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How Is Time Measured?

Accelerated-ideas

A technological evolution

The movements of the Earth and Moon determine the length of the years, seasons, months and days. People have observed the periodicity of the seasons and of the night sky stars patterns since prehistory. Ancient Egyptians knew that the Nile would overflow when the Sirius star raised over the line of the horizon. Some stars were associated with the seeding time in rural Europe. People also focused on the Moon's phases, determined by the incidence angle of the sunlight on the Moon, which caused the full moon, new moon or half moon. Romans based their calendar on the Moon's phases. A full cycle made a month. The day length is given by a complete spin of the Earth around its axis. A year, when the Earth has completed a tour around the Sun, is of about 365 days (but not a round number). To solve the issue, Julius Caesar introduced a system in which one 366-days year followed after three 365-days years . Later, it was found that the year was longer with 11 minutes and 36 seconds than initially calculated. Along the centuries, this created an error of several days. It was corrected by Pope Gregory XIII in 1582, by eliminating 10 days. The years that started the centuries were ordered to have 366 days only if they divided by 400. Today, the Gregorian calendar is still used in the western world. 6,000 years ago, the first attempts to systematically measure the time emerged. Egyptians divided the day in hours. For measuring the time, they used an axis called gnomon, implanted into the ground, whose shadow fell on a hours-divided scale. Following the ostensible movement of the Sun in the sky, the axis made the scale to point the time in hours. But this could not show the time during the night, nor on cloudy weather. By 1,500 BC, Egyptians solved this by inventing the water hourglass. It was a water reservoir with a tiny hole in the bottom and a gradation marked on its edge. The hourglass was filled with water, which poured slowly through the hole. The scale indicated the time passed since the filling of the hourglass. In a later improved variant, the water drained into another reservoir, whose floater indicated the passed time. The sand hourglass used sand pouring through an orifice, usually for 30 or 60 minutes. Candles were used for measuring time as well, but the method was highly imprecise because of the various types of rope, wax and air current in the room that influenced burning speed. The first mechanic clock was invented in Europe in 1275. A weight hung on a rope spinning a wheel that, in its turn, acted a mechanism whose task was to hit a bell from hour to hour. Later, the clocks were endowed with a quadrant. The masterpiece of the mechanic clock was the anchor, which conferred periodicity to the spin of a toothed wheel, thus determining the rhythm of the movement of the mechanism. The rhythm of the anchor's movement was ensured by the regulator mechanism, which determined the exactness of the clock. The precision of the first mechanic clocks was determined by the weight fork: the mechanism consisted in a horizontal axis with weights on its ends, fixed over a vertical axis. Through the swing of the weights, the movement was transmitted to the anchor which determined the movement rhythm of the whole mechanism. Around 1330, the first clocks to signal the time passing with a corresponding number of bangs on a bell were built in Italy. Around 1475, the first axis clocks were made, solving an issue of the weight-acted clocks: portability. Until the 1500s, the clocks only denoted the hour and its fractions had to be approximated. But astronomers needed more precise clocks. This is how the small hand emerged, and some clocks even had a second arm. Around 1600, clocks regulated by pendulum emerged; they were more precise than axis clocks. In 1580, Galileo Galilei discovered the controlled swing of the pendulum and he sketched the project of a pendulum clock in 1641. Next year he died, and the clock was executed by his son, Vincenzo, in 1649. The daily errors of these clocks ranged from 10 seconds to several minutes. In 1658, Robert Hooke invented the regulator arch (hair). The balancer was made using a spiral thin arch, and the balancer rolled and unrolled because of a wheel spinning around an axis, one way to another. This movement regularized that of the anchor. The great advantage was that the come and go movement of the clock did not influence the regularity of the balancer's movements. This way, smaller and preciser clocks could be made. The boom of the navigation during the 17th century required a preciser knowledge of the ships' position. The main issue was to determine the longitude of the Greenwich meridian. But the ship's swing perturbed the precision of the pendulum clocks, and the thin spiral of the balancers was perturbed by the great temperature's variations. The solution was the stop watch, invented around 1760 by John Harrison. In an 156 days trip, it recorded an error of only 54 seconds. He solved the issue of the temperature variation through the method of the automatic compensation of the accumulated errors, by changing the length of the spiral arc of the balancer. Today, electric and electronic watches are more popular. In many electric watches, the hands are acted by an electric engine, the movement of the engine being determined by the frequency of 50 to 60 periods per second of the alternative current. In electronic watches, numbers are indicated through fluorescence. Electronic wrist watches usually work based on quartz crystals, which, when electrically excited, vibrate with a constant frequency. The crystals' vibrations generate regulated electric impulses, controlling the mechanic movement of the hands or the display of the numbers on the screen. Some wall timekeepers work on quartz crystals, too. The quartz crystal watches have an error of 1/30 seconds daily. Atomic watches are much more precise, using the vibrations of certain atoms, like, for example, cesium or hydrogen, and indicate time with an error of 1 second at 1,000 years. These watches are used in experiments that require high time precision and they define time unity: second is now defined as the multiple of 9192631770 or of the vibrations emitted by the cesium133 in precisely determined conditions.