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(*fl*. Alexandria, a.d. 62)

mathematics, *physics*, *pneumatics*, *mechanics*.

Hero (or Heron) of Alexandria is a name under which a number of works have come down to us. They were written in Greek; but one of them, the *Mechanics*, is found only in an Arabic translation and another, the *Optics*, only in Latin. Apart from his works we know nothing at all about him.

His name is not mentioned in any literary source earlier than Pappus (a.d. 300), who quotes from his *Mechanics*.[1] Hero himself quotes Archimedes (*d*. 212 b.c). which gives us the other time limit. Scholars have given different dates, ranging from 150 b.c. to a.d. 250, but the question has been settled by O. Neugebauer, who observed that an eclipse of the moon described by Hero in his *Dioptra* (chapter 35) as taking place on the tenth day before the vernal equinox and beginning at Alexandria in the fifth watch of the night, corresponds lo an eclipse in a.d. 62 and to none other during the 500 years in question.[2] An astronomical date is the most reliable of all, being independent of tradition and opinion. The rather minute theoretical possibility that Hero might have lived long after this date I have discussed and dismissed, while I have elsewhere reviewed the whole controversy about his dates, which is now of historical interest only.[4]

The question of what sort of man he was has also been debated. H. Diels found that he was a mere artisan.[5] I. Hammer-Jensen took him to be an ignorant man who copied the chapters of his *Pneumatics* from works which he did not understand.[6] Although E. Hoppe attempted to defend Hero.[7] Hammer-Jensen maintained her opinion.[8] In 1925 J. L. Heiberg wrote; “Hero is no scientist, but a practical technician and surveyor. This view, which has been challenged in vain, was first put forth by H. Diels: [who called him] ‘Ein reiner Banause.’”[9]

Such adverse judgment was based on a study of the *Pneumatics* at a time when neither the *Mechanics* nor the *Metrica* was known; and the *Pneumatics*, although by far the largest work (apart from the elementary textbooks) was neither by its contents nor form apt to inspire confidence in a serious scholar. The contents are almost exclusively apparatuses for parlor magic, and there is no discernible plan in the arrangement of the chapters. Apart from the introduction, there is no theoretical matter in the book, which consists entirely of practical descriptions.

But since then, the *Mechanics* has been published in Arabic, and a manuscript has come to light giving the *Metrica* in its original form; thus the image of Hero has changed. The *Mechanics* shows nothing of the disorder of the *Pneumatics*, consisting of an introduction, a theoretical part, and a practical part; the *Metrica* shows that Hero possessed all the mathematical knowledge of his time, while a chapter of the *Dioptra* indicates that he was familiar with astronomy. We also find that he quotes Archimedes by preference and has copied many chapters of a lost work of his on the statics of plane figures.

In the introduction to the *Pneumatics*, Diels found a quotation from Strato of Lampsacus (*fl*. 288 B.C.) and suggested that it was taken from Philo of Byzantium (*fl*. 250 b.c.), who probably took it from Ctesibius (*fl*. 270 b.c.);[10] but Philo’s *Pneumatics*, which was discovered later, does not contain this passage, and a strictly

accurate quotation is most likely to have been taken from the original work. The form of this theoretical introduction led I. Hammer-Jensen to assume that Hero was an ignoramus who did not understand what he copied from diverse sources; yet to me the freely flowing, rather discursive style suggests a man well-versed in his subject who is giving a quick summary to an audience that knows, or who might be expected to know, a good deal about it.

This discursive style, so very different from the concise style of the technical descriptions, is found again in the *Mechanics*, in which Hero, before giving the propositions from Archimedes' book *On Uprights*, presents the theory of the center of gravity as explained by Archimedes, not by Posidonius the Stoic, whose definition was not good enough.[11] Here again there is a strong suggestion of a teacher repeating swiftly a piece of knowledge which his students ought to know. Since we know the author as Hero of Alexandria, it seems reasonable to assume that he was appointed to the museum, that is, the University of Alexandria, where he taught mathematics, physics, pneumatics, and mechanics, and wrote textbooks on these subjects.

