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A Duration-Based Procedure for the Indirect Determination of Water Depth in the Work of Abū Bakr ibn Abī ʿĀbis

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ABSTRACT

This study examines a depth-sounding procedure described by the mathematician Abū Bakr ibn Abī ʿĀbis in the opening section of his treatise *fī Akhdh al-abʿād* (*On the Determination of Distances*). Whereas conventional ancient and medieval depth-sounding relied on direct linear measurement, Ibn Abī ʿĀbis proposed an indirect procedure based on a hollow metal ball, a detachable weight, and a pengān[1]. The instrument was first operated at a known depth to establish a reference value from the quantity of water collected during the ball's descent and ascent. The quantity obtained in a subsequent trial at an unknown depth was then compared with this reference value, and the depth was inferred through proportional calculation. This article reconstructs the operation of the instrument and examines its measurement procedure in relation to earlier depth-sounding practices and broader traditions of indirect measurement. It argues that the historical significance of Abī ʿĀbis's procedure lies not in the invention of his instrument but in the combination within a reference-based method of indirect measurement, in which the duration of a body's motion serves as a proxy for an inaccessible linear distance. No equivalent procedure has been identified in the earlier Greek, Roman, or Arabic sources consulted for this study. Although this does not establish absolute historical priority, the treatise preserves an unusually early description of an indirect determination of water depth.

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1 Pengān is common water clock in the middle east. It is consisted of a pot full of water and a perforated cup/bowl. When the cup became full of water, it would sink into the pot in a constant time.

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روشی مبتنی بر مدت زمان برای تعیین غیرمستقیم عمق آب در کار ابوبکر بن ابی‌عابس

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کلیدواژه‌ها: ابوبکر بن ابی عابس، فی اخذ الابعاد، مساحی، ابزار مساحی، عمق سنجی، اندازه گیری غیرمستقیم، اندازه گیری در قرون وسطی، تاریخ تکنولوژی

چکیده

این مطالعه به بررسی یک روش عمق‌یابی می‌پردازد که توسط ابوبکر بن ابی‌عابس در بخش آغازین رساله‌اش فی اخذ الابعاد (درباره تعیین فواصل) شرح داده شده است. در حالی که عمق‌یابی مرسوم باستانی و قرون وسطایی بر اندازه‌گیری مستقیم متکی بود، ابن ابی‌عابس یک روش غیرمستقیم مبتنی بر یک گوی فلزی توخالی، یک وزنه قابل جدا شدن و یک پنگان (ساعت آبی) پیشنهاد کرد. این دستگاه ابتدا در عمق مشخصی به کار گرفته می شود تا یک مقدار مرجع از مقدار آب جمع‌آوری‌شده در طول نزول گوی به عمق دریا و صعود آن به سطح تعیین شود. سپس مقدار به‌دست‌آمده در آزمایش بعدی در عمق نامعلوم، با این مقدار مرجع مقایسه شد و عمق از طریق تناسب ریاضی استنباط می شود. این مقاله عملکرد این دستگاه را بازسازی می‌کند و روش اندازه‌گیری آن را در رابطه با شیوه‌های عمق‌یابی قبلی و سنت‌های گسترده‌تر اندازه‌گیری غیرمستقیم در حوزه های دیگر بررسی می‌کند. این مقاله استدلال می‌کند که اهمیت تاریخی روش ابی‌عابیس نه در اختراع ابزار او، بلکه در ترکیب آن با یک روش اندازه‌گیری غیرمستقیم مبتنی بر مرجع نهفته است که در آن مدت زمان حرکت یک جسم به عنوان نماینده‌ای برای تعیین یک فاصله غیرقابل دسترس عمل می‌کند. هیچ روش معادلی در منابع قدیمی‌تر یونانی، رومی یا عربی که برای این مطالعه به آنها مراجعه شده است، شناسایی نشده است. اگرچه این امر اولویت تاریخی مطلق را برای ابن عابس اثبات نمی‌کند، اما رساله، توصیف غیرمعمول و اولیه‌ای از تعیین غیرمستقیم عمق آب را حفظ می‌کند.

