The history of the clock

The history of clocks is very long, and there have been many different types of clocks over the centuries. Not all historians agree on the history of the clock. The word clock was first used in the 14th century (about 700 years ago). It comes from the word for bell in Latin (“ clocca”).

Using the Sun

The first way that people could tell the time was by looking at the sun as it crossed the sky. When the sun was directly overhead in the sky, it was the middle of the day, or noon. When the sun was close to the horizon, it was either early morning (sunrise) or early evening (sunset). Telling the time was not very accurate.

Sundial Clocks

The oldest type of clock is a sundial clock, also called a sun clock. They were first used around 3, 500 B. C. (about 5, 500 years ago). Sundials use the sun to tell the time. The shadow of the sun points to a number on a circular disk that shows you the time. In the big picture below on the right, the shadow created by the sun points to 9, so it is nine o’clock.

Since sundials depend on the sun, they can only be used to tell the time during the day.

Water Clocks

Around 1400 B. C. (about 3, 400 years ago), water clocks were invented in Egypt. The name for a water clock is clepsydra (pronounced KLEP-suh-druh). A water clock was made of two containers of water, one higher than the other. Water traveled from the higher container to the lower container through a tube connecting the containers. The containers had marks showing the water level, and the marks told the time.

Water clocks were very popular in Greece, where they were improved many times over the years. Look at the picture below. Water drips from the higher container to the lower container. As the water level rises in the lower container, it raises the float on the surface of the water. The float is connected to a stick with notches, and as the stick rises, the notches turn a gear, which moves the hand that points to the time.

Water clocks worked better than sundials because they told the time at night as well as during the day. They were also more accurate than sundials.

Dividing the Year into Months and Days

The Greeks divided the year into twelve parts that are called months. They divided each month into thirty parts that are called days. Their year had a total of 360 days, or 12 times 30 (12 x 30 = 360). Since the Earth goes around the Sun in one year and follows an almost circular path, the Greeks decided to divide the circle into 360 degrees.

Dividing the Day into Hours, Minutes, and Seconds

The Egyptians and Babylonians decided to divide the day from sunrise to sunset into twelve parts that are called hours. They also divided the night, the time from sunset to sunrise, into twelve hours. But the day and the night are not the same length, and the length of the day and night also changes through the year. This system of measuring the time was not very accurate because the length of an hour changed depending on the time of year. This meant that water clocks had to be adjusted every day.

Somebody finally figured out that by dividing the whole day into 24 hours of equal length (12 hours of the day plus 12 hours of the night), the time could be measured much more accurately.

Why was the day and night divided into 12 parts? Twelve is about the number of moon cycles in a year, so it is a special number in many cultures.

The hour is divided into 60 minutes, and each minute is divided into 60 seconds. The idea of dividing the hour and minute into 60 parts comes from the Sumerian sexagesimal system, which is based on the number 60. This system was developed about 4, 000 years ago.

Pendulum Clocks

Before pendulum clocks were invented, Peter Henlein of Germany invented a spring-powered clock around 1510. It was not very precise. The first clock with a minute hand was invented by Jost Burgi in 1577. It also had problems. The first practical clock was driven by a pendulum. It was developed by Christian Huygens around 1656. By 1600, the pendulum clock also had a minute hand. http://www. arcytech. org/java/clock/images/pendulum2. gif

The pendulum swings left and right, and as it swings, it turns a wheel with teeth (see the picture to the right). The turning wheel turns the hour and minute hands on the clock. On the first pendulum clocks, the pendulum used to swing a lot (about 50 degrees). As pendulum clocks were improved, the pendulum swung a lot less (about 10 to 15 degrees). One problem with pendulum clocks is that they stopped running after a while and had to be restarted. The first pendulum clock with external batteries was developed around 1840. By 1906, the batteries were inside the clock. http://www. arcytech. org/java/clock/images/pendulum_mechs3. gif

As you already learned, a clock only shows 12 hours at a time, and the hour hand must go around the clock twice to measure 24 hours, or a complete day. To tell the first 12 hours of the day (from midnight to noon) apart from the second 12 hours of the day (from noon to midnight), we use these terms:

A. M.–Ante meridiem, from the Latin for “ before noon”

P. M.– Post meridiem, from the Latin for “ after noon”

Quartz Crystal Clocks

Quartz is a type of crystal that looks like glass. When you apply voltage, or electricity, and pressure, the quartz crystal vibrates or oscillates at a very constant frequency or rate. The vibration moves the clock’s hands very precisely. Quartz crystal clocks were invented in 1920.

