Antikythera Mechanism: A hypothetical A1 dial to provide in absolute terms both the Egyptian Regnal Year and the offset of the Egyptian Calendar Ring.

Jonathan Trent, https://github.com/jonTrent/AntikytheraMechanismPapers

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Purpose

This paper proposes a hypothetical auxiliary dial on the Antikythera Mechanism, associated with the input crank, with the dual purpose of providing a means to determine in absolute terms both the Egyptian regnal year and the offset of the Egyptian calendar ring. This hypothesis is based on the A1 gear of 48 teeth meshing directly with the B1 solar gear having 223 teeth[1]. Other than the dial, no other physical or engineering elements are required of the current model of the Antikythera Mechanism to incorporate this calendar information.

Principle behind the Hypothetical A1 Dial

With A1 being 48 teeth and B1 being 223 teeth, there are no common factors between the number of teeth, and therefore the gears represent a hunting ratio. Thus, every full rotation of B1, representing a solar year, will increment A1 a fixed rotation relative to the prior solar year. An analysis of the ratio between the A1 and B1 gears reveals a simple relationship useful during the operation of the device.

Every 4 solar years, the B1 gear will turn through 892 teeth (223 * 4), which corresponds to A1 turning 18 full times and an additional 28 teeth. This leaves the A1 gear 210° further (360° * 28 / 48) relative to its position 4 solar years prior. In 8 solar years, the B1 gear will turn 1784 teeth (223 * 8) and subsequently the A1 gear turns 37 full times and an additional 8 teeth.

In short, in 8 solar years, the A1 crown gear will be 8 teeth beyond its initial position. In exactly 16 solar years, the A1 crown gear will be 16 teeth beyond its original position, and in 24 solar years 24 teeth, etc. This simple relationship between the A1 and B1 gears offers the possibility that a dial associated with the input crank existed to determine, in absolute terms, both the Egyptian regnal year and the offset of the Egyptian calendar ring.

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[1] ISAW Papers 4: The Cosmos in the Antikythera Mechanism, Section 2.4.1 Internal Architecture, Feb 2012, Tony Freeth & Alexander Jones.

General Considerations

The Antikythera Mechanism is a phenomenal discovery from antiquity, on par with the Rosetta Stone, brilliantly conceived, with the then known cosmology masterfully woven into a mechanical device with economy bordering beyond belief, requiring decades for modern man to divine.

With the modeling of the cosmos, the Antikythera Mechanism includes the manmade construct of the Egyptian regnal calendar as a means of attributing a date to a cosmological event. The Egyptian regnal calendar is a constant 365 days, and therefore is not tied to any cosmological periods, neither solar, lunar, Callippic, or Metonic.[2] As such, every 4 solar years, it falls behind by 1 day relative to the same point in the solar year. In order to incorporate the alignment of the Egyptian regnal calendar with cosmological events, the designers of the Antikythera Mechanism included a movable calendar ring.

It is interesting to note from the literature on the Antikythera Mechanism that there is much wonder over the construction of gears with such a great number of teeth. The largest gear consists of 223 teeth, but one tends to forget that the front dial has 365 holes in a circular pattern to permit adjustment of the calendar ring. This is 64% more circumference points than the largest gear, and furthermore, drilled rather than filed, likely posing a greater challenge in construction than any single gear. To expend the time to craft a means to periodically rotate the calendar ring is an indicator of the importance of attributing a past or future cosmological event with a known, specific date.

Thus, it is safe to say that correlating an Egyptian regnal date with a cosmological event is of primary importance behind the Antikythera Mechanism. The various dials on the front and back plates provide the visualization of the cosmos along with pointers to the lunar and solar glyphs[3], allowing the operator to move forward and backward in time to the cosmological event of interest. All the dials on the Antikythera Mechanism are configured to naturally rotate through their cycles in perpetuity, keeping in alignment with each other. (Although of course, some dials will lose their accuracy the further away from the baseline setting of the device due to the limitations of the gearing ratios to accurately match the cosmos.) Even the Saros and Metonic dials will rotate through their spiral cycles in perpetuity, although the operator must be mindful to adjust the pointer-followers to the beginning or end of the spiral cycles as the case may be.

