It’s About Time Notes

By: SilverNight

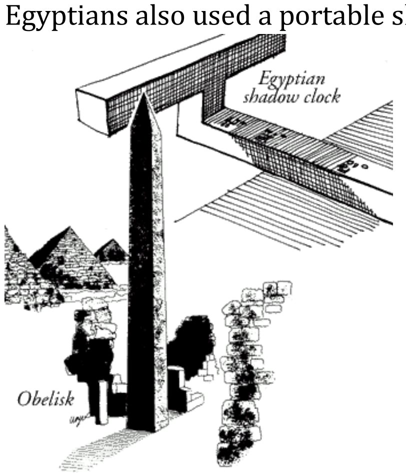
Contents

Clocks and Watches

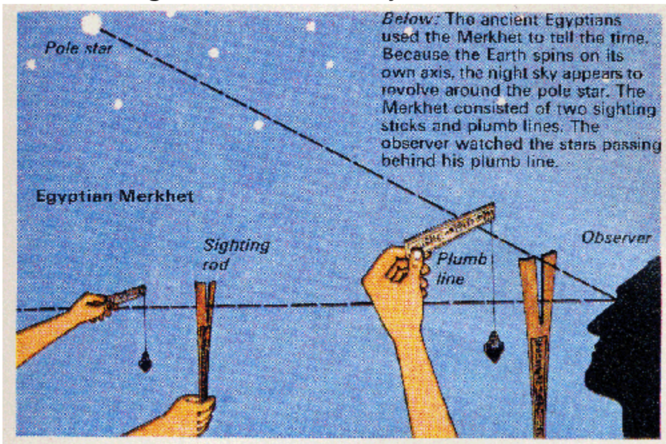
Basics

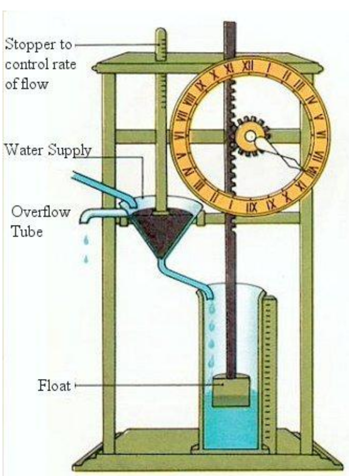
- Basic elements a clock needs
  - A regular, constant, and repetitive action to mark off equal increments of time
    - Achieved by means of an escapement (a type of transformer which converts power generated via springs, water, or weights into a constant mechanical motion)
  - Means of keeping track of the increments of time
  - Should be able to display the result

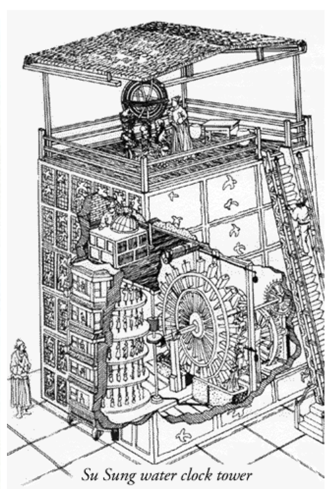
History

- Egyptians used sun clocks as early as 3500 BCE
  - Shadow cast by an obelisk, which is carefully constructed and geographically positioned to enable people to divide the day into morning and afternoon
  - Makers to base of obelisk could indicate further subdivisions of the day
  - First devices to measure time
  - Egyptians also used a portable shadow clock as early as 1500 BC
  - 

- Merkhet: oldest known astronomical tool
  - Developed around 600 BCE
  - Made it possible to measure the night-time hours
  - Two merkhets were used to establish a north-south meridian, by lining them up with the Pole star

- The crossing of this meridian by certain stars indicated the hour
- 

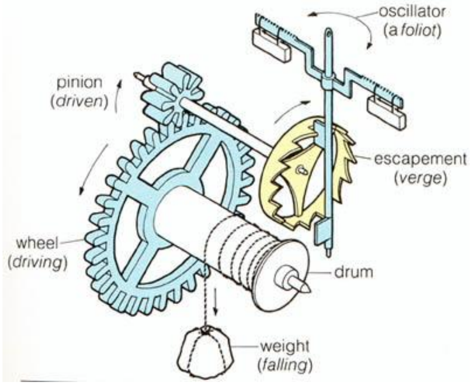
* Clepsydra (water thief): water clock used by Greeks around 325 BCE
  - Oldest was found in the tomb of the Egyptian pharaoh Amenhotep I, buried around 1500 BCE
  - Works on the principle of the flow of water either into, or out of, a container
  - Water would drip at nearly constant rate from a small hole near the base of the container
  - Markings on the side of the container measured the hours
  - Not very accurate, since water dripping depends on pressure and other conditions
  - Chinese developed the clepsydra to drive various mechanisms, which illustrated astronomical phenomena
    - Su Sung built an elaborate clock tower, which stood over 30 feet in height and had doors to reveal manikins which rang bells or gongs, or held tablets indicating the hour
  - 

