Compasses
For Determining the Times of Prayer

In an as yet unpublished manuscript, written most probably by the well-known astronomer Abū ʿAbdallāh Muḥammad b. Mūsā al-Ḥwarizmi¹ (1st half of the 3rd/9th c.), a simple instrument is described which served to determine the times of prayers (barkār yaʿrafa bihi l-aʿaqāṭ li-ṣ-ṣalāt wa-yuqāsu bihi ẓ-zīl). The description was studied by J. Frank and E. Wiedemann.² Their summary runs as follows: “The instrument is a type of compasses, whose arms on their outer sides have a table showing the lengths of the shadow of the compasses when they have been set up vertically in the ground with the iron tips that are affixed at their free ends, at the time of observing the ‘asr [afternoon] prayer, for all positions of the sun in the zodiac. On the outer side of one of the arms the proportions of the values of the northern zodiac are marked, on that of the other those of the southern zodiac (see figure). The two other sides of the arms of the compasses have a scale in which the length of the compass arm (without the tip) is divided into 12 equal divisions (sometimes also into subdivisions). To determine the time of prayer, the folded compasses are pushed with the tips so deep into the ground that the beginning of the divisions of length coincides with the level of the ground. The endpoint of the shadow cast by the compasses is marked and the distance between it and the place where the compasses are pushed into the ground is measured by their length markings. For this purpose the compasses are stretched apart, since the shadow of one arm at the time of the ‘asr prayer is longer than the simple length of the arm. If the distance measured equals the value for the day, which can be derived from the table of the outer sides, then the time for prayer has begun. If this value has not yet been reached, the user must wait until this is the case.”

¹ Active under Caliph al-Maʾmūn (r. 198/813-218/833), v. F. Sezgin, Geschichte des arabischen Schrifttums, vol. 6, pp. 140-143). The preserved manuscript (Berlin 5790, fol. 77b-97b) seems to be a part of his Zīg or of his K. al-Asfurláb.
Chandelier clock
with Twelve Lamps

Replica of a device described by the well-known astronomer ‘Ali b. ‘Abdarrahmân b. Ahmad Ibn Yûnis (d. 399/1009), who was active in Egypt; he called this device for time-measurement Ŧuraiyâ (lit. “Pleiades”).

Each time an hour of the night has elapsed, one lamp goes out. The first lamp holds enough petroleum for one hour, the twelfth for twelve hours. If all the lamps are lit simultaneously, the number of hours can be read off on the basis of whether they are extinguished. According to Ibn Yûnis the twelfth lamp should contain 36 dirhams of oil for the longest night of the year and 24 dirhams for the shortest night. The chandelier therefore indicates temporal, i.e. unequal hours.

Our model:
Diameter: 80 cm.
Brass, gilded.
Height of the glass bottles: 18 cm.
(Inventory No. B 3.03)

Sundial of al-Malik al-Aṣraf

In his book Mu‘in at-tullāb ‘alā ‘amal al-aṣṭurlāb the third sultan of the Rasulid dynasty in the Yemen, al-Malik al-Aṣraf ‘Umar b. Yūsuf (ruled 694/1295-696/1296), offers a sketch of the sundial he designed for the latitude of Cairo. Aside from this astronomical work, treatises by him in the fields of medicine and genealogy have also come down to us. His extant astrolabe (see above, II, 105) testifies to his great abilities as an instrument maker (see above, p. 58).

Our model:
Engraved brass plate: 36 × 46 cm, with gnomon, inlaid in a table of hardwood.
Foot of brass.
(Inventory No. B 2.03)

Cylindrical Sundial

Among the sundials described by Abu l-Hasan al-Marrākušī there are two portable ones, one of which is cylindrical and the other rectangular. Both are valid for a specific latitude between the Equator and ca. 66°30' North or South. The vertical shadow lines, ascertained beforehand, are transferred to the surface of the cylinder, which is made of wood or brass. A prerequisite for the construction and use of both sundials is a table showing the values of the vertical shadow lines for the duration of the hours of daytime and of the night at the beginning of the


Our model:
Height: 19 cm. Wood, lacquered.
Calibrated for latitude 41°.
(Inventory No. B 2.07)
cylindrical dial as follows (see fig. above). For our model we have followed two Ottoman specimens of this type of sundial from the 18th century. One of them is in the museum of the observatory of Kandilli in Istanbul, the other belongs to the estate of Marcel Destombes (presently in the museum of the Institut du Monde Arabe, Paris).

On the question of the possible continuation of this type of sundial, v. A. J. Turner et al (Eds.), *Time*, The Hague 1990, no. 200, pp. 105, 114. There is represented the picture of a European specimen of about 1600 from a private collection:

(anonymous, late 16th c., Florence; Ist. e. Mus. di Storia della Scienza, Florence, Inv. no. 2457).