But the calendar ring, which is critical in establishing a date for a cosmological event, must be manually moved every 4 solar years, with the possibility of the operator losing track of the required rotation relative to the baseline setting of the device. That is, if the Antikythera Mechanism is dialed forward (clockwise) in time 32 solar years, then the calendar ring must be rotated counterclockwise 8 holes to accommodate the 8 leap days over that period. The challenge with the calendar ring is that there is no clear way to set the ring in absolute terms. Furthermore, there is nothing to indicate the Egyptian regnal year, so one must be mindful to keep track of the Egyptian regnal year through every revolution of the solar year.

It is not unreasonable to think that after numerous back and forth uses of the Antikythera Mechanism, that the movement of the calendar ring will be forgotten, not to mention knowing the Egyptian regnal

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[2] Calendrica I: New Callippic Dates, Alexander Jones, 2000.

[3] Decoding the Antikythera Mechanism: Investigation of an Ancient Astronomical Calculator, published in Nature Volume 444 Issue 7119, 2006. Tony Freeth et al.

year currently represented. With the A1 crown gear of 48 teeth and the B1 solar gear of 223 teeth, determining the Egyptian regnal year in absolute rather than relative terms is possible.

Using the Hypothetical A1 Dial in determining the Egyptian Regnal Year and offset of the Egyptian Calendar Ring

With B1 having 223 teeth and A1 having 48 teeth, each rotation of B1 through 8 solar years leaves the A1 gear 8 teeth further in the same clockwise or counterclockwise direction. To leverage this ratio to determine the Egyptian regnal year and subsequently the calendar ring setting, the following are critical prerequisites.

- *Baseline the Antikythera Mechanism*: The Antikythera Mechanism must by necessity be baselined, or set, such that all the gearing for the planets, lunar cycles, and sun are in accordance with the cosmos. This cosmological point in time will have to be attributable to a specific Egyptian calendar date, including not only the month and day as indicated by the calendar ring, but also attributable to an Egyptian regnal year.

- *Use the Olympiad/Games Dial to Determine the Leap Year*: Since the Olympiad dial is established as quad annual[4], it is appropriate for indicating which solar year of the 4 solar year cycle is to be treated as the leap year.

- *Establish Stationary Reference Point for Leap Day Indicator*: The date pointer, being tied directly to the B1 gear as proposed by the most recent evidentiary planetary reconstruction[5], will require a stationary reference point on the front plate to determine when it has made a complete rotation. If this corresponds with the Olympiad/Games dial is in the proper quadrant, then the calendar ring will require adjustment. As to when during the solar year to incorporate the extra day, which necessitates a shift in the calendar ring, is not clear to the author. The shift in the calendar ring is essentially the precipitation of the variance in the Egyptian regnal calendar and the solar year due to the accumulative effects of the extra ¼ day per solar year, and thus the calendar ring shift will likely have to occur at a point which minimizes this variance on a daily basis over the course of the 4 solar years. For the purposes of this conceptual discussion, and to avoid becoming entangled in the complexities of where the stationary reference point is located on the front dial, an arbitrary fixed location will be selected.

In order to make use of the above to determine in absolute terms both the Egyptian regnal year and the offset of the Egyptian calendar ring, a hypothetical dial surrounding the input knob associated with the A1 gear is proposed.

For purposes of this discussion and to exemplify the concept, since the Antikythera Mechanism is estimated to be from the latter half of the 2nd century BC, within the era of Hipparchus, the Egyptian

[4] Calendars with Olympiad and Eclipse Prediction on the Antikythera Mechanism, Nature 2008, Tony Freeth, Alexander Jones, John M. Steele & Yanis Bitsakis.

[5] ISAW Papers 4: The Cosmos in the Antikythera Mechanism, Section 2.4.1 Internal Architecture, Feb 2012, Tony Freeth & Alexander Jones.

regnal year will be based on the Astronomical Era of the Death of Alexander the Great, with 323 BC as regnal year 1.[6] For simplicity sake in explaining the concept, a baseline cosmological setting of the Antikythera Mechanism of 124 BC which conveniently equates to regnal year 200 will be identified at the top of the dial. Again, these example dates are for discussion purposes only, to exemplify the concept at hand.