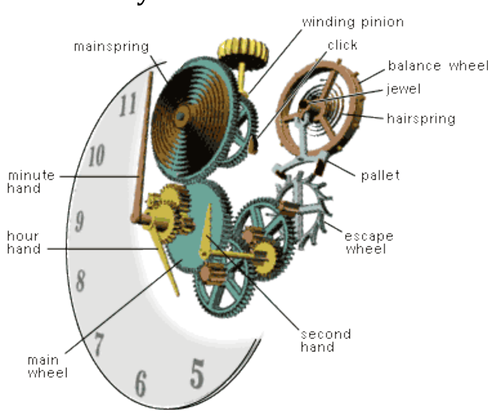


Su Sung water clock tower

* First half of the 1st century BCE: a Macedonian astronomer, Andronikos, supervised the construction of his Horologion, known today as the Tower of the Winds, in the Athens marketplace
  - Featured a 24 hour mechanized clepsydra and indicators for the eight winds from which the tower got its name, and it displayed the seasons of the year and astrological dates and periods
* In the Middle Ages (500-1500 CE), sundials were the favored device

- One different version was the hemispherical dial, a bowl-shaped depression cut into a block of stone, carrying a central vertical gnomon (pointer) and scribed with sets of hour lines for different seasons
  - The hemicycle, said to have been invented about 300 BCE, removed the useless half of the hemisphere to give an appearance of a half-bowl cut into the edge of a squared block
  - By 30 BCE, Vitruvius could describe 13 different sundial styles in use in Greece, Asia Minor, and Italy
  - 
- 1400s: the Prague Astronomical Clock, which dates back to the 15th century, features a background illustrating the Earth and sky; an hourly clock; curved lines that represent 1/12 of the time between sunrise and sunset, and a circle with zodiac signs
  - A small star illustrates the vernal equinox
  - Sidereal time can also be read
  - 
- Large mechanical clocks, weight-driven and used a verge-and-foliot escapement, began appearing in the towers of a number of large Italian cities
  - Mechanism comprised of a freely swinging horizontal bar (foliot) attached to a centrally-located vertical shaft (verge)
    - Driven by gravity

    - As the weight wrapped around the spindle descended, the spindle turned and a toothed crown-wheel on the spindle made the escapement oscillate
    - Passage of time was measured by moving a hand around a marked clock face
    - 

- 1500s: Pocket watches were invented in Tudor, England
    - Cumbersome and worn around the neck
    - Served more as decoration than timekeepers since they were not very accurate
- 1510: spring-driven clocks were accurate to within a minute or two a day
    - Invented by Peter Henlein of Nuremberg
    - 

- 1656: Christian Huygens made the first pendulum clock
    - 1582: Galileo Galilei was credited with the invention but never actually built one
    - The clock had an error of less than 1 minute per day
    - The next year, Huygens developed the balance wheel and spring assembly, which reduced the clock's error to less than 10 seconds a day
- Mid-1660s: Grandfather clocks were built
- 1671: in London, William Clement began building clocks with the new "anchor" or "recoil" escapement, a substantial improvement over the verge because it interferes less with the motion of the pendulum
- 1675: spiral-balance spring-driven mechanism allowed portable timepieces to be more accurate
    - Minute hand was added and the dial was subdivided into minutes
    - Charles II introduced long waistcoats and it became the fashion for men to carry their watch in the pocket instead of wearing it around the neck
- 1721: George Graham improved the pendulum clock's accuracy to 1 second per day by compensating for changes in the pendulum's length due to temperature variations