The Sundial
called 'Locust Leg'

A simplified version of the above-mentioned sundial is described by al-Marrāḵūšī (op. cit., p. 236; transl. Sédillot, op. cit., p. 440) by the name of sāq al-ḡarāda (“locust leg”). The instrument was known by this name probably because of its simplicity and because the user could carry it comfortably. In the Arabic-Islamic world the modesty of a gift is expressed by this term (pāy-i malaḥ in Persian, çekirge buду in Turkish). Al-Marrāḵūšī’s sketch and the accompanying table are reproduced below:

In our model we have followed the specimen which is preserved in the Cabinet des médailles of the Bibliothèque nationale in Paris. It was acquired in 1895 by M. Durighello in Beirut. The instrument had been constructed in 554/1159 by a certain Abu l-Farağ ʻĪsā, pupil of al-Qāsim b. Hibatallāh al-Aṣṭurlābī, for the Syrian ruler Nūraddin Mahmūd b. Zanjī (ruled 541/1146-569/1174).

The Sundial from the Omeyyad Mosque in Damascus

The sundial dating back to 773/1371 of the Umayyad mosque in Damascus, whose original form goes back to the time of the rule of Caliph al-Walid b. 'Abdalmalik (ruled 86/705-96/715), represents the climax of this type in the Arabic-Islamic world. It was made by the astronomer 'Ali b. Ibrāhīm b. Muḥammad Ibn aš-Šāṭir (b. 705/1306, d. 777/1375). The sources praise this scholar for the construction of his sundial, for his astronomical tables, his planetary theory, his universal instrument (al-āla al-ḡāmi’ā) and for his unique clock, which was constructed in such a way that it could run by itself, day and night, without the aid of sand or water, and could show the equal hours as well as the unequal hours.² In Damascus, Ibn aš-Šāṭir acted as mosque astronomer (muwaqqit) and as chief muezzin (ra‘is al-mu‘adžīnīn).

The sundial which he made, measuring 1 × 2 metres, is of an unusual size. Until 1958, the original was thought lost. While repair work was being carried out, it was found again, broken into three pieces. Probably it had broken during a correction [92] undertaken in 1873 by the astronomer aṭ-Ṭaṭāwī.³ He claimed to have found an error and

---


then replaced the original with a copy, which is now in a passage at the foot of the minaret known as al-ÆArús at the north side of the mosque. The sundial constructed by at-ŒTanŒawi is in fact a true copy of the original, the three parts of which are now preserved in the Syrian National Museum in Damascus.

The sundial consists of three parts. The central part shows the unequal, or temporal, hours, with a precision of four minutes. The northern and the southern parts are calibrated for the equal, or equinoctial, hours.

Photograph of the original from Centaurus, vol. 16, to p. 288.

Figure from: Centaurus, vol. 16, p. 289.

The Sundial
of Ibn al-Muhallabi

The sundial, which Zainaddin 'Abdarrahmān b. Muḥammad Ibn al-Muhallabi al-Miqāī, an Egyptian mosque astronomer (muwaqqit), described and drew in 829/1426 in his book 'Umdat ad-dākir li-wad' ḥuṭṭ faddl ad-dā’ir, is preserved in a manuscript of the Chester Beatty Library in Dublin. It was calibrated for the latitude of Cairo (30°). It shares its unusual, bipartite construction with the sundial of the Ibn Ṭūlūn mosque in Cairo of 696/1296, whose remains were depicted in the Napoleonic Description de l’Égypte around 1800.

1 No. 3641 (copied 858/1455), fol. 11b.
What is most probably a pseudo-Archimedean treatise on the water clock reached the Arabic-Islamic world quite early. The historian of science Ibn an-Nadim\(^1\) registered a *Kitāb Ālat sā'āt al-mā' allati tarmī bi-l-banādīq* among the works by Archimedes known in the Islamic world. Donald R. Hill, who examined the booklet and translated it into English,\(^2\) is of the opinion that the first four chapters were translated from a Greek copy and that the other parts originated in the Arabic-Islamic world. It was Baron Carra de Vaux\(^3\) who drew attention to the existence in a Paris manuscript (Bibliothèque nationale, ar. 2468) of the treatise on the water clock ascribed to Archimedes. Subsequently Eilhard Wiedemann and Fritz Hauser translated the treatise into German using the Paris manuscript and two other manuscripts (London and Oxford).\(^4\) Today a total of seven manuscripts are known.

Our figures (see below) are taken from the Istanbul manuscript of the Ayasofya collection 2755 (fol. 70b-80b).

