

Significant Time Clock Inventions (Philosophic Question: are clocks and time separable?)

Time resides in the noumenal realm of ideas derived from an accounting of the relative motion of bodies of matter possessing mass - Relativity Science Calculator

"I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted." - Alan Turing (1912 - 1954)

"The clock, not the steam engine, is central to the industrial revolution. The clock is the crowning achievement that all other machines aspire to." - Louis Mumford (1895 - 1990)

from 3500 BC to roughly 700 BC: **pre - Greek Sundials:** obelisks (3500 BC); shadow clocks (1500 BC from Egyptian and Babylonian astronomies); the "the dial of Ahaz" (approx. 700 BC from the Old Testament, Isaiah 38:8 - "Behold, I will bring again the shadow of the degrees, which is gone down in the sun dial of Ahaz, ten degrees backward. So the sun returned ten degrees, by which degrees it was gone down." - Modern Hebrew: הנני משיב את־צל המעלות אשר ירדה במעלות אחז בשמש אחרנית עשר מעלות ותשב השמש עשר מעלות במעלות אשר ירדה:)

560 BC: **Greek Sundials:** the Suda (or Souda, both meaning "fortress" or "stronghold"), a 10th - century Byzantium encyclopedia with 30,000+ entries of the ancient Mediterranean world written in Medieval (Byzantine) Greek, mentions Anaximander of Miletus (circa 610 BC - c. 546 BC, citizen of Miletus in Anatolia, Asia Minor, greatest and wealthiest of the Greek Ionian cities before the Persian invasions of the 6th century; pre - Socratic Greek philosopher of the pre - modern, ancestral scientific tradition; metaphysician, astronomer, geometer) as having been the person to have introduced shadow - casting *gnomons* or vertical pillar or rod - like sundials into Sparta (Lacedaemon), Greece to indicate time of day, seasons and solstices (the date for the longest or shortest day of the year) and equinoxes (the days of equal light and darkness).

300 BC: **The Thirteen Towers of Chankillo (for 13 - months calendar):** Ancient Peruvian sundial calendar constructed atop one of the mountains of Chankillo of thirteen regularly - spaced towers, forming a huge earth - sun timepiece. Still in use and accurate to 1 or 2 days out of our modern 12 months calendar!

3rd century BC: **Escapement Mechanism:** Philo of Byzantium, Greek engineer, described the first liquid - driven escapement (a mechanical device that transfers energy to the timekeeping element of a clock in small portion in order to enable time counting; escapements are also used for other applications) for a washstand water pouring automaton, possibly used also in ancient water clocks.

150 - 100 BC: **The Antikythera Mechanism:** discovered by sponge divers more than a hundred years ago this extraordinary mechanism was found at the bottom of the sea near the island of Antikythera, Greece. The Antikythera Mechanism is known to model astronomical phenomenon with remarkable detail. The Antikythera is thought to date from between 150 and 100 BC and it precedes any other known clockwork mechanisms of similar complexity by more than a millennium, providing us with an encyclopedia of the astronomical knowledge of the Greek Classical time.

45 BC: **Julian Calendar:** introduced by Julius Caesar after consultation with the astronomer Sosigenes of Alexandria. The Julian calendar was faulty because it was inconsistent with the solar year - 11 minutes difference per year.

2nd century AD: **Water clock:** Zhang (or Chang) Heng (78 - 139, Chinese astronomer, mathematician, geographer, cartographer, inventor, and literary scholar) introduced an inflow water clock by adding another compensating water tank between the reservoir tank and the inflow vessel as an improvement for time measurement. This configuration is more accurate than the simple outflow model which otherwise suffers from falling head pressure into the reservoir as the inflow vessel fills.

520 AD: **Candle Clock:** a long thin candle that when burned marks off periods of time. The earliest reference to their usage appears in a Chinese poem by You Jiangu in 520 AD. An extremely rudimentary timepiece, these nevertheless were good for telling time indoors, at night and on cloudy days.

