Physics

Technology
Despite admirable individual studies by Eilhard Wiedemann and his disciples and despite the excellent work by Matthias Schramm, *Ibn al-Haythams Weg zur Physik* (1963), the discipline of physics belongs to those areas of Arabic-Islamic science which still await a historical survey however modest in scope. Approaching Ibn al-Ha‘tam (1st half of the 11th c.) from his main work on optics (*Kitāb al-Manāẓir*) and his astrophysical writings, Schramm came to the conclusion that in these works Aristotelian physics, applied mathematics, traditional astronomy and optics are combined, and that this can be considered as typical of Ibn al-Ha‘tam’s scientific research. On the other hand, he succeeded, according to Schramm, “in transforming Aristotelian metaphysics of nature, with the study of which he began his scientific endeavours, into a physical theory that provides a dynamic explanation of the kinematic model postulated by Ptolemy.” With his efforts in this respect, Ibn al-Ha‘tam had “taken the first step that was to lead to one of the most remarkable achievements of the human mind as such, from the metaphysics of nature and its mathematical description towards physics, towards exact natural science based on mathematical methods.” (Catalogue I, p. 29)
A Book on Mechanical Devices: 
*Al-Ḡāmiʿ bain al-ʿilm wa-l-ʿamal an-naḍīʿ*

This book was written by the otherwise unknown Ibn ar-Razzāz al-Ḡazari (around 1200) upon commission by the local ruler of Ḍam, ʿAṣiraddīn Ṭāhī b. Muḥammad b. Qarāʿarslān (r. 1200–1222), and was completed two years after the latter’s accession to power. Several manuscripts of the book with illustrations in colour have come down to us. It is without doubt the most beautiful of the extant works in the field of mechanics. The author mentions amongst the contents of his book “water driven machines for equinoctial- and temporal hours” and devices used for “moving bodies from their natural position by means of [other] bodies”. He describes fifty machines and devices in all clarity from the point of view of an engineer and provides them with fifty complete and about a hundred partial drawings of such quality that one can reconstruct the machines without any substantial problems.

This book, originating in the eastern part of Asia Minor under the adverse political conditions of those times when the war against the crusaders impeded communication amongst the people and the exchange of books and knowledge between the countries of the Islamic world, probably does not reflect the state-of-the-art reached by Arabic-Islamic technology at that time or even in general. It is a book compiled by a capable engineer according to his talents and his understanding on the basis of his knowledge of the sources and within the bounds of the conditions of his environment. For instance, when the conical valve for regulating the water level in hydraulic devices appears for the first time in al-Ḡazari’s book, this is no sufficient reason to consider him its inventor. Incidentally, this type of valve was not known in Europe until the 18th century. Whether it reached the West from the Arabic-Islamic area or whether it developed again independently remains a matter of speculation.
Some of the Instruments and Devices Constructed by Taqīyaddīn

Taqīyaddīn enjoyed considerable fame in the Ottoman Empire not only as ar-rāṣid (observing astronomer) but also as a muhandis (engineer). From his two extant treatises on pneumatic constructions and clocks he indeed emerges as an eminent physicist and technician. In his book on pneumatics, at-ṭuruq as-sanāʿa fi l-ālat ar-rūḥāniyya written in 953/1546, Taqīyaddīn describes a number of machines and devices that reveal an already well-developed level of technology. (Catalogue I, p. 75; V, pp. 41-42)

Skewers

Taqiyyaddin describes the three types of mechanised skewers most common in his time, one of which is turned by steam and the other by hot air. The description of the second device resembles a turnspit-construction sketched by Leonardo da Vinci which was also intended to be powered by hot air. Moreover, Taqiyaddin describes numerous devices functioning by transmission of force with cogwheels. They must have been very common in his days. He refers to one of them as his own invention. (Catalogue I, p. 77; V, pp. 37-40)
Balance, constructed according to the original dated 10th century, which is preserved in the Science Museum at London.

(Cat. V, 7; E 1.19)

Balance with an exactitude of 1:60000.
Designed in the 12th century CE by al-Khāzīnī and called mizān al-ḥikma.

(Cat. V, 5; E 1.01)

Device for the determination of the specific gravity of solid bodies. Invented by al-Bīrūnī (d. 1048 CE). Model reconstructed after the drawing and description contained in his book.

(Cat. V, 9; D 1.23)

Areometer for the determination of the specific gravity of liquids after ʿAbdarrahmān al-Khāzīnī (12th century).

(Cat. V, 12; D 1.24)
Screw Pump
Archimedes (3rd century BCE) encountered a simple helical pump operated by a crank during his travels in Egypt where it was used for irrigation. A more elaborate type from the Islamic era which uses water power is found in the book by Taqiyaddīn (1553 CE).
(Cat. V, 16; E 1.15)

Machine for Raising Water by means of an endless chain of buckets. Our model was made after descriptions in Arabic manuscripts and a surviving structure in Damascus, dating from the 13th century CE. The latter was built in order to supply a hospital and a mosque with fresh water.
(Cat. V, 19; Nr. E 1.14)

Tympanum
A drum-shaped water lifting wheel, constructed according to the description in the manuscript Maqāmāt (1237) by al-Ḥarīrī (d. 1122)
(Cat. V, 23; E 1.18)
Machine for raising water from stagnant waters using animal power

This model of a gin which was in widespread use throughout the Muslim world and is occasionally still found in Egypt, Spain and India was built according to the description contained in al-Gazari’s book (ca. 1200). The gear train is powered by a draught animal.

