

Horology

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1. Synonyms (if possible)

2. Related Topics

- Measurement

3. Definition/Introduction

Horology refers to the measurement of time, as well as the art of building instruments with which to study and measure time. There were two important developments in the early modern period: the dramatic improvement of the quality of mechanical clocks due to highly skilled craftsmen, and the introduction of the pendulum as time-keeper in the escapement mechanism. The latter innovation not only allowed a further jump in precision, it also had important conceptual implications.

4. Main Text

Astronomical phenomena have provided the most important means of measuring time throughout most of human history. This has often been combined with the formulation of different kinds of theoretical schemes treating these phenomena, which in turn could lead to more fine-grained determinations of time. Different instruments were developed to mediate these determinations, by providing the means to register observations and translate the outcomes into information about the passing of time: most ubiquitous is the sundial, most intricate the astrolabe that was first developed in the Arabic world (Evans 1998). The flow of water is the one other physical phenomenon that has naturally suggested itself as a means to determine time, by measuring the amount of water flown out of a container during a certain interval. Water-clocks that were synchronized with astronomical time were not only used as independent means to tell the time for social purposes, they were also called upon by Babylonian and Chinese astronomers to time astronomical phenomena such as lunar eclipses (Steele, Stephenson and Morrison 1997; Steele and Stephenson 1998).

Mechanical clocks were introduced in the thirteenth century in Western Europe (Dohrn-van Rossum 1996). They consisted of a drive force, such as a heavy weight, an escapement mechanism that periodically interrupts the accelerated motion produced by the force, and a dial that counts the periodic

time delivered by the escapement. The escapement exploits the inertia of a heavy bar (the foliot) that is put into horizontal rotation by the drive force to temporarily stop the gear train and release it again (using a cleverly disposed crown wheel) according to a rhythm that is regulated by the bar's rotational inertia, which can be adjusted by sliding weights. By the end of the sixteenth century the potential accuracy of mechanical clocks had dramatically improved thanks to the craftsmanship of specialist artisans. Some clocks were claimed to have an accuracy of up to a minute per day, and clocks were used by astronomers like Taqi al-Din in Istanbul, landgrave Wilhelm IV of Hessen-Kassel and Tycho Brahe (Matthes and Sánchez-Barrios 2017). While they could be useful aids in astronomical practice, the uncertainty surrounding their accuracy meant that one could never be sure whether an observational result diverging from theoretical expectations was due to details in the astronomical phenomenon or had to be blamed on the means of measuring the time.

The main drawback of the mechanical clock was its high sensitivity to unavoidable irregularities in the force transmitted to the foliot, as the rhythm of the foliot's rotational motion was directly coupled to the impulse it received. This limitation was overcome in the seventeenth century by the replacement of the foliot by a pendulum, which has a natural frequency solely determined by its length (at least for small amplitudes), as first noticed by Galileo at the beginning of the century. The role of the drive force could be limited to powering the time dial and restoring the motion that the pendulum lost due to friction, and small changes in its impulse did not affect the pendulum's proper period (Mahoney 1980). After Christiaan Huygens had constructed the first pendulum clock in 1656, it very quickly became a standard instrument for the timing of astronomical observations, with the margin of error reduced to the order of seconds. This led to exciting new possibilities, as demonstrated for example by Ole Roemer's determination of the speed of light based on precise timings of the eclipses of one of Jupiter's moons (Cohen 1940).

The pendulum had already been used as a time-keeper before Huygens' design of a mechanical pendulum clock, most systematically by the Jesuit mathematician Giovanni Battista Riccioli, who used it to perform sustained tests of Galileo's law of fall, a task for which Galileo himself had used a water-clock (Graney 2015). As Galileo had already surmised, there was an intimate relationship between the pendulum's property as a time-keeper, and the law of fall that characterizes the acceleration of falling bodies – such as the pendulum bob itself (Büttner 2019). This has profound implications. The flow of water was used to measure the passing of time that was referred back to astronomical phenomena, but it was never studied in its own right as a physical phenomenon that could implicate time as a physical parameter. The pendulum, on the other hand, was from the very beginning simultaneously a measuring instrument and a theoretical object. It provided the crucial means to mediate between a new kind of theoretical scheme, developed through the work of Galileo,

Huygens and Newton, and empirical phenomena – now including motions on earth on an equal footing with motions in the heavens (Koyré 1953, Mahoney 2000).

5. Cross-References

- Time in Early Modern Philosophy and Science
- Hydrostatics
- Instruments and Instrument makers
- Astronomy
- Galileo's natural philosophy

6. References

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