---

\(^{1}\) *Kitāb al-Fihrist*, ed. Gustav Flügel, Leipzig 1872, p. 266.


The clock shows unequal temporal hours in two pillars, in each of which a weight passes an hour scale (on the left upwards, on the right downwards). Besides, after each hour a ball is released and, gliding through the beak of a bird, falls on to a bell. Moreover, the eyes in the face painted on the clock change their colour.

In the course of the day, or of the night, water, emptying uniformly from a tank, propels and guides the underlying mechanism, whose speed (over the water inlet) can be regulated according to the season by turning the end of the pipe, which is bent towards a semi-circular calendar sheet.

We are grateful to Professor André Wegener Sleeswyk, Rijksuniversiteit Groningen, for reconstructing the clock which he also described: Archimedisch: de Mijlenteller en de Waterklok. Natuurkundige Voordrachten N. R. 67, Lezing gehouden voor de Koninklijke Maatschappij voor Natuurkunde Diligentia te s’Gravenhage of 19 september 1988.

Fig. in the MS Istanbul, Ayasofya 2755 (fol. 70b-80b).
In his book\(^1\) al-Ġazari (ca. 600/1200) describes a candle clock (\textit{finkān al-kāthib}) made by one Yūsuf\(^2\) al-Asflurlābī, which he criticises from different aspects and replaces by his own construction. About its function he says: “The thing functions in the following way: the candle is inserted into the sheath at sunset, putting one ball after the other into the beak, up to 15 pieces. At that time the reed pen is outside the first degree. Now the candle is lit. Its flame is larger than that of a candle burning without this arrangement. This is a consequence of the wax collecting around the wick. The reed pen moves until its tip has reached the first mark; this is the first degree; then 1 degree of an hour (4 minutes) of the night has elapsed. When the tip reaches the 15th degree, the falcon throws a ball into the bowl under the candlestick. Thus it goes on until the night is over. There are as many balls in the bowl as there are hours in the night. The reed pen indicates the degrees, which do not result from the balls.”\(^3\)

\(^{1}\) Al-Ġāmi’ bain al-‘ilm wa-l-‘amal (MS Istanbul, Topkapı Sarayı, Ahmet III, No. 3472), 151-152; D. R. Hill, \textit{The Book of Knowledge of Ingenious Mechanical Devices}, pp. 87-89.

\(^{2}\) Some manuscripts have Yūnūs instead of Yūsuf.

\(^{3}\) Translated by E. Wiedemann and F. Hauser, \textit{Über die Uhren im Bereich der islamischen Kultur}, op. cit., p. 157 (reprint, op. cit., p. 1367).

---

\textbf{Our model:}
Total height: 60 cm.
Wood with engraved brass facings.
Brass candle holder.
Copper bowl with brass ornaments soldered to it.
Carved wooden figures.
(Inventory No. B 3.10)
As the Andalusian polyhistorian Lisânaddîn Ibn al-Ḥāṭîb (Muḥammad b. ʿAbdollāh b. Saʿīd, d. 776/1374) reports, the ruler of Granada, Muḥammad V (ruled 1354–1359, 1362–1391) displayed a clock meant for night hours on the occasion of the Maulid (celebration of the birthday) of the Prophet Muḥammad in 763/1362. After the discovery of the manuscript of the third part of the Ṣūfādat al-ǧirāb fī ʿalāqat al-īgtîrâb—long thought lost—by Ibn al-Ḥāṭîb,1 the Spanish Arabist E. García Gómez2 edited the relevant text and translated it into Spanish.

The container of the clock consists of a covered twelve-sided wooden case with twelve doors. At the centre of the top cover stands a candle that is divided into twelve equal parts. As the candle burns down, twelve pegs weighted with a counterweight are released from the wax, one after the other. The pegs are affixed in such a way that the distance between them corresponds to one hour’s burning of the candle. When one of the pegs falls down, in each case the counterweight pulls another peg with it, which releases a lattice in one of the doors. This falls down into a rail inside the clock, with the result that a rolled up scrap of paper with verses appears in the opening of the door, describing the hour of the night that has just elapsed. At the same time a ball falls into a beaker, producing an acoustic signal. The equal hours that have elapsed can be read off from the number of opened doors.

Water Clock
of Riḍwān as-Sāʿāti

Our model:
- Scale: 1:2.5.
- Measurements:
  - 130 × 80 × 180 cm.
- Hardwood with inlaid mother-of-pearl ornamentations.
- Birds and bowls of brass.
- On the back, glass doors with brass frames.
- Water container of copper inside the clock.
  (Inventory No. B 1.01)

The water clock constructed by Muhammad b. ʿAli (d. 618/1231), which was much damaged after his death, was repaired by his son, Riḍwān “the clock maker”, who described it in detail with all its components in a book on clocks. According to our knowledge, two manuscripts of the book are preserved, one in Istanbul, Köprülü Collection 949, and the other in Gotha, Forschungsbibliothek 1348. The book was translated into German in 1915 by Eilhard Wiedemann after the Gotha manuscript.¹

Inside view of our replica.