725 AD: **Water Clock:** Yi Xing (683 - 727, Chinese astronomer, mathematician, mechanical engineer and Buddhist monk) is noted for his work in astronomical instrumentations, his greatest and last one of which is called the 'Water-Driven Spherical Bird's-Eye-View Map of the Heavens' or 'Celestial Sphere Model Water-Engine'. This water clock begun by Yi Xing was probably fully completed by his team of engineers in 725+ after his demise in 727 AD. It is further believed that Yi Xing and his team of engineers introduced the first known hydraulic clock with an escapement design.

9th century AD: **Candle Clock:** the most famous candle clock is commonly attributed to King Alfred the Great (849 - 899) - also King of Wessex (871 - 899), consisting of 6 candles each one of which had 12 marks for 20 minutes of time passage. Each candle would burn for 4 hours, thus the entire array of 6 candles would thereby accomodate a full 24 hours for a day afterwhich a replenishment of a new set of candles would be lit. Wooden frames holding glass paneling provided the necessary protection against air disturbances.

996: **Turret (Public) Clock, the Horological Balance (brake enabling weight - driven wheels, fitted into towers):** maybe the first weight - driven clock was built by Gerbert d'Aurillac or Gerbert of Aurillac (c. 946 - 1003; French Abbot monk, first French Pope from 999 - 1003; buried in St. John Lateran; noted scientist and prolific scholar and teacher of his time in matters of geometry, astronomy, music, and arithmetic such as bringing the abacus into mainstream European usage; and the future Pope Sylvester II, AD 999) for the St. Maurice Abbey (founded 937; later the Cathedral of Magdeburg consecrated in 1263) in Magdeburg, Germany.

11th century AD: **Incense Clock ("fragrance clock"):** a Chinese timekeeping device that appeared during the Song Dynasty (960 - 1279) and spread to neighboring countries such as Japan. The clock consists of incense sticks or seals that have been manufactured to a known rate of combustion, used to measure minutes, hours, or days which were commonly used at homes and temples.

1088 - 1094: **Astronomical clock (water - driven):** year 1088 - wooden pilot model, year 1094 - bronze completed: Su Song (1020 - 1101, renowned Han Chinese polymath, astronomer, horologist and mechanical engineer), engineered during the Song Dynasty a 40-foot-tall hydro - mechanical astronomical clock tower in the medieval City of Kaifeng. His culminating life's written work: *Xinyi Xiangfayao*, 1092 (translate: "Essentials of a New Method for Mechanizing the Rotation of an Armillary Sphere and a Celestial Globe").

1330: **Astronomic Clock (mechanical - driven):** described in the 1327 manuscript *Tractatus Horologii Astronomici* by Abbot Richard of Wallingford, the most complex clock mechanism in existence at the time in England but later destroyed during Henry VIII's Protestant Reformation. That is, Abbot Richard of Wallingford (1292 – 1336, English mathematician publishing major works on horology, trigonometry, celestial coordinates, astrology, and various other religious works; abbot of Abbey of St. Alban in Hertfordsire where he died), built a mechanical clock as an astronomical orrery (a mechanical device that illustrates the relative positions and motions of the planets and moons in the Solar System).

1335: **2nd Public Clock** : Milan, Italy hosted the first public clock that struck the hours.

ca 1386: **the Salisbury Anglican Cathedral Clock (built between 1220 to 1258, formerly the Cathedral Church of the Blessed Virgin Mary):** Salisbury, England hosts the oldest working clock in the world since beginning from 1386, still extant with most of its original parts in addition to housing the best four surviving original copies of Magna Carta!

1462: **Early Proto Pocket Watch:** an early reference to a pocket watch is made in a letter in November, 1462 from (clockmaker? more probably Renaissance painter) Bartholomew (-meo) Manfredi (born Mantua or Mantua, Italy, 1582 - died sometime after 1622) to the Marchese di Manta (Mantova) Federico Gonzaga, where he offers him a "pocket clock" better than that already belonging to the Duke of Modena.

ca 1500 ... More probably 1508, 09: **Next Generation Proto Pocket Watch:** Peter Henlein (spelled Henle or Hele, 1485 - 1542, Nuremburg, Germany, locksmith and timepiece maker having the skills and even more rare tools) manufactured the first truely small, portable ornamental brass timepieces often worn as very rare and expensive neck pendants or attached to outer clothing for the nobility of the times, by replacing other cumbersome weights, sand, water, etc., with a coiled, flat steel mainspring in driving the clock mechanism, thus ushering in a great stride for the incremental Age of Horology. And certainly by 1524 Peter Henlein (Henle or Hele) was regularly manufacturing pocket watches and thereafter the Age of Horology (Latin: *horologium*) had finally arrived!