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مقدمه

1. Introduction

The measurement of inaccessible distances constituted a recurrent problem in ancient and medieval mathematical and technical traditions. Heights, horizontal distances, and depths could not always be determined by direct measurement, and various procedures were therefore developed to infer unknown magnitudes from observable quantities. Geometrical methods provided solutions for determining inaccessible distances through proportional relations. The documented measurement of water depth, however, was predominantly associated with a direct procedure: lowering a rod or weighted line until it reached the seabed.

The use of the sounding rod and/or the weighted line is attested by both literary and archaeological evidence from antiquity and continued into the medieval period (Oleson, 2008, p. 118). In these methods, the immersed length of a rod or the deployed length of a line directly represented the vertical distance between the water surface and the seabed. Although the design and practical use of sounding equipment could vary, the underlying principle remained the same.

Against this background, a procedure described by Abū Bakr ibn Abī ʿĀbis in his work, *fī Akhdh al-abʿād*, presents a notably different approach. Ibn Abī ʿĀbis describes a hollow ball that descends with a detachable weight. Upon reaching the seabed, the weight disengages, allowing the ball to return to the surface. During the interval between the release of the instrument and the reappearance of the ball, water is collected in a pengān. The collected water is then weighed and compared with a reference value previously obtained by operating the same instrument at a known depth. The unknown depth is inferred through a proportional comparison between the two measurements (ʿĀbis, pp. 210b-211f).

The individual elements of this procedure should not in themselves be regarded as unprecedented. Weighted descent had long been employed in maritime contexts;[1] indirect and proportional measurement formed an established part of geometrical surveying;[2] and water-based instruments had been used to represent elapsed time before Ibn Abī ʿĀbis (Al-Hassani, 2016). The historical problem posed by the treatise therefore concerns not the invention of any single

1. For example, for oyster or pearl hunting.
2. For example, see Euclid’s *Optics* Proposition 20

component, but the particular manner in which these elements were combined. Ibn Abī ʿĀbis employed a measurable representation of the duration of a body's motion as an intermediate quantity from which an inaccessible linear distance could be inferred.

Despite its unusual character, the procedure described in *fī Akhdh al-abʿād* has received little analytical attention in the history of measurement and technology. Consequently, the relationship between Ibn Abī ʿĀbis's method and earlier depth-sounding practices, as well as its place within broader traditions of indirect measurement, remains insufficiently examined.

This article addresses two related questions. First, how does Ibn Abī ʿĀbis's method differ from the direct depth-sounding techniques attested in ancient and medieval maritime practice? Second, how should its use of a reference trial, proportional comparison, and a duration-based intermediate quantity be situated in relation to contemporary traditions of measurement? To address these questions, the study examines the opening section of *fī Akhdh al-abʿād*, reconstructs the operational sequence of the instrument, and compares its measurement principle with direct-sounding.

The argument advanced here is necessarily limited by the surviving evidence. The absence of an equivalent procedure in the sources examined does not establish Ibn Abī ʿĀbis's absolute historical priority. The aim is instead to clarify the measurement principle described in his treatise and to determine its relationship to the technical and metrological practices considered in the following sections.

2. Historical Context

Very little is known about the life of Abū Bakr ibn Abī ʿĀbis. The available bibliographical literature provides no detailed information about his education, geographical origin, teachers, or intellectual affiliations, and even his chronological position remains uncertain. Modern scholars have therefore attempted to date him primarily on the basis of bibliographical notices and the surviving manuscript of his work.

The dates proposed for Ibn Abī ʿĀbis vary considerably. Fuat Sezgin placed him before the middle of the fifth century AH/eleventh century CE and identified him as the author of a work *On the Determination of Dimensions* (Sezgin, 1974, p. 392). Rosenfeld and İhsanoğlu dated him more broadly to the tenth or eleventh century and likewise recorded a manuscript work concerned with the measurement of dimensions (Rosenfeld & İhsanoğlu , 2003, p. 193). Zuhayr Ḥumaydān described Ibn Abī ʿĀbis as a mathematician but provided no date for his death (Ḥumaydān, 1995, p. 184). Mahā al-Shaʿʿār, in reviewing these notices, emphasized the scarcity of biographical evidence and noted that the surviving manuscript was copied in 626 AH/1228 CE (al-Shaʿʿār, 2021, p. 16).