Figure from the Köprülü MS.

The outflow nozzle is shifted to the position of the respective zodiac sign upon a plate, calculated for the calendar of Frankfurt on Main. The mechanism is driven by water, which flows out between sunrise and sunset (or vice versa) and, while doing so, propels a float. Uniform outflow is achieved through pressure compensation. The twelve segments of time of the temporal hours are indicated in such a way that, after each hour of the day, a door at the front opens. Moreover, a crescent of the moon above the doors indicates a quarter of these periods, by passing 48 golden nails one after the other from the left to the right. Aside from the optical indications, after each hour of the day two acoustic signals can be heard which occur when the figures of two falcons drop one ball each from their beaks into a beaker. During the night, twelve illuminated circles of a disc are released one after the other on the roof of the clock. These circles are illuminated by a lamp and indicate the hours.
The Water Clock
(with the Elephant)

Our model:
Total height: 230 cm.
Elephant, figures
and tower of wood.
Domes and snakes of brass.
Water container of copper
inside the elephant.
(Inventory No. B 1.06)
Reconstruction in original size of a water clock invented by al-Ḡazārī ca. 600/1200 and described in his book *al-Ḡāmi‘ bain al-‘ilm wa-l-‘amal an-nāfi‘ fi ṣinā‘at al-hiyal*. This is a water clock which signals 48 intervals, spaced at 30 minutes each, thus indicating 24 equal hours. (For demonstration purposes the time interval was shortened to about three minutes). A “scribe”, sitting on the back of the elephant, indicates these intervals by discreetly moving his reed pen after each half hour by one mark on the scale. The clock also shows half and full hours by a figure in the tower who lifts his right arm at each full hour and his left arm at each half hour. The mechanism is set in motion every 30 minutes by a hemispherical float [102], which drifts on a basin filled with water inside the elephant. The float has a precisely calculated hole in its base through which so much...
water within 30 minutes enters that it no longer has buoyancy and sinks. When this happens, a ball in the tower is released via a thread and, with its downward movement, sets various figures in motion. A bird turns around, the figure in the tower lifts his arms one after the other, two snakes move downwards and pull the float again to its original position. The scribe moves and the figure sitting on the head of the elephant strikes the elephant with a whip in his right hand and a drum with a stick in his left hand.

The elephant clock seems to have stirred the imagination of makers of figurine clocks in Europe in the 16th and the 17th centuries. Several elephant clocks are known at present. One of them dates from the early 17th century and is in the Bayerisches Nationalmuseum in Munich. A second one, from ca. 1580, belongs to a private owner, also in Munich. On the third specimen, made ca. 1600 in Augsburg and in a private collection in 1980, see Die Welt als Uhr, p. 266, no. 92.

2 Die Welt als Uhr, p. 264, no. 91.
Among the numerous clocks listed by al-Ḡazarī (ca. 600/1200) in his Gāmi‘ bain al-ʿilm wa-l-ʿamal, he describes the beaker clock as his own invention:\(^1\) “The ruler, aš-Ṣāliḥ Abu l-Fath Maḥmūd b. Muḥammad b. Qarā-arslān … requested me to make an instrument which has no chains, balances (mīzān)\(^2\) or balls, which does not change quickly and does not decay, and from which one can see the passage of the hours and their divisions. It should have a beautiful shape and be a companion during journeys and at home. I exerted my mind and made it in the following way. The clock consists of a beaker on a base, on the top it is covered with a flat lid. Around its periphery runs a chiselled gallery (ṣūrfā) and on the gallery is a delicate horizontal ring, divided into 217½ (=14 ½ × 15) divisions; each 15 divisions represent one equal hour.”


\(^2\) On this Wiedemann remarks: “Balances and apparatuses for tilting were used in numerous ingenious devices.”
“A scribe is seated on a seat at the centre, holding in his hand a reed pen, the tip of which is on the ring a little outside the first mark on the scale. It moves nearly imperceptibly from the beginning of the day to the left uniformly until it reaches up to the first division of the 15 divisions of the equal hours and one hour of the day has elapsed.”

Inside the container there is a water clock. It shows hours of the day, to be read from the position of the reed pen on the cover above. For this, the time between sunrise and sunset is divided into twelve divisions, the so-called temporal hours. The seasonal difference in the motion of the sun is taken into account before the start by adjusting the reed pen towards the diameter, where various scales are marked (see above).