- 1760s-ish: John Arnold invented jeweling, the use of precious stones such as rubies as bearings to reduce friction
- 1800: a pocket chronometer, a more accurate watch, became available
    - A second hand was added
- Pierre Curie: in 1880, discovered that the application of pressure to a quartz crystal caused it to vibrate at a constant frequency
    - WA Marrison built the first quartz clock in 1928
    - Became possible to measure the accuracy of the clock up to a millionth of a second
- 1889: Refinements to Siegmund Riefler's clock with a nearly free pendulum attained an accuracy of a hundredth of a second a day and became the standard in many astronomical observatories
- 1898: R.J. Rudd introduced the true free-pendulum principle, stimulating development of several free-pendulum clocks
    - 1921: One of the most famous, the W.H. Shortt clock, was demonstrated
        - Almost immediately replaced Riefler's clock as a supreme timekeeper in many observatories
        - This clock contained two pendulums, one a slave and the other a master
            - The slave pendulum gave the master pendulum the gentle pushes needed to maintain its motion, and also drove the clock's hands
            - This allowed the master pendulum to remain free from mechanical tasks that would disturb its regularity
- 1930s and 1940s: the development of radar and extremely high frequency radio communications made possible the generation of the kind of electromagnetic waves (microwaves) needed to interact with atoms
    - Research aimed at developing an atomic clock focused first on microwave resonances in the ammonia molecule
- 1949: NIST built the first atomic clock, which was based on ammonia
    - However, its performance wasn't much better than the existing standards, and attention shifted almost immediately to more promising atomic-beam devices based on cesium
- 1945: wristwatches were made with more robust mechanisms to make them waterproof, shockproof, and able to function in extremes of pressure
    - During WWI, soldiers were given machine-made wristwatches
- 1952: battery-powered watches were embraced and developed by Asian watch manufactures, particularly those in Japan
- 1955: L Essen and J Perry: English physicists who constructed the first practical cesium atomic frequency standard at the national Physical Laboratory in England
    - In collaboration with the U.S. Naval Observatory (USNO), the frequency of the cesium reference was established or measured relative to astronomical time
    - While NIST was the first to start working on a cesium standard, it wasn't until several years later that NIST completed its first cesium atomic beam device, and soon after, a second NIST unit was built for comparison testing
- 1960: cesium standards had been refined enough to be incorporated into the official timekeeping system of NIST
    - Standards of this sort were also developed at a number of other national standards laboratories, leading to wide acceptance of this new timekeeping technology

- 1967: the cesium atom's natural frequency was formally recognized as the new international unit of time
    - The second was defined as exactly 9,192,631,770 oscillations or cycles of the cesium atom's resonant frequency, replacing the old second that was defined in terms of the Earth's motions
    - Quickly became the physical quantity most accurately measured by scientists
    - As of January, 2002, NIST's latest primary cesium standard was capable of keeping time to about 30 billionths of a second per year
    - Called NIST-F1, it is the 8th of a series of cesium clocks built by NIST and NIST's first to operate on the "fountain" principle

Current

- Most clocks and watches today keep time by applying electric energy to a quartz crystal, a system developed in the 1930s
    - How it works
        - If you apply an electric field to the crystal, it changes its shape, and if you squeeze it or bend it, it generates an electric field
        - When put in a suitable electronic circuit, this interaction between mechanical stress and electric field causes the crystal to vibrate and generate an electric signal of relatively constant frequency that can be used to operate an electronic clock display
        - This then produces regular electric pulses that regulate a motor
        - The motor advances a display
    - Quartz crystal clocks were better because they had no gears or escapements to disturb their regular frequency
        - Even so, they still relied on a mechanical vibration whose frequency depended critically on the crystal's size, shape and temperature
        - Thus, no two crystals can be exactly alike, with just the same frequency
        - Such quartz clocks and watches continue to dominate the market in numbers because their performance is excellent for their price
        - But the timekeeping performance of quartz clocks has been substantially surpassed by atomic clocks
- Mechanical watches use a coiled mainspring for power
    - Mainspring drives gears that cause a hairspring to oscillate
    - Hairspring rocks a lever to and fro
    - Lever drives other gears which move the hands
- Atomic clocks are the world’s most accurate timekeepers
    - They use the natural vibration/oscillation of the cesium atom as its resonator
        - Cesium atoms vibrate exactly 9,192,631,770 times a second
    - Ground based atomic clocks are accurate to 1 second in 400,000 years
        - Within a millionth of a second per year
    - Other kinds of atomic clocks (besides cesium) have also been developed for various applications
        - Those based on hydrogen offer exceptional stability
        - Those based on microwave absorption in rubidium vapor are more compact, lower in cost, and require less power