The *Pneumatics* can best be regarded as a collection of notes for such a textbook, of which only the introduction and the first six chapters have been given their final shape. All the chapters are uniform in style, even those taken from Philo, and eminently clear, so the idea of an ignorant compiler cannot be upheld. But there is more to be learned from the *Pneumatics*. While there is no order at all in the general arrangement of the chapters, we find here and there a short series of related chapters in which it is clear that Hero is searching for a better solution to a mechanical problem. This shows unmistakably that he was an inventor; it is therefore probable that he himself invented the dioptra, the screw-cutter, and the odometer, as well as several pneumatic apparatuses. This is all that can be learned about Hero himself.

The following works have survived under the name of Hero: *Automata, Barulkos, Belopoiica, Catoptrica, Cheirobalistra, Definitiones, Dioptra, Geometrica, Mechanica, De mensuris, Metrica, Pneumatica*, and *Stereometrica*. These can be divided into two categories, technical and mathematical. All the technical books, except the *Cheirobalistra*, seem to have been written by Hero; of the mathematical books only the *Definitiones* and the *Metrica* are direct from his hand. The others are, according to J. L. Heiberg, Byzantine schoolbooks with so many additions that it is impossible to know what is genuinely Heronian and what is not.[12]

The *Pneumatics* is by far the longest book, containing an introduction and two books of forty-three and thirty-seven chapters, respectively; but it is merely a collection of notes for a textbook on pneumatics. Only the introduction and the first six or seven chapters are finished. The introduction treats the occurrence of a vacuum in nature and the pressure of air and water; although it is written in a very prolix style with occasional digressions, the train of thought is never lost. It seems to have been written by a man very well versed in his subject, who is summarizing for students of pneumatics matters already known to them from their textbooks. Some of the theory is right, some is wrong (for instance, the *horror vacui* of nature), but it was the best theoretical explanation to be had at the time; a real understanding of the phenomenon had to wait for the experiments of Torricelli.

The first chapters, most of them taken from Philo's *Pneumatics*, describe experiments to show that air is a body, and that it will keep water out of a vessel unless it can find an outlet and will keep water in if it cannot enter. Hero goes on to siphons; but soon all order is lost, and the chapters appear haphazardly. Yet there is nothing haphazard about the chapters themselves, each of which—whether taken from Philo or a description of an apparatus seen by Hero—is written in the same concise style and according to a fixed plan, beginning with a description of the apparatus, with letters referring to a figure, then a description of how it works, then last (if necessary) an explanation. With very few exceptions it is evident that the chapters were written by Hero himself, and without exception they are very clear: each instrument can be reconstructed from the description and the figure.

The contents, on the other hand, have always been a source of puzzlement and despair for serious-minded scholars. Certainly Hero describes some useful implements—a fire pump and a water organ—but all the rest are playthings, puppet shows, or apparatuses for parlor magic. Trick jars that give out wine or water

separately or in constant proportions, singing birds and sounding trumpets, puppets that move when a fire is lit on an altar, animals that drink when they are offered water—how can one respect an author who takes all these frivolities in earnest?

But Hero's treatment of these childish entertainments is quite matter-of-fact; he is interested in the way they work. In 1948 I explained this by the assumption that he was writing a handbook for the makers of pneumatic instruments, but this is not necessarily correct.[13] Hero was a teacher of physics, of which pneumatics is part. The book is a text for students, and Hero describes instruments the student needs to know, just as a modern physics textbook explains the laws governing the spinning top or the climbing monkey. Playthings take up so much of the book because such toys were very much in vogue at the time and the science of pneumatics was used for very little else. (Among the many toys of the *Pneumatics* there are even a few that use hot air or steam as a moving power, which has given rise to ill-founded speculations that the steam engine could have been invented at this time.) To this we must add that Hero was an inventor; and to a real inventor any clever apparatus is of interest, regardless of its purpose.

There is a slightly different text, found only in four manuscripts, that is generally designated Pseudo-Hero. of seventy-eight chapters, seven have been radically changed; elsewhere the changes are only verbal corrections to clarify an already quite clear text. This text cannot have been written later than a.d. 500; therefore when the two texts agree, neither of them has been changed since then. For every chapter there is a figure, and the text in most cases begins with a reference to it, such as "Let *ABCD* be a base...." Since Pseudo-Hero has the same figures as Hero, the figures cannot have been changed after a.d. 500; and there is every reason to believe that they were drawn by Hero himself. A complete set of these illustrations has been published in a reprint of Woodcroft's translation of the *Pneumatics*.[14] The *Pneumatics* was by far the most read of Hero's works during the Middle Ages and the Renaissance; more than 100 manuscripts of it have been found.