Time Zones

Because the Earth turns, it is daytime in part of the world when it is nighttime on the other side of the world. In 1884, delegates from 25 countries met and agreed to divide the world into time zones. If you draw a line around the middle of the Earth, it is a circle (equator). The delegates divided the 360 degrees of the circle into 24 zones, each 15 degrees (24 x 15 = 360). They decided to start counting from Greenwich (pronounced GREN-ich), England, which is 0 degrees longitude.

In the continental United States, there are four time zones: Eastern, Central, Mountain, and Pacific. Each time zone varies by one hour, so when it is 7 p.

m. in the Eastern time zone, it is 6 p. m. in the Central time zone, 5 p. m. in the Mountain time zone, and 4 p. m. in the Pacific time zone.

Time

Time, a central theme in modern life, has for most of human history been thought of in very imprecise terms.

The day and the week are easily recognized and recorded – though an accurate calendar for the year is hard to achieve. The forenoon is easily distinguishable from the afternoon, provided the sun is shining, and the position of the sun in the landscape can reveal roughly how much of the day has passed. By contrast the smaller parcels of time – hours, minutes and seconds – have until recent centuries been both unmeasurable and unneeded.

Sundial and water clock: from the 2nd millennium BC

The movement of the sun through the sky makes possible a simple estimate of time, from the length and position of a shadow cast by a vertical stick. (It also makes possible more elaborate calculations, as in the attempt of Erathosthenes to measure the world – see Erathosthenes and the camels). If marks are made where the sun’s shadow falls, the time of day can be recorded in a consistent manner.

The result is the sundial. An Egyptian example survives from about 800 BC, but the principle is certainly familiar to astronomers very much earlier. However it is difficult to measure time precisely on a sundial, because the sun’s path throug the sky changes with the seasons. Early attempts at precision in time-keeping rely on a different principle.

The water clock, known from a Greek word as the clepsydra, attempts to measure time by the amount of water which drips from a tank. This would be a reliable form of clock if the flow of water could be perfectly controlled. In practice it cannot. The clepsydra has an honourable history from perhaps 1400 BC in Egypt, through Greece and Rome and the Arab civlizations and China, and even up to the 16th century in Europe. But it is more of a toy than a timepiece.

The hourglass, using sand on the same principle, has an even longer career. It is a standard feature on 18th-century pulpits in Britain, ensuring a sermon of sufficient length. In a reduced form it can still be found timing an egg.

A tower clock in China: AD 1094

After six years' work, a Buddhist monk by the name of Su Song completes a great tower, some thirty feet high, which is designed to reveal the movement of the stars and the hours of the day. Figures pop out of doors and strike bells to signify the hours.

The power comes from a water wheel occupying the lower part of the tower. Su Song has designed a device which stops the water wheel except for a brief spell, once every quarter of an hour, when the weight of the water (accumulated in vessels on the rim) is sufficient to trip a mechanism. The wheel, lurching forward, drives the machinery of the tower to the next stationary point in a continuing cycle.

This device (which in Su Sung's tower must feel like a minor earthquake every time it slams the machinery into action) is an early example of an escapement – a concept essential to mechanical clockwork. In any form of clock based on machinery, power must be delivered to the mechanism in intermittent bursts which can be precisely regulated. The rationing of power is the function of the escapement. The real birth of mechanical clockwork awaits a reliable version, developed in Europe in the 13th century.

Meanwhile Su Sung's tower clock, ready for inspection by the emperor in 1094, is destroyed shortly afterwards by marauding barbarians from the north.

Clockwork in Europe: 13th – 14th century AD

Europe at the end of the Middle Ages is busy trying to capture time. The underlying aim is as much astronomical (to reflect the movement of the heavenly bodies) as it is to do with the more mundane task of measuring everybody's day. But the attraction of that achievement is recognized too. A textbook on astronomy, written by ' Robert the Englishman' in 1271, says that ' clockmakers are trying to make a wheel which will make one complete revolution' in each day, but that ' they cannot quite perfect their work'.

What prevents them even beginning to perfect their work is the lack of an escapement. But a practical version of this dates from only a few years later.

A working escapement is invented in about 1275. The process allows a toothed wheel to turn, one tooth at a time, by successive teeth catching against knobs projecting from an upright rod which oscillates back and forth. The speed of its oscillation is regulated by a horizontal bar (known as a foliot) attached to the top of the rod. The time taken in the foliot's swing can be regulated by moving weights in or out on each arm.

The function of the foliot is the same as that of the pendulum in modern clocks, but it is less efficient in that gravity is not helping it to oscillate. A very heavy weight is needed to power the clock, involving massive machinery and much friction.

Nevertheless the foliot works to a degree acceptable at the time (a clock in the Middle Ages is counted a good timekeeper if it loses or gains only a quarter of an hour a day), and in the 14th century there are increasingly frequent references to clocks in European cities. A particularly elaborate one is built between 1348 and 1364 in Padua by Giovanni de' Dondi, a professor of astronomy at the university who writes a detailed description of his clock. A 14th-century manuscript of his text has the earliest illustration of a clock mechanism with its escapement.