Designer Watches

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Time

History

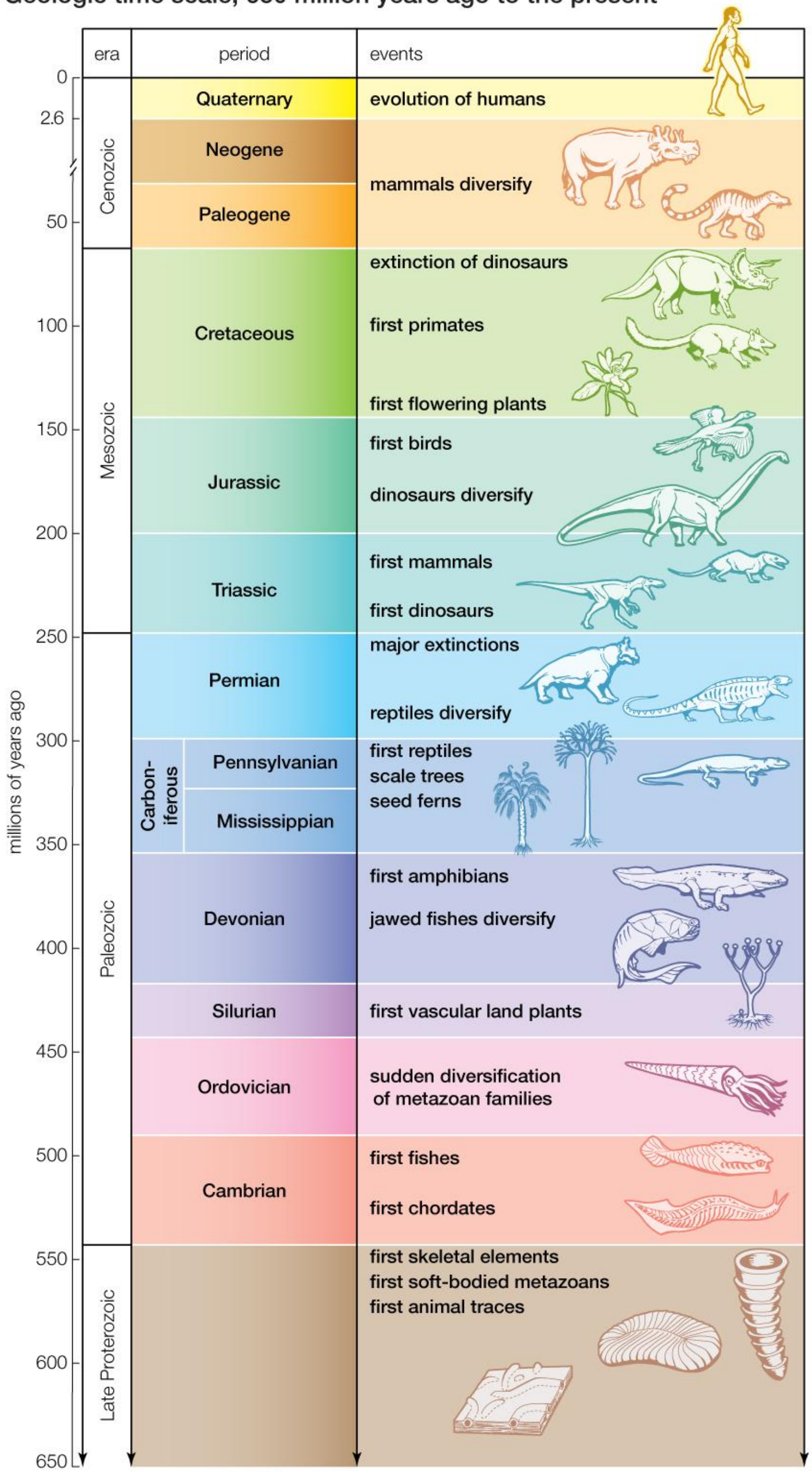
- 1830: the U.S. Navy established a depot, later to become the U.S. Naval Observatory (USNO), with the initial responsibility to serve as a storage site for marine chronometers and other navigation instruments and to "rate" (calibrate) the chronometers to assure accuracy for their use in celestial navigation
  - For accurate "rating," the depot had to make regular astronomical observations
  - It was not until December of 1854 that the Secretary of the Navy officially designated this growing institution as the "United States Naval Observatory and Hydrographic Office"
  - Through all of the ensuing years, the USNO has retained timekeeping as one of its key functions
- 1840s: a railway standard time for all of England, Scotland, and Wales evolved, replacing several “local time” systems
- 1852: The Royal Observatory in Greenwich began transmitting time telegraphically
  - For the railroad network, England decided to adopt London time, as determined by the Royal Observatory at Greenwich
  - By 1855, all public clocks throughout Great Britain had adopted GMT (Greenwich Mean Time)
  - Greenwich Mean Time subsequently evolved as an important and well-recognized time reference for the world
- 1869: Charles Dowd came up with a plan to divide the entire US into 4 time zones
  - At 12 noon on November 18, 1883, the entire nation switched over to what had previously been referred to as railroad time