The date of the surviving copy should not, however, be confused with the chronological position of the author. It establishes only that the text existed by 626 AH/1228 CE. Earlier chronological assignments proposed in modern bibliographical literature place Ibn Abī ʿĀbis in or before the eleventh century, but the absence of independent biographical evidence prevents a more precise reconstruction of his life. His place of origin, education, and connections with particular mathematical or technical circles remain unknown.

Ibn Abī ʿĀbis is known through his treatise *fī Akhdh al-abʿād*, preserved in a manuscript at the Ayasofya Library in Istanbul. The treatise presents procedures for determining distances, heights, and depths, combining geometrical problems with descriptions of practical measuring operations. The opening section, which is the subject of the present study, describes an indirect procedure for determining the depth of a sea or other body of water.

Given the scarcity of biographical information, the treatise itself remains the principal source for assessing Ibn Abī ʿĀbis's technical interests. The surviving evidence does not support a detailed reconstruction of his intellectual biography; it does, however, permit an analysis of the measurement procedure preserved in his work and its relationship to earlier depth-sounding practices.

3. Depth-Sounding before Ibn Abī ʿĀbis

The determination of water depth was a practical problem long before the time of Ibn Abī ʿĀbis, particularly in maritime navigation. The best-attested methods of antiquity relied on direct measurement. In shallow water, a sounding rod could be lowered until it reached the seabed; in deeper water, mariners employed a weighted line, commonly referred to in modern scholarship as the “lead and line”. In both cases, the same basic principle applied: the vertical distance between the water surface and the seabed was determined from the immersed length of a physical measuring element. These methods remained fundamental techniques of depth-sounding for a long period (Kemp, 2014, p. 481).

One of the earliest explicit literary descriptions of sounding with a weighted line occurs in Herodotus. In his discussion of the formation of the Egyptian coast, Herodotus states that a sailor approaching Egypt could lower a sounding line while still a day's voyage from land and bring up mud from a depth of eleven fathoms (Kemp, 2014, p. 481). The passage indicates that sounding lines were familiar instruments of maritime practice by the fifth century BCE.

This additional function is also attested archaeologically. A number of ancient sounding weights have depressions in their bases that could be filled with tallow or another adhesive substance, enabling sediment from the seabed to adhere to the weight. The geographical distribution and chronological range of these finds indicate the long-standing use of sounding weights in Mediterranean navigation (Kemp, 2014, p. 481).

Ancient authors also record attempts to determine considerably greater depths. Strabo, citing Posidonius, describes the Sardinian Sea as the deepest of the seas that had been sounded and reports a depth of approximately one thousand fathoms (Oleson, 2008, p. 128). Such accounts indicate that sounding was not confined to shallow coastal waters or harbor approaches. The depth of large bodies of water could itself become an object of geographical and natural-philosophical inquiry. The surviving accounts, however, do not reveal a fundamentally different principle of measurement: the documented techniques continued to depend on a physical object reaching the seabed and on the direct determination of the linear distance between the surface and the bottom.

Evidence for depth-sounding practices in the Islamic world before the eleventh century remains difficult to assess due to the uneven survival of technical and practical records. Although maritime activity in the Indian Ocean and the Persian Gulf was extensive (Islam, 2011, pp. 13-14), the available sources do not provide a continuous account of the instruments and procedures employed by mariners for measuring water depth. Surviving Arabic navigational writings from later periods offer valuable evidence for maritime knowledge and practices, but they cannot be used alone to reconstruct earlier traditions in detail. Therefore, the limited number of explicit technical descriptions from earlier periods should be understood as a limitation of the surviving evidence rather than as proof that depth-sounding methods were unknown or absent among Muslim mariners.