Research shows that when facing the front face, the A1 input gear is forward the B1 gear[7]. Therefore, a clockwise rotation of the A1 input crank yields a clockwise rotation of the B1 solar gear. Thus, after forwarding B1 clockwise a total of 8 solar years or 1784 teeth (223 * 8), the A1 gear will have turned 37 full times plus an additional 8 teeth, leaving the A1 gear 60° (ie, 360° * 8 / 48) clockwise from where it was prior, now representing year 208. Rolling B1 forward 16 solar years leaves the A1 gear 16 teeth offset, or 120°, representing year 216, and so on.

If only representing the 8 year solar cycles, the dial appears as follows, indicating the Egyptian regnal year and the offset of the calendar ring, that is, the number of leap days, relative to regnal year 200:

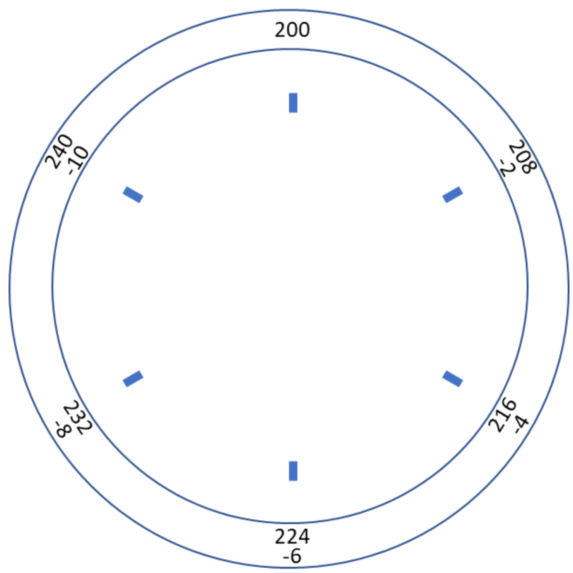

Figure 1: Input crank dial with indicators every 8 solar years.

Likewise, if starting at year 200 and reversing B1 counterclockwise a total of 8 solar years, then the A1 gear will be 60° counterclockwise of year 200, representing year 192. This introduces potential overlap of the indicators on the dial, so a proposed inner scale is employed to show the regnal years before regnal year 200. Such a dial appears as follows:

[6] Egyptian Dates, http://www.tyndalehouse.com/Egypt/ptolemies/chron/egyptian/chron_lnk_intro.htm, 2011 Chris Bennett.

[7] ISAW Papers 4: The Cosmos in the Antikythera Mechanism

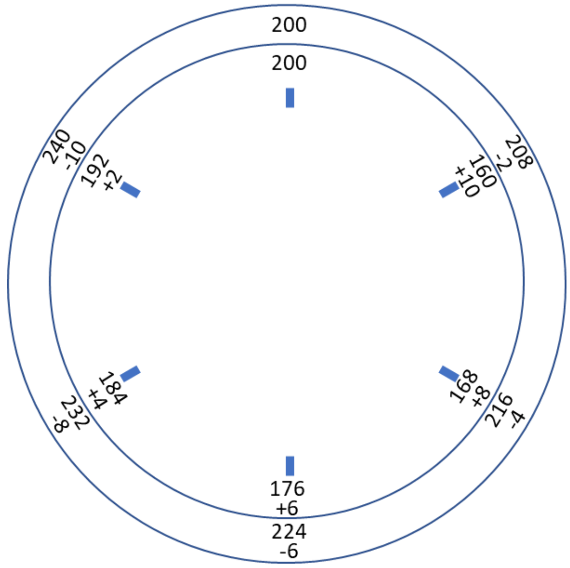

Figure 2: Conceptual input crank dial with both forward and backward indicators.