Johann Cockläus (born Schwabach, Germany 1479 - died Wroclaw, Poland, 1552, humanist, controversialist) first credited Henlein (Henle, Hele) with constructing the first true pocket watch by this 1511 passage:

"Peter Hele, still a young man, fashions works which even the most learned mathematicians admire. He shapes many - wheeled clocks out of small bits of iron, which run and chime the hours without weights for forty hours, whether carried at the breast or in a handbag."

1519 - 1522: **Hourglass (sand clock)**: Ferdinand Magellan (1480 - 1521, Portuguese navigator and explorer) used 18 hourglasses on each ship during his Magellan - Elcano expedition (sailing 1519 Seville, Spain in 1519 - arriving 1522, Sanlúcar de Barrameda) for the very first circumnavigation of the earth.

1556: **Clock (weight - driven)**: Taqi al-Din Muhammad ibn Ma'ruf (born 1526 Damascus - died 1585 Istanbul, polymath, astronomer, engineer, mathematician, natural philosopher, celestial clock maker) described in his book, *In the Nabk Tree of the Extremity of Thoughts*, a weight - driven, mechanical clock with a verge-and-foliot escapement, gears, an alarm, and a representation of the moon's phases, all of which he used in his observations of the Great Comet of 1577. Taqi ad-Din had accomplished this Great Comet observation after having first built the Great Istanbul Observatory in 1577 by means of the financial and political support of the Sultan of the Ottomans. Shortly thereafter, however, the Great Istanbul Observatory (1577 - 1580) which rivaled Tycho Brache's Observatory Uraniborg on Hven (1576 - 1597) was destroyed in 1580 at the instigation of the Islamic Chief Mufti of the Ottomans as being "un - Islamic" and hence against Mohammed's Koranic Vision.

1577: **1st Clock marking seconds**: Jost (Joost, or Jobst) Bürgi (born Lichtensteig, St. Gallen, Switzerland 1552 - died Kassel, Germany 1632, Swiss clockmaker, maker of astronomical instruments, mathematician), mathematically derived logarithms independent of Scottish contemporary John Napier, and developer of some of the first astronomical charts, he nevertheless built many astronomical instruments for Landgrave William IV of Hesse - Kassel (1532 - 1592, also called William the Wise)'s excellent Landgrave Kassel observatory such as the "reduction compass" and the "triangulation instrument", both of which had military usage in addition to marking the movements of celestial bodies. Jost Bürgi is best remembered in addition to his many other outstanding accomplishments for inventing the clock minute hand in 1577 marking seconds of celestial time of bodies in distant motion. In 1581, Tycho Brache or Tyge Brahe (1546 - 1601, Danish astronomer and nobleman, born in Scania, then part of Denmark now part of modern Sweden), in intimate collaboration with Jost Bürgi, redesigned minute hand clocks displaying seconds for Brache's Observatory Uraniborg on Hven (1576 - 1597) so they could better calculate celestial seconds. Upon Brache's death in 1601, Johannes Kepler (1571 - 1630, German mathematician, astronomer and astrologer) became the immediate inheritor of Brache's jealously guarded astronomical data, owing in no little amount to Jost Bürgi's clock making! See: "[Bürgi, Jost](#)" from Oliver Knill History pages, http://www.math.harvard.edu/~knill/history/burgi/bea_proofs_burgi.pdf

1582: **Gregorian Calendar (the Western Calendar, the Christian Calendar)**: introduced in 1582 by Pope Gregory XIII (Latin: Gregorius III, 1502 - 1585), after whom the calendar was named. The motivation for the Gregorian calendar was to correct errors created by the Julian Calendar (see above).

