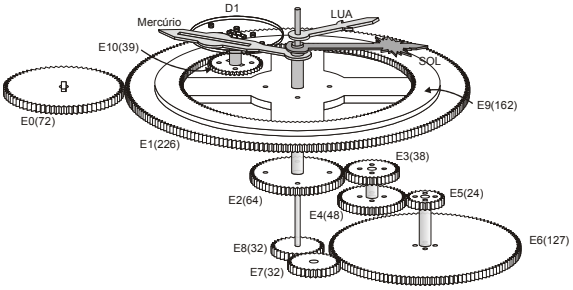

Fig. 6. Replica R3 gear train. In parentheses are the number of gear teeth. Author's design and illustration

Fig. 7. Replica R3: front face (left) and highlight the epicyclic gear and the planet Mercury pointer (right). Author's design and images

1.5 Simplified Didactic Replica of Sun-Moon-Mercury of Single Panel (R3)

The simplified didactic replica R3 was designed from the layout of the previous model, that is, with the unitary planetary panel. The difference is that, in addition to the indicator hands of the Sun and Moon, this model also features the indicator hand of the planet Mercury. For this, modifications were made to the larger gear to allocate the epicyclic gears that control the pointer that represents the position of Mercury. The acrylic front panel has also been modified, featuring a large internal teething gear. Fig. 6 illustrates the gear train of replica R3. In figure 7 are photos of the assembled and functional replica R3.

2. CONCLUSION

The original drawings of the pieces in real size are available in files for download. From these files it is possible to manufacture the parts in laser cutting systems. Instructions for building auxiliary parts, such as gear axles, and for mounting replicas are also included. The files are available on the Physics Resources website, by prof. Dr. Ricardo Francisco Pereira, at http://www.recursosdefisica.com.br[3], who kindly provided the space on his portal.

The Antikythera Mechanism synthesizes the Science of Greek Antiquity in an optimized and harmonious set of gears. Astronomy and mathematics are found in this machine that is more than 2,000 years old. The Mechanism's history and sophistication makes it a motivating tool for students and astronomy and science enthusiasts.

Having pointed out these aspects about the Antikythera Mechanism, the construction of simplified didactic replicas was proposed. These replicas of the Mechanism, and didactic instruments in general, give more materiality to the concepts studied, converging them in a single device. The costs for the construction of these replicas, in the three different levels of complexity presented in this study, are feasible for an educational institution, a scientific dissemination group and even for many individuals, such as education professionals and enthusiasts of Astronomy and History of Science [14] [15] [16].

[3] *More specifically in: http://www.recursosdefisica.com.br/manual-de-montagem.html This website, authored by Ricardo F. Pereira, presents a complete description of the different parts that make up the replica, including Wilson Guerra's Master dissertation work, supervised by Prof. Marcos C.D. Neves.*

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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