The world's three oldest surviving examples of clockwork date from the last years of the 14th century.

The famous clock in Salisbury cathedral, installed by 1386 and still working today with its original mechanism, is a very plain piece of machinery. It has no face, being designed only to strike the hours. Striking is the main function of all early clocks (the word has links with the French cloche, meaning ' bell').

In 1389 a great clock is installed above a bridge spanning a street in Rouen. It remains one of the famous sights of the city, though its glorious gilded dial is a later addition and its foliot has been replaced by a pendulum (in 1713). The historical distinction of the Rouen clock is that it is the first machine designed to strike the quarter-hours.

In 1392 the bishop of Wells instals a clock in his cathedral. The bishop has previously been in Salisbury, and the same engineer seems to have made the new clock. It not only strikes the quarters. It steals a march on Rouen by having a dial, showing the movement of astronomical bodies.

With escapements, chiming mechanisms and dials, clocks are now set to evolve into their more familiar selves. And the telling of time soon alters people’s perceptions of time itself. Hours, minutes and seconds are units which only come into existence as the ability to measure them develops.

Domestic clocks: 15th century AD

After the success of the clocks in Europe’s cathedrals in the late 14th century, and the introduction of the clock face in places such as Wells, kings and nobles naturally want this impressive technology at home.

The first domestic clocks, in the early 15th century, are miniature versions of the cathedral clocks – powered by hanging weights, regulated by escapements with a foliot, and showing the time to the great man’s family and household by means of a single hand working its way round a 12-hour circuit on the clock’s face. But before the middle of the 15th century a development of great significance occurs, in the form of a spring-driven mechanism.

The earliest surviving spring-driven clock, now in the Science Museum in London, dates from about 1450. By that time clockmakers have not only discovered how to transmit power to the mechanism from a coiled spring. They have also devised a simple but effective solution to the problem inherent in a coiled spring which steadily loses power as it uncoils.

The solution to this is the fusee. The fusee is a cone, bearing a spiral of grooves on its surface, which forms part of the axle driving the wheels of the clock mechanism. The length of gut linking the drum of the spring to the axle is wound round the fusee. It lies on the thinnest part of the cone when the spring is fully wound and reaches its broadest circumference by the time the spring is weak. Increased leverage exactly counteracts decreasing strength.

These two devices, eliminating the need for weights, make possible clocks which stand on tables, clocks which can be taken from room to room, even clocks to accompany a traveller in a carriage. Eventually, most significant of all, they make possible the pocket watch.

Watches: 16th – 17th century AD

The first watches, made in Nuremberg from about 1500, are spherical metal objects, about three inches in diameter, designed to hang on a ribbon round the neck. They derive from similar metal spheres used as pomanders, to hold aromatic herbs which will protect the wearer against disease or vile odours.

The first watchmakers place their somewhat primitive mechanism inside cases of this sort. A single hand set into a flat section at the base makes its way round a dial marked with the division of twelve hours.

For their first century and more, watches are worn outside the clothes and are regarded more as jewels than as useful instruments (a comment also on their timekeeping abilities). The best of them are exquisitely decorated in enamel.

The spherical watch of this kind evolves in the late 17th century into the slimmer pocket watch, thanks largely to Christiaan Huygens. This distinguished Dutch physicist makes two important contributions to time-keeping – the pendulum clock and the spiral balance spring.

The pendulum clock: AD 1656-1657

Christiaan Huygens spends Christmas day, in the Hague in 1656, constructing a model of a clock on a new principle. The principle itself has been observed by Galileo, traditionally as a result of watching a lamp swing to and fro in the cathedral when he is a student in Pisa. Galileo later proves experimentally that a swinging suspended object takes the same time to complete each swing regardless of how far it travels.

This consistency prompts Galileo to suggest that a pendulum might be useful in clocks. But no one has been able to apply that insight, until Huygens finds that his model works.

A craftsman in the Hague makes the first full-scale clock on this principle for Huygens in 1657. But it is in England that the idea is taken up with the greatest enthusiasm.

By 1600 London clockmakers have already developed the characteristic shape which makes best use of the new mechanism – that of the longcase clock, more affectionately known as the grandfather clock.

The pocket watch: AD 1675

Nineteen years after making his model of the pendulum clock, Huygens invents a device of equal significance in the development of the watch. It is the spiral balance, also known as the hairspring (an invention also claimed, less convincingly, by Robert Hooke). This very fine spring, coiled flat, controls the speed of oscillation of the balance wheel. For the first time it is possible to make a watch which is reasonably accurate – and slim.