The surviving evidence nevertheless indicates that direct sounding provides the principal documented context against which Ibn Abī ʿĀbis's procedure should be assessed. The following sections examine the construction and operation of his instrument before analyzing the measurement principle that distinguishes it from these earlier methods.

4. Construction and Operation of the Instrument

The first section of *fī Akhdh al-abʿād* describes an instrument consisting of three principal components (ʿĀbis, pp. 210b-211f):

1. **A metal ball** fitted with a ring at its bottom (Fig.2).
2. **A detachable weight** connected to the ball's ring by a hook, pulling the ball downward and releasing it upon contact with the bottom of the sea (Fig.4).
3. **A pengān**, a perforated brass cup used to represent elapsed duration through the quantity of water collected during the operation.

The ball is made of brass. A weight is attached to the ring by means of a hook and is sufficiently heavy to carry the ball downward through the water. Ibn Abī ʿĀbis specifies the form of the hook and explains that the weight should remain attached during descent. When the assembly reaches the seabed, the weight rotates, causing the hook to disengage from the ring. Once released from the weight, the ball rises to the surface.

A separate brass cup is used during the descent and ascent of the ball. The cup has a small aperture in its base and is placed in the water when the ball-weight assembly is released. It is removed as soon as the ball reappears at the surface. Water entering through the aperture during this interval is retained in the cup and subsequently weighed.

Before the instrument is used for depth measurement, Ibn Abī ʿĀbis instructs the operator to test it in clear water near the bottom. This preliminary trial allows the descent of the ball and the disengagement of the weight to be observed directly. If the mechanism does not operate as intended, the hook is to be adjusted before the measurement procedure is carried out.

5. Numerical Example and Proportional Calculation

Ibn Abī ʿĀbis illustrates the measurement procedure with a numerical example. He first assumes that the instrument is operated in a pool ten fathoms deep. The measurement interval begins when the ball is released and ends when it reappears at the surface. The water collected in the perforated cup during this interval is then weighed. In the example given in the treatise, it weighs four drachmas.

The same procedure is subsequently performed in a sea of unknown depth. Ibn Abī ʿĀbis assumes that the water collected during this second operation weighs two hundred drachmas. The numerical relation may be expressed as follows:

- Reference pool depth: 10 fathoms
- Water collected at the reference depth: 4 drachmas
- Water collected at the unknown depth: 200 drachmas

Computation:

- $200 \div 4 = 50 \rightarrow$ The sea is 50 times deeper than the pool.
- Depth of the sea = $50 \times 10 = 500$ fathoms**.**

Hence, the depth of the sea is calculated as 500 fathoms.

6. Scientific and Metrological Significance

The significance of Ibn Abī ʿĀbis's depth-measuring procedure lies primarily in its operational structure. Its use involves preliminary testing and adjustment, the establishment of a reference under known conditions, and the proportional inference of an unknown magnitude from a subsequent observation.

This sequence may cautiously be described, in modern terminology, as a reference-based calibration procedure. The term is used here descriptively and does not imply that Ibn Abī ʿĀbis possessed a modern theory of measurement or calibration. What is significant is the explicit establishment of a reference under known conditions before the instrument is employed to determine an unknown quantity.

The procedure also depends on an intermediate measurable quantity. Depth is not directly represented by the length of a rod, rope, or other physical measuring element. Instead, the amount of water entering the pengān provides a quantitative representation of the interval between the release of the instrument and the return of the ball to the surface. This observed quantity is related to depth through proportional calculation. The procedure therefore transforms the determination of an inaccessible linear magnitude into a comparison between experimentally obtained quantities.

The proportional relation assumed in the treatise, however, requires qualification from the perspective of modern physics. The measured interval combines two mechanically distinct phases: the descent of the ball together with the attached weight and the buoyant ascent of the ball after the weight has disengaged. The inference that depth varies directly with the measured interval presupposes that the effective descent and ascent velocities remain sufficiently stable between the reference trial and the subsequent measurement. Ibn Abī ʿĀbis neither formulates a theory of fluid resistance nor analyzes the dynamics of the descending and ascending bodies. His procedure should therefore not be interpreted as an anticipation of a hydrodynamic law.