The *Mechanics*, preserved only in an Arabic version, was published in 1893 with a French translation and in 1900 with a German translation. A textbook for architects (that is, engineers, builders, and contractors), it is divided into three books. Book 1 deals with the theoretical knowledge and the practical skill necessary for the architect: the theory of the wheel, how to construct both plane and solid figures in a given proportion to a given figure, how to construct a toothed wheel to fit an endless screw, and the theory of motion. Drawing largely upon Archimedes, Hero then presents the theory of the center of gravity and equilibrium, the statics of a horizontal beam resting on vertical posts, and the theory of the balance.

Book 2 contains the theory of the five simple "powers": the winch, the lever, the pulley, the wedge, and the screw. The five "powers" are first described briefly, then the mechanical theory of each is presented and the results of a combination of the powers are calculated. Next is a chapter with answers to seventeen questions about physical problems, evidently inspired by Aristotle's *Mechanical Problems*, followed by seven chapters on the center of gravity in different plane figures and on the distribution of weight on their supports, once more from Archimedes. Book 3 describes sledges for transporting burdens on land, cranes and their accessories, other devices for transport, and wine presses: the last chapter describes a screw-cutter for cutting a female screw in a plank, which is necessary for direct screw presses.

Apart from the first chapter of book 1, which contains the *Barulkos*, the work proceeds in an orderly fashion; it shows nothing of the disorder of the *Pneumatics*, but the style is equally clear and concise, with a single exception. In book 1, chapter 24, Hero gives the theory of the center of gravity, and there he uses the same prolix and discursive style as in the introduction to the *Pneumatics*. This chapter would also seem to be a summary for students who should already know the subject. There are figures for most of the chapters; that they go back to the original Greek text can be seen from a mistake in the translation of a Greek work in one of the figures.[15] Editions of the work give only an interpretation of the figures; facsimilies have been published, with an English translation of many chapters, by A. G. Drachmann.[16] The fragments from Archimedes have been published in English with the manuscript figures.[17]

The *Dioptra* contains a description of an instrument for surveyors; it consists of a pointed rod to be planted in the ground, with two interchangeable instruments: a theodolite for staking out right angles and a leveling instrument. The description, which unfortunately is imperfect owing to a lacuna in the manuscript, covers six chapters; chapters 7–32 contain directions for the use of the two instruments in a great number of tasks. In chapter 33 Hero criticizes the *groma*, the instrument then used for staking out lines at right angles; chapter 34 describes an odometer actuated by the wheel of a car, used for measuring distances by driving slowly along a level road. Chapter 35 indicates the method for finding the distance between Alexandria and Rome by simultaneously observing a lunar eclipse in the two cities; this chapter has been thoroughly studied by O. Neugebauer.[18] There is no chapter 36, and chapter 37 is the *Barulkos*, which is also chapter 1 of book 1 of the *Mechanics*; it is out of place in both. Chapter 38 describes a ship's odometer and is certainly not by Hero.[19]

The *Belopoiika* contains the description of the *gastraphetes*, or stomach bow, a sort of crossbow in which the bowstring is drawn by the archer's leaning his weight against the end of the stock, and two catapults worked by winches; two bundles of sinews provide the elastic power to propel the arrow, bolt, or stone. The catapults are shaped like those described by Vitruvius and Philo.[20]

The *Automata*, or *Automatic Theater*, describes two sorts of puppet shows, one moving and the other stationary; both of them perform without being touched by human hands. The former moves before the audience by itself and shows a temple in which a fire is lit on an altar and the god Dionysus pours out a libation while bacchantes dance about him to the sound of trumpets and drums. After the performance the theater withdraws. The stationary theater opens and shuts its doors on the performance of the myth of Nauplius. The shipwrights work; the ships are launched and cross a sea in which dolphins leap; Nauplius lights the false beacon to lead them astray; the ship is wrecked; and Athena destroys the defiant Ajax with thunder and lightning. The driving power in both cases was a heavy lead weight resting on a heap of millet grains which escaped through a hole. The weight was attached by a rope to an axle, and the turning of this axle brought about all the movements by means of strings and drums. Strings and drums constituted practically all the machinery; no springs or cogwheels were used. It represents a marvel of ingenuity with very scant mechanical means.