Both elements are important, for the sober gentlemen of the late 17th century are less inclined than their ancestors to wear jewels round the neck. A watch which will keep the time and slip into a waistcoat pocket is what they require.

Thomas Tompion, the greatest of English clock and watchmakers, is one of the first to apply the hairspring successfully in pocket watches (of which his workshop produces more than 6000 in his lifetime). The new accuracy of these instruments prompts an addition to the face of a watch – that of the minute hand.

The familiar watch face, with two concentric hands moving round a single dial, is at first considered confusing. There are experiments with several other arrangements of the hour and minute hand, before the design which has since been taken for granted is widely accepted.

Chronometer: AD 1714-1766

Two centuries of ocean travel, since the first European voyages of discovery, have made it increasingly important for ships' captains – whether on naval or merchant business – to be able to calculate their position accurately in any of the world's seas. With the help of the simple and ancient astrolabe, the stars will reveal latitude. But on a revolving planet, longitude is harder. You need to know what time it is, before you can discover what place it is.

The importance of this is made evident when the British government, in 1714, sets up a Board of Longitude and offers a massive £20, 000 prize to any inventor who can produce a clock capable of keeping accurate time at sea.

The terms are demanding. To win the prize a chronometer (a solemnly scientific term for a clock, first used in a document of this year) must be sufficiently accurate to calculate longitude within thirty nautical miles at the end of a journey to the West Indies. This means that in rough seas, damp salty conditions and sudden changes of temperature the instrument must lose or gain not more than three seconds a day – a level of accuracy unmatched at this time by the best clocks in the calmest London drawing rooms.

The challenge appeals to John Harrison, at the time of the announcement a 21-year-old Lincolnshire carpenter with an interest in clocks. It is nearly sixty years before he wins the money. Luckily he lives long enough to collect it.

By 1735 Harrison has built the first chronometer which he believes approaches the necessary standard. Over the next quarter-century he replaces it with three improved models before formally undergoing the government’s test. His innovations include bearings which reduce friction, weighted balances interconnected by coiled springs to minimize the effects of movement, and the use of two metals in the balance spring to cope with expansion and contraction caused by changes of temperature.

Harrison's first ' sea clock', in 1735, weighs 72 pounds and is 3 feet in all dimensions. His fourth, in 1759, is more like a watch – circular and 5 inches in diameter. It is this machine which undergoes the sea trials.

Harrison is now sixty-seven, so his son takes the chronometer on its test journey to Jamaica in 1761. It is five seconds slow at the end of the voyage. The government argues that this may be a fluke and offers Harrison only £2500. After further trials, and the successful building of a Harrison chronometer by another craftsman (at the huge cost of £450), the inventor is finally paid the full prize money in 1773.

He has proved in 1761 what is possible, but his chronometer is an elaborate and expensive way of achieving the purpose. It is in France, where a large prize is also on offer from the Académie des Sciences, that the practical chronometer of the future is developed.

The French trial, open to all comers, takes place in 1766 on a voyage from Le Havre in a specially commissioned yacht, the Aurore. The only chronometer ready for the test is designed by Pierre Le Roy. At the end of forty-six days, his machine is accurate to within eight seconds.

Le Roy's timepiece is larger than Harrison's final model, but it is very much easier to construct. It provides the pattern of the future. With further modifications from various sources over the next two decades, the marine chronometer in its lasting form emerges before the end of the 18th century. Using it in combination with the sextant, explorers travelling the world's oceans can now bring back accurate information of immense value to the makers of maps and charts.

A millennium clock: AD 1746

In 1746 a French clockmaker, Monsieur Passemont (his first name is not known), completes a clock which is almost certainly the first in the world to be able to take account of a new millennium. Its dials can reveal the date of the month in any year up to AD 9999.

It is a longcase clock, in an ornate baroque casing which conceals a mechanism consisting of more than 1000 interconnecting wheels and cogs. Their related movements, as they turn at their different speeds with each swing of the pendulum, are designed to cope with the complexities of the Julian calendar. Thus, for example, one large brass wheel has the responsibility of inserting February 29 in each leap year.

This particular wheel takes four years to complete a single revolution. When it has come full circle, it pops in the extra day. (M. Passemont decides, however, not to grapple with Gregorian refinements; the absence of February 29 in 1700, 1800 and 1900 has had to be manually achieved.)

Louis XV buys the clock in 1749, three years after its completion. It is still ticking away two and a half centuries later in the palace of Versailles. The minutiae of daily time-keeping are also adjusted by hand (the clock loses a minute a month), but Monsieur Passemont's masterpiece requires no assistance in making a significant change in the first digit of its year display – from 1 to 2, at midnight on 31 December 1999.