The 4 solar year cycles are just as easily employed but are not necessarily in sequence with the 8 year solar cycles. During the 4 solar year cycles, the B1 turns 892 teeth (223 * 4), which correlates to A1 turning 18 times and an additional 28 teeth, leaving the A1 dial at 210° (ie, 360° * 28 / 48). Then, every additional 4 solar years are once again 210° further around the dial. Carrying this logic to both the inner dial (less than regnal year 200) and outer dial (greater than regnal year 200) results in a hypothetical dial as follows:

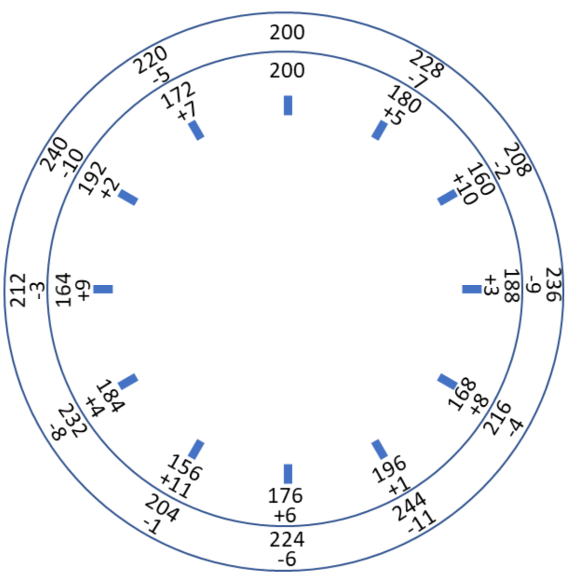

Figure 3: Hypothetical input crank dial with all indicators.

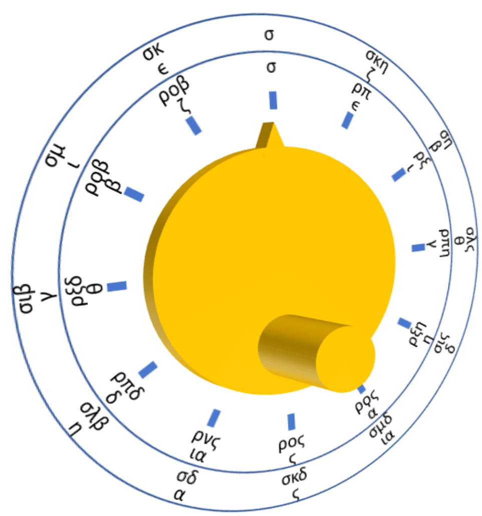

Figure 4: Hypothetical input crank dial with Greek numbers.[8]

[8] Historical Numbers, WolframAlpha: https://www.wolframalpha.com/examples/mathematics/numbers/historical-numbers/

Each tick mark represents a 4 solar year cycle, identifying the Egyptian regnal year and the number of leap days that the Egyptian calendar must be rotated relative to its origin when baselined at regnal year 200.

To illustrate the use of the input crank dial with an example, let us suppose the following:

- The Antikythera Mechanism is baselined at 124 BC, or Egyptian regnal year 200.
- The stationary reference point for the leap day is near the 1 o'clock position of the front dial, and let us say that in Egyptian regnal year 200, this reference point coincides with the beginning of Egyptian month ΦΑΡΜΟΥΘΙ.[9]
- The 1st of Egyptian month ΦΑΡΜΟΥΘΙ then is also always considered a reference point from which to begin counting off the movement of the calendar ring relative to the stationary reference point.
- Assume the Olympiad/Games pointer when referencing Olympia is considered the leap year.
- It can then be assumed that with the date pointer at the 1st of Egyptian month ΦΑΡΜΟΥΘΙ, in Egyptian regnal year 200, and the Olympiad being Olympia, that we are at the beginning of a 4 solar year cycle prior to the next leap day that affects the Egyptian calendar ring.
- The pointer on the input crank is initially set to 200 on the hypothetical dial.

Now, suppose that someone comes along and begins using the mechanism, dazzled by the cosmos in miniature. They eventually discover a cosmological point of interest, somewhere in the vicinity of Egyptian regnal year 220, but have lost track of the number of full turns of the solar year. Let's assume the mechanism, unbeknownst to the operator, is actually 17½ solar years ahead of the baseline point of Egyptian regnal year 200. To determine the Egyptian regnal year and establish the orientation of the calendar ring requires the following straightforward steps.