The *Catoptrica*, found only in a Latin version, was formerly ascribed to Ptolemy, but is now generally accepted as by Hero. It deals with mirrors, both plane and curved, and gives the theory of reflection; it also contains instructions on how to make mirrors for different purposes and how to arrange them for illusions.

Barulkos, "the lifter of weights," is the name given by Pappus to his rendering of the *Dioptra*, chapter 37, and the *Mechanics*, book 1, chapter 1.[21] It is an essay describing how one can lift a burden of 1,000 talents by means of a power of five talents, that is, he power of a single man. The engine consists of parallel toothed wheels and is derived from the *Mechanics*, book 1, chapter 21; however, it is only a theoretical solution: parallel toothed wheels were not used for cranes during antiquity.[22] L Nix takes *Barulkos* to be the name of the *Mechanics*, even though Pappus mentions the *Barulkos* and the *Mechanics* in the same sentence, because the Arabic lame of the *Mechanics* is "Hero's Book About the Lifting of Heavy Things."[23] But since the essay is found as the first chapter of the *Mechanics* (where it does not belong), the translator would seem to have taken this title to be the title of the whole work, The *Cheirobalistra* was published in 1906 by Rudolf Schneider, who regarded it as a fragment of a dictionary dealing with catapults; it consists of six items, each describing an element that begins with the letter *K*.[24] E. W. Marsden has interpreted these chapters s a description of a sort of catapult, which he has reconstructed.[25] It is unlikely, however, that the *Cheirobalistra* is actually a work by Hero.

NOTES

1. Pappus of Alexandria, *Collectionis quae supersunt*..., Friedrich Hultsch, ed., III. pt. 1 (Berlin, 1878), 1060–1068.

2. O. Neugebauer, “Über eine Methode zur Distanzbestimmung Alexandria-Rom bei Heron,” in *Kongelige Danske Videnskabernes Selskabs Skrifter*, **26** , no, 2 (1938). 21–24.

3. A. G. Drachmann, “Heron and Ptolemaios,” in *Centaurus*, 1 (1950), 117–131.

4. A. G. Drachmann, *Ktesibios, Philon and Heron*, vol. IV of Acta historica Scientiarum naturalium et medicinalium (Copenhagen, 1948), pp. 74–77.

5. H. Diels, “Über das physikalische System des Straton.” in *Stizungsherichte der k. Preussischen Akademie der Wissenschaften zu Berlin*, no. 9 (1893), 110, n. 3.

6. I. Hammer-Jensen, “Die Druekwerke Herons von Alexandra,” in *Neue Jahrbücher für das klassischen Altertum*, **25** , pt. 1 (1910), 413–427, 480–503.

7. Edmund Hoppe, “Heron von Alexandrien,” in *Hermes* (Berlin), **62** (1927), 79–105.

8. I. Hammer-Jensen, “Die heronische Frage,” *ibid*., **63** (1928), 34–47.

9. J. L. Heiberg, *Geschichte der Mathematik und Naturwissenschaften im Altertum*, which is in Iwan von Müller, ed., *Handbuch der Altertumswissenschaft*, V, pt. 1, sec. 2 (Munich, 1925), 37.

10. Diels, *op. cit*., pp. 106–110.

11. Hero, *Mechanics*, ch. 24.

12. Heiberg, *loc. cit*.

13. Drachmann, *Ktesibios*..., p. 161.

14.*The Pneumatics*, facs. of the 1831 Woodcraft ed., with intro. by Marie Boas Hall (London-New York, 1971).

15. A. G. Drachmann, *The Mechanical Technology of Greek and Roman Antiquity*, vol. XVII of Acta historica Scientiarum naturalium et medicinaliuin (Copenhagen, 1963), p. 110, text for fig. 44.

16.*Ibid*., pp. 165 ff.

17. A. G. Drachmann, “Fragments from Archimedes in Heron’s *Mechanics*,” in *Centaurus*, **8** (1963), 91–146.

18. Neugebauer, *op. cit*.

19. Drachmann, *The Mechanical Technology*....

20. Vitruvius, *De architectura*, X, ch. 11; and Philo, *Belopoiika*, Greek and German versions by H. Diels and E. Schramm, in *Abhandlungen der Preussischen Akademie der Wissenschaften* for 1918, Phil.-hist. K.I., no. 16 (1919).