7. Comparative Perspective

Comparison with earlier and contemporary measurement practices helps to clarify the position of Ibn Abī ʿĀbis's procedure. In conventional depth sounding, the measured quantity and the quantity sought were of the same kind: the depth was determined from the immersed length of a rod or the deployed length of a weighted line. A physical measuring element extended between the surface and the seabed, and its length directly represented the depth. Ibn Abī ʿĀbis's instrument differs from this arrangement because no rod or line is used to represent the unknown vertical distance. Contact with the seabed instead forms one stage in a sequence that ultimately yields the depth through proportional calculation.

A second comparison concerns geometrical surveying. Procedures for determining inaccessible heights and distances through observable relations and proportional reasoning were well established in the mathematical sciences of the Islamic world. An eleventh-century example is al-Karajī's *Inbāṭ al-miyāh al-khafiyya*, which describes surveying and leveling instruments and methods for determining distances and heights (Rahimi, 1999, pp. 55-56). Ibn Abī ʿĀbis similarly employs proportional inference to determine an inaccessible magnitude. The principal difference lies in the quantity subjected to comparison: whereas geometrical surveying relies on measured lengths or relations, his procedure compares quantities of water collected during two operations.

The pengān provides a further comparative context. Water-based timekeeping had a long history before Ibn Abī ʿĀbis, and an Arabic technical tradition concerning water clocks was already in existence by the ninth century (Al-Hassani, 2016). The Arabic treatise attributed to Archimedes, *Kitāb Arshimīdas fī ʿamal al-binkāmāt*, preserves descriptions of water clocks and related mechanisms, while later Arabic mechanical writings continued this tradition (Al-Hassani, 2016). In Ibn Abī ʿĀbis's procedure, however, the pengān performs a more restricted measuring function. The quantity of water collected during the operation represents the interval between the release of the instrument and the return of the ball and is subsequently used in a proportional calculation of depth.

These comparisons indicate that the components and reasoning employed by Ibn Abī ʿĀbis can be related to established technical practices, although their specific arrangement in his depth-measuring procedure is unusual.

8. Conclusion

The depth-measuring procedure described by Abū Bakr ibn Abī ʿĀbis represents a distinctive departure from the direct sounding methods documented in ancient and medieval maritime practice. Rather than determining depth from the immersed length of a rod or the deployed length of a weighted line, the procedure infers an unknown depth by comparing an observed quantity obtained during the operation of the instrument with a reference established at a known depth. Its historical significance lies in this measurement sequence: preliminary testing and adjustment, the establishment of a reference under known conditions, and the proportional inference of an inaccessible magnitude from a duration-based intermediate quantity.

The physical validity of the proportional relation assumed in the treatise remains uncertain. A reconstruction of the instrument based on the dimensions and materials specified in the manuscript could clarify its mechanical operation and assess the practical accuracy of the proposed method. Such experimental work would contribute to a more precise evaluation of Ibn Abī ʿĀbis's procedure and its place in the history of measurement technology.

Appendix I: The original text in Arabic

الف- القول علی مثال آلة نعرف بها عمق بحراً و برکة

[۲] نَصنع کرةً من شَبَهٍ ونَلصق علی ظهرها عروةً منه، ونَّضع ثقالةً في أعلاها، حجمةً تدخل في العروة لتَرسبَ بالکرة. ویکون شکل الثقالة علی هیئةٍ إذا إنتهتْ بالکرة إلی القعر تخلتْ عن الکرة، وارتفعتٍ الکرة.

[۳] ویُعدَل زمان رسوبها إلی أن تبدوا الکرة علی الماء طافیةً، بظرفٍ من الشبه مثقوب في قاعه ثقباً ضیغاً علی ما عند إرسال الألة إلی أن تبدوا الکرة. فإن بدت رُفع الظرف ساعة، ثمّ یوزَن ما اجتمع فیه من الماء، ویُنسَب ذلک الماء إلی ما یوزَن في زمن رسوبها في غدیرٍ معلوم عدد قیام عمقه. فستکون نسبةُ وزن الماء إلی وزن الماء کنسبة عدد القیام إلی عدد قیام عمق البحر المطلوب معرفة عمقه.