In order to ensure a constant angular velocity of the indicator, the problem of water pressure, which depends on the volume, has to be solved in all kinds of water clocks; there were various approaches chosen for this (see above).

The decisive achievement in the present case consists in the construction of a beaker shape which balances the decreasing water pressure with the sinking water level through a reduced volume of flowing water (i.e. the container becomes narrow in such a way that the water level sinks uniformly, despite the decreasing outflow; in the manuscripts (see above) the beaker is seen to be drawn in the shape of a funnel; however, the text describes how the parabola—which we took as the basis for our model—was achieved empirically). A float, sinking on a central spindle, constantly turns the scribe with his pen by means of a cord and a wheel.

The longest day in the region where the clock was designed consisted of 14.5 hours. The exact calculation of the diameter of the cord pulley results in the scribe turning around himself exactly once between sunrise and sunset on this day. The time can be read on this day at the outermost scale marked on the disc, provided the reed pen was put on this position.

The shortest day has 9.5 hours. These can be read off the inner circular ring of the disc.

---


2 ibid, p. 136 (reprint p. 1346).
The division of the disc was described as follows by E. Wiedemann after al-Gazari:

“This figure gives, according to the statements of the text, an overview of the disc of the beaker clock for the ‘temporal’ hours. The division into hours was drawn completely in only some of the circles”

(Wiedemann, Gesammelte Schriften, vol. 3, p. 1350).

“The division of the disc was probably as is represented in the figure above for a dial equipped with 18 divisions (corresponding to 10 days each). All the 18 arcs of the circle started at an incised radius which represented the starting position of the scribe when the beaker was full. From here they progressed towards the left until each of them reached a radius that represented the position of the reed pen or, rather, of the dial at the sunset of the day corresponding to the relevant arc; provided the clock had been set in motion at sunrise. Since the outermost arc represented the longest day, the result was a system of concentric arcs of the circle which became shorter and shorter towards the middle. Since, according to the description, the outer wall of the beaker had been hammered in such a way that the hourly rotation was almost constant, and since the outermost arc representing the longest day of 14 1/2 hours subtended an angle at the centre of 360°, the innermost arc representing the shortest day of 9 1/2 hours subtended an angle of only 236°. Thus, of the 18 arcs each subsequent arc was approximately 7.3° shorter than the preceding one. The individual arcs were then divided into 12 equal divisions, each one separately; in addition, the outermost one was also divided into 14 1/2 divisions (this latter division was omitted in the figure above, with the former being executed completely in the case of a few arcs, while the remaining ones were only divided into four divisions). Each arc represented—assuming a year of 360 days—10 days each, both with decreasing and increasing daylight. Therefore, at each arc two numbers had to be entered for the days corresponding to it. In any case, these numbers were engraved on both sides of the inscribed radius, as shown above. If the numbering was begun at the longest day, then with the shortest day only one number—namely 180—had to be entered; but if, on the other hand, the user began with the numbers at the shortest day, then the same was the case with the longest day. With such a method of entering the numbers, these came to be always written on the same side of the proper arc of the circle. An arc which was at a distance of 180 from that of the day always represented the arc of the night.”

Translated (with minor changes) from E. Wiedemann’s version, ibid., pp. 139-140 (reprint pp. 1349-1350).
Water Clock
from Fez

Replica of a clock whose original is in the Qarawiyyin Mosque in Fez (Morocco) and was repaired by the Institute for the History of Arabic-Islamic Sciences. The maker of the original was called Abū Zaid ʿAbdarrāḥīm b. Sulāmān al-Lāḡāʿī. He constructed the clock in 763/1362 at the request of Sultan Ibrāhīm b. Abī l-Ḥasan b. Abī Saʿīd.

Our replica:
Wood, lacquered.
The wooden elements, elaborately painted over in a modern style, were made in Morocco.
Brass clock face, diameter 46 cm, 24 bronze bells.
All water containers inside the clock, made of copper.
Width: 4.30 m; height: 2.40 m.
(Inventory No. B 1.04)
This is the oldest extant water clock which divides the day into 24 equal hours. These can be read off a dial, which is divided into 4 minutes each. Every four minutes a small ball and every hour a large ball fall into one of the 24 brass bowls, producing a sound. Altogether 360 small balls and 24 large ones fall within 24 hours into the bowls and from there go into a collective receptacle. In addition to the acoustic signals, at the beginning of each hour one of the wooden doors closes, which give an overview of the hours elapsed and can even be recognised from afar. The mechanism is set in motion by water flowing out; this results in the sinking of a float to which all the functional components are attached by rolls of cord. The uniform outflow is achieved by means of a precisely calculated container for pressure compensation. An ingeniously designed, surprisingly advanced technology ensures that the two carriages move opposite to the direction of the sinking of the float.