- The mechanism must first be rolled back until the Olympiad/Games pointer is referencing Olympia, and then further adjusted within that solar year such that the date pointer is aligned with the 1'oclock stationary point on the front face. If the Antikythera Mechanism is 17½ solar years ahead of the baseline (unknown to the operator), then rolling back 1½ solar years bring about the alignment of the Olympiad dial with Olympia and the date pointer with the 1'oclock stationary point on the front face. That is, the device is now exactly 16 solar years (i.e., 4 Olympiads) in advance of its baseline position, but this amount is not yet known by the operator.
- At 16 solar years since the baseline setting of the Antikythera Mechanism, that is equivalent to 223 * 16, or 3568 teeth of the B1 gear meshing with the A1 crown gear. This represents 74 full turns of the A1 crown gear, and an additional 16 teeth.
- Thus, the operator can now look at the hypothetical A1 dial, which will now be 16 teeth clockwise relative to the starting point of Egyptian regnal year 200, and now pointing at the tick mark indicating Egyptian regnal year 216, and the 4 leap days that need to be applied to the Egyptian calendar ring.
- So, bearing in mind that the baseline position for the stationary reference point was the 1st of the Egyptian month ΦΑΡΜΟΥΘΙ, the calendar ring must now be realigned counterclockwise 4

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[9] The selection of this point simply coincides with the Fig 4 in the ISAW Papers 4: The Cosmos in the Antikythera Mechanism.

holes, such that the 5th day of ΦΑΡΜΟΥΘΙ is now aligned with the stationary reference point on the front plate.

- The Antikythera Mechanism date pointer is now accurately referencing the 5th day of ΦΑΡΜΟΥΘΙ regnal year 216.
- The operator can now proceed to move forward again the 1½ solar years to the cosmological point of interest, this time easily keeping track of the Egyptian calendar date.

At first blush the sequence involved to determine the Egyptian regnal date and set the calendar ring might appear to be involved, but a recap of the general steps show that it is straightforward:

- Roll backward in time, aligning to the appropriate Olympiad/Game and then refining the alignment of the date pointer with the stationary reference point on the front plate.
- Simply read the A1 dial, noting the Egyptian regnal year and the amount of rotation of the calendar ring. Of course, the operator will have to generally know whether the device is representing a time before or after the baseline setting regnal year 200.
- Lift, orient, and set the calendar ring by using the stationary reference point and the baseline Egyptian month and day as the starting point, and then proceed forward to the cosmological point of interest.

Additionally, there is nothing preventing the operator observing the hypothetical dial as the Olympiad/Games and date pointers pass their critical positions, in order to note at that moment the Egyptian regnal year and calendar ring offset.

Concluding Remarks

Attributing an Egyptian date to a cosmological event appears to be a critical function of the Antikythera Mechanism, as the builders went to great lengths to incorporate a rotatable calendar ring involving a circle of 365 drilled holes among other calendar functions. Currently, there is no apparent means in the reconstructed models that suggests how in absolute terms, through the continued use of the Antikythera Mechanism, that the Egyptian regnal year is determined along with the orientation of the calendar ring. With the A1 crown gear, though, having 48 teeth and the B1 gear 223 teeth, the A1 crown gear advances 210° every 4 solar years, yielding a means to incorporate a dial on the input crank that provides critical calendar information, specifically both the Egyptian regnal year and the number of leap days to adjust the Egyptian calendar ring.

The dial as hypothesized only covers a span of 80 solar years, but it has also been noted that the Antikythera Mechanism is not all that accurate, and thus an 80 year range is likely sufficient for confirming the Mechanisms ability to calculate cosmological events in the past, and predicting events in the future. Of course, the operator can manually track the 48 year epochs represented by the hypothetical dial, and readily determine the regnal year and leap days using minor math.

Additionally, there is likely no physical evidence remaining to even suggest a dial on the side of the Antikythera Mechanism was collocated with the input crank, but given the masterful, thoughtful design, it is hard to imagine that something as basic as knowing with certainty the Egyptian regnal year and the alignment of the Egyptian calendar ring when employing the device was left unaddressed…