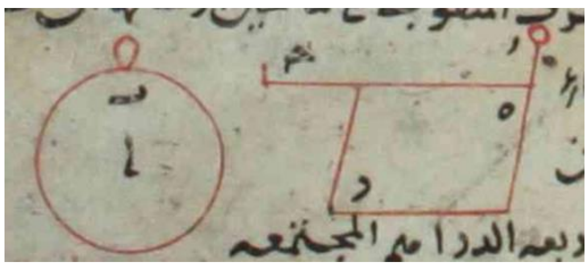

Fig.1- The ball and the weight in the original text.

[۴] مثالُ ذلک: کرةٌ علیها **اب** و علی العروة الملصقة فیها **ب** وشکل الثقالة علی هیئة الشکل الذّي علیه **جـ د ه ز** علی الحجمة **جـ**، یکون زاویةُ الحجمة قائمةً أو أقلّ من قائمةٍ قلیلاً. ویکون الثقالةُ من الثقالة بمقدارٍ ما تَرسُب بالکرة إذا أدخلت حجمةُ **جـ** في عروة **ب**. فإذا انتهت إلی القعر بالکرة، نزلت الثقالة علی عمود **ه ز** و تَمیلُ **جـ د ه**. فیخرُج حجمةُ **جـ** [من] عروة **ب** و ترتفِعُ الکرة.

[۵] وقبل أن تُستَعملَ هذه الآلةُ، یُنزَل ماءٌ قریب القعر لتُری کیفیّةُ نزولها في القعر وکیفیّةُ تَخلّی الثقالة عنها. فإن احتاجت إلی إصلاح شيءٍ فیها، أُصلح قبل ما تَبدوا به الحجمة.

[۶] ثمّ یتقدَّم قبل إرسالها لامتحان عمق بحرٍ، نَضعُ ثقالةً کثقالة **جـ د ه ز** في الوزن والشکل. ثمّ نُرسل بالکرة علی ما ذکرنا. فکأنّها قد أُرسلت في غدیرٍ عمقه عشر قیام، ووُضع الظرفُ المثقوب علی ما سعة إرسالها في الغدیر. فلمّا ظهر الکرة طافیةً، رُفعَ الظرفُ ذلک الحین عن الماء، ووُزنَ الماء المجتمع فیه في المدة التّي نزلت الثقالة بالکرة إلی حین خروج الکرة. فکأنّه قد اُلقيَ وزنُ الماء أربعةُ دارهمَ، فکان وزنُ هذا الماء

وعددُ القيام التّي اجتمعَ هذا الماء بالظرف المثقوب في زمن رسوب الثقالة بالكرة فى العشر قيام إلى حين خروج الكرة، اصلاً يُحفَظ، يُنسَب إليه ما اجتمع في زمن رسوبها في بحرٍ أو غيره.

[۷] فكأنّها أُرسِلت في بحرٍ لمعرفة عمقه. ووُضعَ الظرفُ المثقوب على ماءٍ حين أرسلها إلى أن تبدوَ الكرةُ طافيةً. فحينئذٍ، فما اجتمعَ في الظرف من الماء في الزمن الذّي فيه رَسبتْ إلى أن ظهرت الكرةُ، وزنُ مئتي درهمٍ. فيكون نسبةُ هذه المئتي درهمٍ إلى الأربعة الدراهم المجتمعة من الماء في زمن رسوب الكرة إلى أن ظهرتْ في العشر قيام، كنسبة عدد قيام عمق ذلک البحر إلى العشر قيام. والمئتان خمسون مثل الأربعة. فكذلک يكون عمق ذلک البحر خمسين مثل العشر قيام، وذلک خمس مئةٍ. فهو عدد قيام عمود ذلک البحر، إن شاء الله.

Appendix II: The English translation of the Arabic text

A- An Instrument by which we may determine the depth of a sea or a pool.

[2] We make a ball of brass and attach to its back a ring made of the same material. We place a weight above it, fitted with a hook that enters the ring and causes the ball to sink. The weight is shaped in such a manner that, when the ball reaches the bottom, it separates from the ball and the ball rises.