In the eastern and central areas of the Islamic world technologies were cultivated which quickly reached the western part of this region too, and were disseminated and improved there; without doubt clock-making was also among those technologies. At present we are nowhere near being able to describe exactly the stages of development which clock-making underwent in continuation of the achievements of the preceding periods in the eastern and western areas of Islam. In this connection it is of great importance that in a book which basically represents a compilation of Arab-Islamic sciences, the *Libros del saber de astronomía* commissioned by Alfonso X of Castile and written in Toledo around 1267-68, five clocks are described in a special chapter: a water clock, a mercury clock, a candle clock and two sundials.
The relogio dell agua is one of the five clocks mentioned in the Libros del saber de astronomía. Its detailed discussion is accompanied by a sketch. The compiler of the book is of the opinion that the description of this clock in his sources was “very meagre”. According to these, the water container had simply been bored through at the bottom, with the result that the water does not flow out uniformly, but less and less because of the decreasing pressure accompanying the diminishing volume. He had rectified this defect by his own “subtle inventions”. In reality, the provision for a uniform outflow of water, not only for water clocks, but also for other hydraulic automata, was known and commonly used in the Arabic-Islamic world, as had been done earlier by the Greeks. What is measured is the unequal temporal hours.

As the model shows, in this clock the water from the container, which is placed at a higher level, flows across a pressure compensator, providing buoyancy to a float in the lower container. By this means a table affixed to it is pushed above the top edge of the container, where the time for the zodiacal sign concerned can be read off.

Our model was constructed by Eduard Farré (Barcelona).
2. Mercury Clock

The fourth clock mentioned in the special chapter of Libros del saber de astronomía is a mercury clock (relogio dell argent uiuo). A. Wegener describes it as follows: “The mechanism of this clock consists of a wheel which completes only one rotation in 24 hours. The propelling force is a weight; the escapement is provided by mercury inside the wheel and gives way to the pull of the weight only gradually, slowed down by transverse walls with only very small openings. The rotation of this wheel is transferred to an astrolabe which, in a way, can be considered the very ingenious dial of this clock, on which can also read off, besides the hours, the position of the sun and the stars at the same time and, in general, the entire view of the sky for that moment. It is said that it was also possible to combine the clockwork with a celestial globe instead of an astrolabe. Through a suitable attachment of bells it could be turned into a kind of alarm clock.”

On the process of the survival and the impact of this clock on subsequent developments in Europe, there is an excellent essay entitled The Compart-mented Cylindrical Clepsydra by Silvio A. Bedini. He establishes that the Libros del saber de astronómia were translated into Italian before 1341 and draws the conclusion: “The existence of this Italian codex is of considerable significance with relation to the subsequent development of the mercury clock in Europe and particularly in Italy, despite the fact that horological writers of the next six centuries made no reference to it.”

More than three hundred years after the Alfonsine compilation, the mercury clock appears again in European literature, viz. in a book by Attila Parisio that appeared in 1598 in Venice, in which Parisio claims to be the inventor of the clock ([111] (Dis-corso Sopra la Sua Nuova Invenzione d’Horologio con una sola Ruota)). In the clock which he allegedly invented the mercury was replaced by water. Shortly after the publication of Parisio’s book, the description and illustration of this clock appeared

---

2 Published in: Technology and Culture (Chicago) 3/1962/115-141.
4 Bedini, op. cit., p. 118.
5 ibid, p. 118.
as one of the “fundamentals of motive forces” (raisons des forces mouvantes) by Salomon de Caus (1615).  

The clock is also mentioned by Johannes Kepler.  

In this form, which was basically nothing more than the specimen described in the Libros del saber de astronomía, whose 12-part barrel was merely half filled with water instead of mercury and which is designated by Bedini as “compartmented cylindrical clepsydra”, this clock enjoyed wide dissemination in Europe in the 17th and 18th centuries. One of several types, differing slightly, is connected with the name of Pater Francesco Eschiniardi (1648). A similar apparatus was presented by the three Campani brothers (1656) to Pope Alexander VII. The barrel of this clock again contained mercury instead of water and it functioned about as inaccurately as the others. Still, it was praised by the Pope as an important invention. Nothing remains of the Campani clock except the description of a few of the features of its construction. 

After the clock by the Campani brothers, other versions appeared, now filled again with water instead of mercury. Mention may be made of the makers: Domenico Martinelli (1669), Dom Jacques Allexandre, who claimed in 1734 that this type of clock was an invention of Charles Vailly, and M. Salmon who, in an illustration in his L’Art Du Potier D’Étain, depicts the production of several cylindrical water clocks and thus establishes that they were very popular in France, particularly in the 18th century.