21. Pappus, *op cit*., pp. 1060 ff.

22. Drachmann. *The Mechanical Technology*..., p. 200.

23. Hero, *Mechanics*, introduction, pp. xxii ff.; Pappus, *op. cit.*, p. 1060.

24. Rudolf Schneider, ed. and trans., "Herons Cheirohalistra," in *Mitteilungen des kaiserlich deutschen archaeaologischen Instituts*. Römische Abt., **21** (1906), 142–168.

25. E. W. Marsden, *Greek and Roman Artillery. Technical Treatises* (Oxford, 1971), pp. 206–233.

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I. Original Works. *Heronis Alexandrini Opera quae supersunt omnia*, 5 vols. (Leipzig, 1899–1914), contains all Hero's works except the *Belopoiica*. *Automata* is published with *Pneumatica, Opera*, 1. *Belopoika* appeared as "Heron's Belopoiica Griechisch und Deutseh von H. Diels und E, Schramm," in *Abhandlungen der K. Preussischen Akademie der Wissenschaften*, Phil.-hist. K1. no. 2 (1918); and in E. W. Marsden. *Greek and Roman Artillery. Technical Treatises* (Oxford, 1971), with English trans, and notes. *Catoptrica* is published with *Mechanica, Opera*, II, pt. 1. *Cheirobalistra*, edited and translated by Rudolf Schneider, is in *Mitteilungen des kaiserlich deutschen archaeologischen Institut* s, Römische Abt., **21** (1906). 142ff.; and in Marsden, above. *Dioptra* is published with *Metrica, Opera*, III. *Definitiones and Geometrica* appear as *Heronis definitiones cum variis collectionibus Heronis quae feruntur Geometrica*, J. L. Heiberg, ed., *Opera*, IV. *Mechanica* is available as Carra de Vaux, "Les mécaniques ou l'élévateur de Héron d'Alexandrie," in *Journal asiatique*, 9th ser., **1** (1893), 386–472, and **2** (1893), 152–269, 420–514, consisting of Arabic text and French translation; and as *Herons von Alexandria Mechanik und Katoptrik*, edited and translated by L. Nix and W. Schmidt, *Opera*, II, pt. 1. *De mensuris* is published with *Stereometrica, Opera*, V. *Metrica* is available in three versions: *Herons von Alexandria Vermessungslehre und Dioptra*, Greek and German versions by Hermann Schöne, *Opera*, III: *Codex Constantinopolitanus Palatii Veteris*, no. 1. E. M. Bruins, ed., 3 pts. (Leiden, 1964)—pt. 1, reproduction of the MS; pt. 2, Greek text; pt. 3, translation and commentary; and *Heronis Alexandrini Metrica...*, E, M. Bruins, ed. (Leiden. 1964). *Pneumatica* can be found as *Herons von Alexandria Druckwerke und Automalentheater*, Greek and German versions edited by Wilhelm Schmidt, *Opera*, I; and *The Pneumatics of Hero of Alexandria*, translated for and edited by Bennet Woodcroft (London, 1851) and fac, ed. with intro. by Marie Boas Hall (London-New York, 1971). *Stereometrica* appears as *Heronis quae feruntur Stereometrica et De mensuris*, J. L. Heiberg, ed., *Opera*, V. *Fragmenta*, the commentary on Euclid's *Elements*, is found as *Codex Leidensis 399, l. Euclidis Elementa ex interpretatione Al-Hadschdschadschii cum commentariis Al-Narizii*, Arabic and Latin edited by R. O. Besthorn and J. L. Heiberg, 3 vols. (Copenhagen, 1893–1911).

II. Secondary Literature. See A. G. Drachmann, *Ktesibios, Philon and Heron*, vol. IV in Acta historica Scientiarum naturalium et medicinalium (Copenhagen, 1948), on *Pneumatics;* and *The Mechanical Technology of Greek and Roman Antiquity*, vol. XVII in Acta historica Scientiarum naturalium et medicinalium (Copenhagen, 1963), on *Mechanics;* J. L. Heiberg, *Geschichte der Nathematik und Kantrwissenschaften un Altertum*, in Iwan von Müller, ed., *Handbuch der Altertumswissenchaft*, V, pt. 2, sec. 1 (Munich, 1925), on the mathematical works; and O. Neugebauer, "Über eine Methode zur Distanzbestimmung Alexandria-Rom bei Heron," in *Kongelige Danske Videnskabernes Selskab Meddelelser*, **26** , no. 2 (1938), on *Dioptra*.

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