[3] The duration of its sinking until the ball appears floating on the surface of the water is determined by means of a brass vessel perforated at its base with a small hole. The vessel is placed [in the water] when the instrument is released and remains there until the ball appears. When the ball appears, the vessel is immediately removed, and the water collected in it is weighed. This water is compared with the water weighed during the sinking of the instrument in a pool whose depth is known in qiyāms. The ratio of one weight of water to the other will be as the ratio of the number of qiyāms [of the known depth] to the number of qiyāms of the depth of the sea whose depth is to be determined.

Example

[4] An example of this is a ball marked **A**, with the ring attached to it marked **B**. The weight has the form represented by the figure **GDHZ**, with the hook at **G**. The angle of the hook is a right angle or slightly less than a right angle. The weight is sufficiently heavy to cause the ball to sink when hook **G** is inserted into ring **B**. When the ball reaches the bottom, the weight descends along the vertical **HZ**, and **GDH** tilts, causing hook **G** to leave ring **B**; the ball then rises.

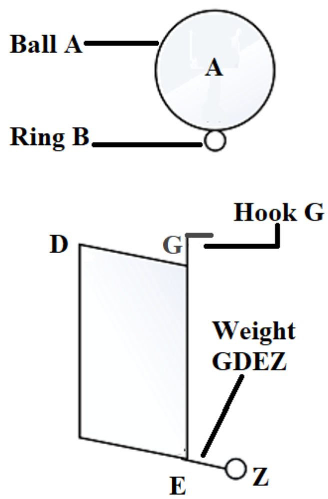

Fig.2- The ball and the weight in a modern illustration.

[5] Before this instrument is used, it is lowered in clear water near the bottom so that the manner of its descent to the bottom and the manner in which the weight separates from it may be observed. If anything in it requires adjustment, it should be corrected before [the instrument] is used.

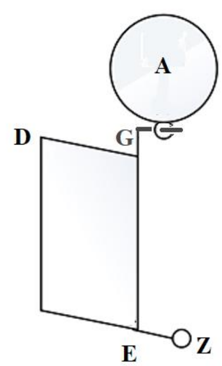

Fig.3- The ball and the weight combination.

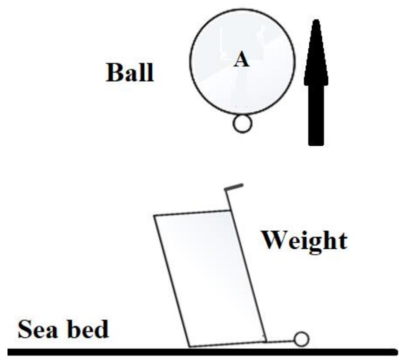

Fig.4- The ball will be released automatically.

[6] The ball is then released in the manner described. Let the pool, for example, be ten qiyāms deep. The perforated vessel is placed in the water at the moment the ball is released. When the ball appears floating at the surface, the vessel is immediately removed from the water, and the water collected in it during the interval from the descent of the weight with the ball until the reappearance of the ball is weighed. Suppose that the water weighs four drachmas. The weight of this water and the number of qiyāms during which it accumulated in the perforated vessel—from the sinking of the weight with the ball through ten qiyāms until the reappearance of the ball—are retained as a reference against which the quantity collected during its descent in a sea or elsewhere may be compared.

[7] When the instrument is released into a sea in order to determine its depth, the perforated vessel is placed in the water at the moment of release. When the ball appears floating at the surface, the water collected in the vessel during the interval from its sinking until the appearance of the ball is weighed. Suppose that it weighs two hundred drachmas. The ratio of these two hundred drachmas to the four drachmas of water collected during the sinking of the ball and its reappearance through ten qiyāms is as the ratio of the number of qiyāms constituting the depth of that sea to ten qiyāms. Two hundred is fifty times four; accordingly, the depth of that sea is fifty times ten qiyāms, that is, five hundred. This is the number of qiyāms in the vertical depth of that sea, God willing.

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