---

7 v. Anton Lübke, Die Uhr: Von der Sonnenuhr zur Atomuhr, Düsseldorf 1958, p. 78; Bedini, op. cit., p. 125.
8 Bedini, op. cit., p. 125.
9 ibid, pp. 127–128.
10 ibid, p. 129.
11 ibid, p. 129.
12 ibid, pp. 131–135.
13 ibid, p. 136.
14 ibid, pp. 137–138.
3.

Spanish-Arabic
Candle Clock

This clock is the third to be listed, under the name relogio de la candela, in the chapter on clocks of the Libros del saber de astronomía. There it is described at length and illustrated with diagrams.¹ On the side where it is burning, the candle sits in a sleeve, so that as it gets shorter its base can be pushed up by a counterweight. A thread connected to the bottom and loaded with an additional further counterweight then pulls the tablet up on which a table of the unequal hours (temporal hours) on the corresponding calendar days is inscribed. On the horizon of the clock the time can be read off when the date is known. The table is valid for only one specific climate zone.

Our model:
Brass.
Total height: 42 cm.
(Inventory No. B 3.08)

The model was constructed by Eduard Farré (Barcelona).

¹ A. Wegener, *Die astronomischen Werke Alfons X.*, pp. 163–164 (reprint, pp. 91–92).
Spanish-Arabic Sundial

The relogio de la piedra de la sombra is listed as the fourth among the clocks of the *Libros del saber de astronomía* and is illustrated with a figure. The spiritual father of this compilation, Alfonso X, opines that he had “for the construction of the sundial found no book which was complete in itself, so that one did not need any other book for the work.” It was for this reason, he said, that he had commissioned a detailed description.\(^1\)

---

\(^1\) v. A. Wegener, *Die astronomischen Werke Alfons X.*, op. cit., p. 162 (reprint., p. 90).
In the 44th chapter of his “Treatise on the Knowledge of Shadows” (Risāla fi ‘Ilm az-zilāl), Abū ʿAbdallāh Muḥammad b. Ibrāhīm ar-Raqqām1 (d. 715/1315) describes a sundial which is connected to a floating compass.2 This astronomer, mathematician and physician from Murcia was one of the scholars who were active under the Nasrids in Granada.

The lodestone, fixed to a piece of wood, serves to regulate the north-south direction for the sundial engraved on the lid of the wooden bowl. The dial is kept in equilibrium by being suspended from silk threads. A very similar apparatus (v. the next model) is ascribed to Pedro Nunes (1537).

---

Sundial
of Pedro Nunes (1537)

Figure from:
Instrumentos de navegación: Del Mediterráneo al Pacífico,
Barcelona n.d., p. 84.

Our model:
Diameter: 26 cm.
Brass, etched.
(Inventory No. B 2.15)
Water Clock
with Alarm Function

Our model:
Measurements: 60 × 60 × 30 cm.
Wheel and frame of hardwood.
Water containers of clay.
Brass dial with engraved Roman numerals (I-XXIV).
Bells of bronze.
(Inventory No. B 1.05)

The clock is described in the Latin manuscript 225 of the Benedictine monastery Santa Maria de Ripoll (at the foot of the Pyrenees). The manuscript, which might date back to the 13th century, is now in the Archivo de la Corona de Aragón in Barcelona. The mechanism of the clock betrays similarity to the first water clock described in al-Gazari’s book.1 The relatively simple mechanism is driven by a float in the lower container, which moves up as the water flows in and sets the wheel in motion. A small tin plate, placed on the rim of the wheel upon any given notch (= time of the day or night), drops a lead weight at the desired time while rotating.

This results in the unbolting of a clapper which, connected to a spool, is put into a rotary motion and, for about 5 seconds, strikes against the bells. Since the water flows with varying speed, due to lack of pressure compensation, a uniform measurement of time is not possible.

The model was built by Eduard Farré (Barcelona), who also described the construction: A Medieval Catalan Clepsydra and Carillon, in: Antiquarian Horology (Ticehurst, East Sussex) 18/1989/371-380.

The physicist 'Abdarrāhmān al-Ḥāzinī describes in the eighth chapter of his *Mīzân al-hikma* (515/1121) a ‘time balance’ which serves for measuring the 24-hourly rotation of the heavens. This balance, called *mīzân as-sāʿāt wa-azmānīhā*, consisted of a reservoir of water or sand, suspended from the beam of the balance and endowed with a precisely calculated small opening. By balancing the loss of weight through shifting of weight on the arm of the balance, the time elapsed could be read from a corresponding scale, almost as if one was weighing the weight of the minutes.