(Cat. V, 25; E 1.07)

Automatic Water Pump with Two Plungers

This type of water-works with two piston-like plungers driven by the current of a river is described in the books by al-Gazari (ca. 1200) and Taqiyyaddin (1553). The two plungers sit opposite to each other and, powered by a common water-wheel, raise water up to about 11 m.

(Cat. V, 27; E 1.08)
Pump with Six Piston-like Plungers
by Taqīyaddīn

The precise descriptions enabled us to reconstruct several devices without great difficulty; of these, we may first of all mention an automatic pump with six piston-like plungers powered by the current of a river, transferred through a waterwheel onto a camshaft. The cams in turn move six levers which drive the plungers. This type of waterwork with six plungers appears for the first time in Taqīyaddīn’s book. About 350 years earlier Ibn ar-Razzāz al-Gazārī had already known waterworks with two plungers. Thus it is possible that there was an intermediate stage of development in the period between the two authors. In this respect it is interesting that Taqīyaddīn praises a work by ‘Ali al-Qūšī (d. 1474) on pneumatics and mentions it as one of his sources. At the present time it is not known whether the concept of waterworks with multiple pistons as described shortly afterwards in Europe by Georgius Agricola (1494–1555) and Agostino Ramelli (1531–1600?) was connected with the Arab–Islamic world or whether it developed independently.
(Catalogue I, p. 75)
Ship-mill. This type of mill was in widespread use throughout the Islamic world. Our model is based on a description found in the book *Sīrat al-ard* by the Arab geographer Ibn Ḥauqal (10th century CE).

(Cat. V, 30; E 1.03)

Windmill
Our model was made after the drawing and description in the 13th century CE geographical book by Šamsaddin Muḥammad al-Dimaṣqī.

(Cat. V, 32; E 1.04)
Lever with Scissors-like Construction
A device like multiple scissors, used to lift objects weighing up to about 200 kg. Built according to the description found in an Arabic manuscript from around the 12th century CE.

(Cat. V, 35; E 1.17)

Apparatus for lifting water by means of fire.
(Codices Gotha 1348 und Leiden, Warn. 499)

(Cat. V, 36; E 1.23)

A lamp that does not go out even under strong winds, constructed according to the description and the illustration by the Banū Mūsā (9th century).

(Cat. V, 45; E 1.16)
**Grab Dredger** for lifting heavy objects from water, model made after the description of the Banū Mūsā (9th century CE).

(Cat. V, 43; E 1.05)

**Lifting Screw (crane) with Cog-Wheel Gearing.** Taqiyaddin (1553 CE) describes and draws a mechanism with dented wheels that allows it to lift a weight of 1450 kg with a force of only 15 N (i.e. pull of 1.5 kg).

(Cat. V, 41; E 1.12)

**Pulley**

Taqiyaddin (1553 CE) describes a sophisticated type of polypast in which two sets of eight wooden blocks are arranged cylindrically. Its strong gearing allows it to lift weights with only 1/16 of the force required normally.

(Cat. V, 42; E 1.11)
Fountain with varying appearance by al-Ġazari.

(Cat. V, 53; B 1.07)

The second of the Fountains constructed and described by al-Ġazari.

(Cat. V, 54; B 1.08)

Entertainment Machine
operating by waterpower a scene of moving figurines in set intervals. Made after the book on automata by al-Murādi (11th century CE)

(Cat. V, 51; B 1.09)
Model of a mechanical **Door Lock with Four Bolts** by al-Ḡazari (ca. 1200). The bolts are pushed forward and opened by a special key so that the door is protected on all sides.

*(Cat. V, 59; E 1.10)*

A **Palace Door** (before 1200 CE)

This artistically crafted door of a palace in Amid (Diyarbekir) is described by al-Ḡazari (ca. 1200 CE).

*(E 1.29)*

Security or **Combination Lock**. Our model was made after drawings and descriptions in al-Ḡazari’s book (ca. 1200 CE)

*(Cat. V, 56; E 1.02)*
**Perpetual Motion**
An Arabic manuscript from the 12th century CE speaks of machines which upon an initial impulse keep moving by themselves forever for the first time. This idea was introduced to Europe and caused innumerable futile experiments well into the 19th century CE.

Eventually the Académie Française declared all further attempts useless. In the Islamic world, however, it was Taqiyaeddin who rejected the concept as early as 1553.

(Cat. V, 60; E 1.21-22)

**Ibn Firnas's Attempt at flying**
Abu l-Qasim Ibn Firnas (880 A.D.), the versatile physicist of Andalusia, constructed the glider consisting of a suit of feathers with wings, with which he flew some distance.