1638: **Water Clock (use in physics)**: in his "*Discorsi e dimostrazioni matematiche, intorno à due nuove scienze*" (Discourses and Mathematical Demonstrations Relating to Two New Sciences, Third Day: Naturally Accelerated Motion), Galileo Galilei (1564 - 1642, Tuscan - Italian physicist, mathematician and astronomer), used a water clock to measure the time taken for a bronze ball to roll a known distance down an inclined plan, whereby he experimentally arrived at his famous "Law of Falling Bodies" equation. Water Clocks in conjunction with sundials are among the oldest time - measuring systems throughout the Classical Period of Antiquity.

1657: **Pendulum Clock**: invented by Christiaan Huygens (1629 - 1695, Dutch mathematician and astronomer), he is also best remembered for his major studies of optics, mechanics and probability game theory.

1675: **Greenwich Mean Time (GMT; originally Mean Solar Time at the Royal Observatory, Greenwich, London, England)**: although slowly being displaced by UT (Universal Time) and CUT (Coordinated Universal Time), GMT was established by King Charles II when the Royal Observatory was built as an aid to English mariners to greatly (more!) determine exact ship longitudes at sea, thus providing a needed reference time for delivering ships, munitions and crew to exact surface locations on the globe in order to do successful ocean and land battles. Also because in the Discovery Era of 1600s - 1700s, time - keeping was the province of each individual English city anyone of which kept a different local time, hence GMT provided a standarization of time throughout the British Isles and beyond way into the entire English Empire.

1687: **Absolute time:** in the mathematical physics of Sir Isaac Newton (1643 - 1727 , English physicist, mathematician and astronomer) in his *Philosophiæ Naturalis Principia Mathematica*, or *Principia* for short, Absolute Time and Space are independent aspects of objective external reality, a concept which provides the philosophic foundation upon which Newtonian Mechanics resides and thereby most conveniently provides the theoretical underlying basis for both Euclidean and René Descartes' Analytic geometries.

1767: **Marine H4 Chronometer:** invented by John Harrison (1693 - 1776), English carpenter and clockmaker, who won the English Crown's Longitude Prize by successfully having completed both the First Trial Voyage, 1761- 62, to Port Royal, Jamaica and back to Portsmouth, England, and again in the Second Trial Voyage, 1764, to Bridgetown, Barbados and returning back again to Portsmouth. Harrison's H4 clock was able to place men and guns at precise time and locations on the surface of the globe, and thus fully demonstrated the merging of time with space! Or, rudimentary spacetime.

1781: **Subjective Time:** Immanuel Kant (1724 - 1804, German philosopher) and Gottfried Wilhelm Leibniz (1646 - 1716, German mathematician and philosopher) both maintained contrary views to Newton's idea of Absolute Time (see above); namely, that time does not refer to any kind of materially real noumenon or externally objective entity but that it is instead a part of a fundamental intellectual structure, together with space and number, of the mind within which humans sequence and compare point - events. Or in other words, externally perceived reality is mentally subjective, intellectually constructed and psychologically "relative".

1859: **Big Ben begins ticking:** The designers were the English lawyer and amateur horologist Edmund Beckett Denison, and George Airy, the Astronomer Royal. Construction was entrusted to clockmaker Edward John Dent and after his death in 1853 his stepson Frederick Dent completed the work.

1868: **Patek Philippe & Co. - Wristwatch:** Co - founders Antoni Patek (1811 - 1877, Polish watchmaker) and Adrien Philippe (1815 - 1894, French watchmaker) combined in union in 1851 to form this Swiss luxury watch manufacturer. Patek Philippe & Co. invented a lady's bracelet watch intended simply as jewelry. It is also believed that Girard - Perregaux (Jean - François who signed his first watches in 1791 combined with Constant Girard, Swiss watchmaker, in 1856 to form Girard - Perregaux, a high - end Swiss watch manufacturer) equipped the entire German Imperial Navy as early as the 1880s for its naval officers as ordered by Kaiser Wilhelm, with wristwatches to be used in synchronizing naval attacks and firing artillery.