The ‘absolute balance’ (*al-mīzân al-kulli*) was contrived to run for 24 hours and was correspondingly large; it had two sliding weights and scales for hours and minutes. Our model is a reconstruction of the smaller ‘balance of minutes’ (*al-mīzân al-latīf al-ḡuz’ī*), which runs for one hour only and is equipped with a scale of 60 minutes for this purpose (*at-taqsīm as-sittīn*).

---

Mechanical Clocks of Taqiyyaddin

The Ottoman scholar of Arabic origin, Taqiyyaddin Muhammad b. Ma'ruf (b. 927/1521 in Damascus, d. 993/1585 in Istanbul), wrote in 966/1559, when he was qadi at Nablus, his book on mechanical clocks, *Kitab al-Kawkib ad-durriya fi wa'd al-bingamat ad-dauriya*. This work was preceded, among others, by his book on pneumatic apparatuses, *at-Tiruq as-saniya fi l-alaat ar-ruhaniya*, written in 959/1552, in which he devotes some space to the construction of water clocks.

In his book of clocks Taqiyyaddin laments that in the Arabic-Islamic world it was mainly water clocks and sand clocks which were discussed, the mechanical clock being neglected. Besides water and sand, he was concerned about the other motive power, with the aim, as he puts it “of pulling a weight with minor force for a long time across a long distance” (ga'd at-taq'it bi-q'wa qalila ... zam'anu tawilan fi masafa ba'id). However, here it should be noted that he refutes the idea of a perpetuum mobile (see below, vol. V, p. 61).

Taqiyyaddin, who also displays in his other works great competence in working with cogwheel systems, seems to have been inspired—at least in the use of the crown escapement and the use of the ascending spiral line on the outer casing of a truncated cone—by European mechanical clocks which had found their way into the Ottoman empire during his lifetime. In any case, he makes no secret of it that he knew of such European clocks.

On the other hand, a possible influence from the Arabic-Islamic world upon Europe in the development of the mechanical clock is still an open question. It is known that in Islamic countries escape- ments were used with water and mercury clocks. The question remains, “when the simple escapement came into use in clocks with cogwheels.”

In his book Taqiyaddin describes about ten clocks, which he divides into two groups: clocks driven by weights and clocks with a spiral spring. The first kind he calls *bingamit siryaqiya*, the latter *bingamit dauriya*.

Because of the idea of introducing time as an element of observations, Taqiyyaddin decided to construct a large astronomical clock (*bingam ra'sadi*). He described it at length in his treatise *Sidrat al-muntahya*, which is devoted to the instruments of the Istanbul observatory. We recognise in it a most interesting planetary model clock. A figure of its dial for hours, degrees and minutes is preserved in the autograph of the treatise:

Fig. from Tekeli, *16‘inci asırda Osmanlılarda saat*, p. 13.

---


4 Ibid., p. 218.

5 Feldhaus, *Die Technik*, op. cit., col. 1216.


7 İstanbul, Kandilli Rasathanesi, MS No. 56; S. Tekeli, *16‘inci asırda Osmanlılarda saat*, op. cit., p. 13.
The simplest among the weight-driven clocks (bingämät siryäqiya) described by Taqīyaddīn in his book on clocks of 966/1559 contains a clockwork whose speed is regulated by a crown escape-ment. The external appearance of the clock and its measurements are not mentioned in the text. We can gather some idea of it from the drawing of a table clock to be seen in the picture of Taqīyaddīn and his team at work in the observatory in Istanbul (see above, vol. II, pp. 34 ff., 53 ff.).

“The clock has a roller wheel with 54 teeth, which interlocks with the six drive of the intermediate gear. The latter has 48 teeth and interlocks with the six drive of the verge wheel with 21 teeth. The verge carries a balance beam with weights,” according to G. Oestmann and F. Lühring (Bremen), who constructed the clock for us.
beam of the balance
verge
escapement
verge wheel
six drive of the intermediate gear
hour wheel
roller wheel
six drive of the verge wheel
In the second part of his book Taqiyaddin describes a clock with spring tension, striking mechanism and indicators for the phases of the moon, the days of the week, hours and degrees. For the museum of the Institute two models of this clock were made which, compared with one another, have advantages and disadvantages. The advantage of model a) consists in its having a complete dial that shows all the four of the indicators envisaged by Taqiyaddin, while with b) the indicators for the days of the week and the degrees are missing. The disadvantage of a) is that it makes do with a simple tension spring instead of using the spiral spring described and shown clearly by Taqiyaddin. Taqiyaddin requires not only this spiral spring, but a second one for the striking mechanism. If one leaves aside the difference between the driving gears, the clockwork is identical with that of the clock driven by weights.
b). Brass, steel, wire ropes. Spring mechanism with key. Height 50 cm. (Inventory No. 3.14)

Lock discs – striking mechanism (schematic)