1879: **Atomic clock:** Lord Kelvin (1824 - 1907, Irish - English, mathematical physicist and engineer), first proposed in 1879 the idea of using atomic energy transitions (when electrons are excited from one energy level to a higher quantum energy level) in order to measure the passage of time.

1895: **The Time Machine:** such a time machine is first proposed in a science fiction novella of the same name by H. G. Wells, English science fiction author. In his time machine story, H.G. Wells popularized the concept of time travel using an accelerating, whirling vehicle that allows an operator to travel back in time. Wells also coined the expression "time machine".

1905: **Special Relativity:** Albert Einstein (1879 - 1955, Jewish - German, later American, theoretical physicist and philosopher of science) overturned the concept of absolute time and space, and thus overturned Newton, by mathematically proposing relativistic length contraction and expanding time dilation or, equivalently, a clock slowing down.

1908: **Spacetime (or space - time):** a mathematical physics model that combines space and time into a single continuum of point - events - it was first explicitly proposed mathematically by Hermann Minkowski (Russian born 1864 - 1909, Jewish - German mathematician), building on and extending Einstein's original Special Theory of Relativity. His concept ("Minkowski space") is the earliest treatment of space and time as two aspects of a unified field, the essence of special relativity.

1911: **Twin paradox:** Paul Langevin (1872 - 1946, French physicist) is renowned for his most famous WWI submariner ultrasound work involving Pierre Curie's piezoelectric effect. But Langevin was also most responsible in France for widely disseminating Einstein's theories of both special and general relativity whilst also raising the conundrum in 1911 for what is now called the Twin Clock Paradox.

1916: **General Theory of Relativity:** Einstein's Theory of General Relativity generalises Special Relativity by extending Newton's Universal Law of Gravitation thus providing a unified field description of gravity as a geometric continuum property of spacetime (space - time).

1924 - 27: **Quantum Mechanics:** developed by Niels Bohr, Danish physicist, Werner Heisenberg, German theoretical physicist, et al. According to quantum theory a quantum particle can be present in two different states (wave – particle duality) at the same time, but not observed simultaneously. The Copenhagen interpretation (one of the earliest and most commonly taught interpretations of quantum mechanics) states that the wave - particle duality does not mean that a photon or any other subatomic particle is both a wave and particle simultaneously, but that it could manifest either a wave or a particle aspect depending on circumstances.

1927: **Quartz clock (crystal frequency oscillator):** the first electronic oscillating quartz clock was built by Warren Marrison (1896 - 1980, Canada), Canadian telecommunications engineer and J. W. Horton at Bell Telephone Laboratories in Canada.

1927: **Arrow of Time (Time's Arrow):** a concept developed by British astronomer Arthur Eddington to describe the seemingly asymmetric, "one - way direction" of time.

1955: **Atomic clock:** Louis Essen (1908 - 1997, English physicist) in collaboration with Jack Parry, most notably built the first practically accurate atomic clock for the most precise measurement of time as well as involving himself in yet another determination of the speed of light, all based upon a certain transition of the caesium - 133 atom, at the National Physical Laboratory UK. As a greater sceptic of time dilation (time slows) as part of special relativity, Essen published "The Special Theory of Relativity: A Critical Analysis", 1971.

1994: **GPS (Global Positioning System):** a space - based satellite navigational system, consisting of a constellation of five geosynchronous satellites, was developed by the U.S. Department of Defense (DOD) under the DARPA program for locating space and time information here on earth by employing both Special and General Relativity triangulation calculations. GPS is used to synchronize timekeeping systems all across the earth's surface.

2011: **World's 2nd most accurate clock:** [UK's atomic clock is world's 2nd most accurate](#) at the UK's National Physical Laboratory (NPL).

2015: **World's most accurate clock:** a joint project of the University of Warsaw, Jagiellonian University and Nicolaus Copernicus University, now "ticking away" at the National Laboratory of Atomic, Molecular and Optical Physics in Torún, Poland '[is world's most accurate](#)', where "... it would take tens of billions of years for an error of a single second to accumulate - which is several times longer than the time that has passed since the Big Bang."