    - The four zone time system was legalized in 1918
- 1883: The time-zone process began for the United States
    - Nation was divided into four standard time zones
    - Each zone was centered on a meridian of longitude
        - Eastern Standard Time (EST) at 75 degrees W (west of the Prime Meridian)
        - Central Standard Time (CST) at 90 degrees W
        - Mountain Standard Time (MST) at 105 degrees W
        - Pacific Standard Time (PST) at 120 degrees W
    - 1884: Prime meridian was designated the meridian passing through Greenwich at a conference held in Washington called the International Meridian Conference (IMC)
        - One factor Greenwich meridian was the post popular was because of the reputation for reliability and correctness of the Greenwich Observatory's publications of navigational data
- 1899: Marconi's wireless telegraph led to the adoption of uniform time worldwide
- March 1918: the standard timekeeping system related to the arrangement of time zones was made official in the United States by an Act of Congress
    - This was 34 years following the agreement reached at the international conference
    - November 18, 1883: In an earlier decision prompted by their own interests and by pressures for a standard timekeeping system from the scientific community (meteorologists, geophysicists and astronomers) the U.S. railroad industry anticipated the international accord when they implemented a "Standard Railway Time System"
        - This Standard Railway Time, adopted by most cities, was the subject of much local controversy for nearly a decade following its inception
- January 1, 1972: the new Coordinated Universal Time (UTC) became effective internationally
    - UTC runs at the rate of the atomic clocks, but when the difference between this atomic time and one based on the Earth approaches one second, a one second adjustment (a "leap second") is made in UTC
    - NIST's clock systems and other atomic clocks located at the USNO and in more than 25 other countries now contribute data to the international UTC scale coordinated in Paris by the International Bureau of Weights and Measures (BIPM)
    - As atomic timekeeping has grown in importance, the world's standards laboratories have become more involved with the process, and in the United States today, NIST and USNO cooperate to provide official U.S. time for the nation
    - Liberia was the last country to adopt the Greenwich Meridian in 1972

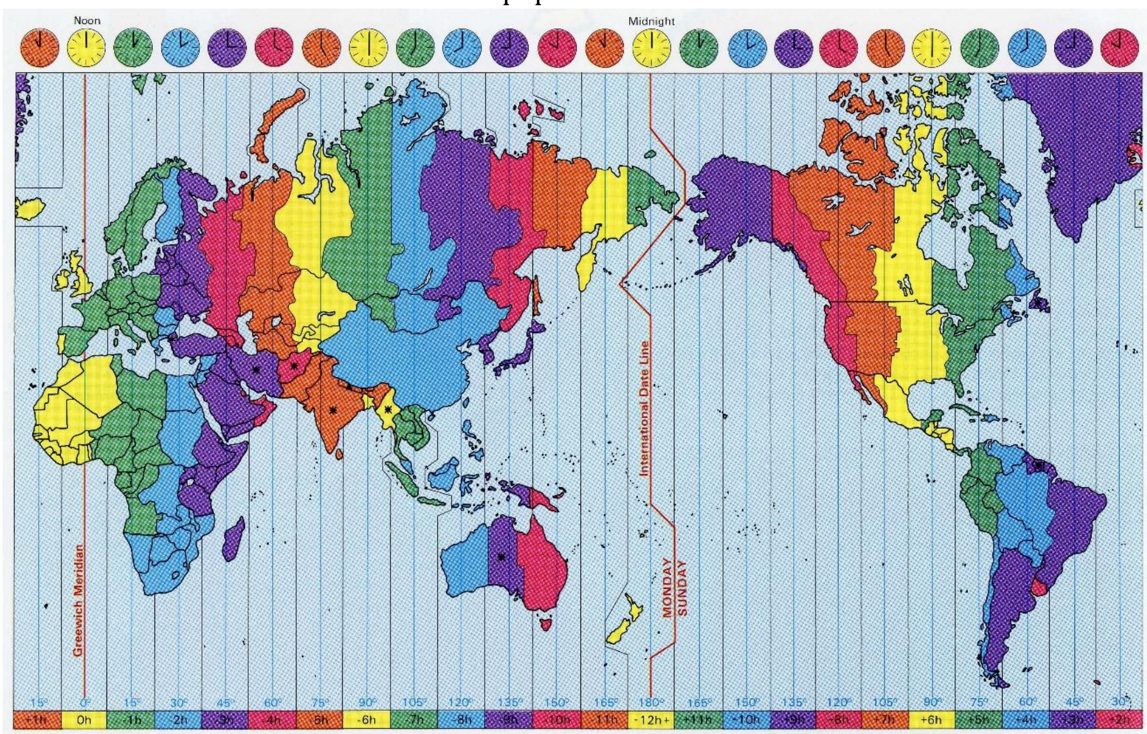
Geologic Time

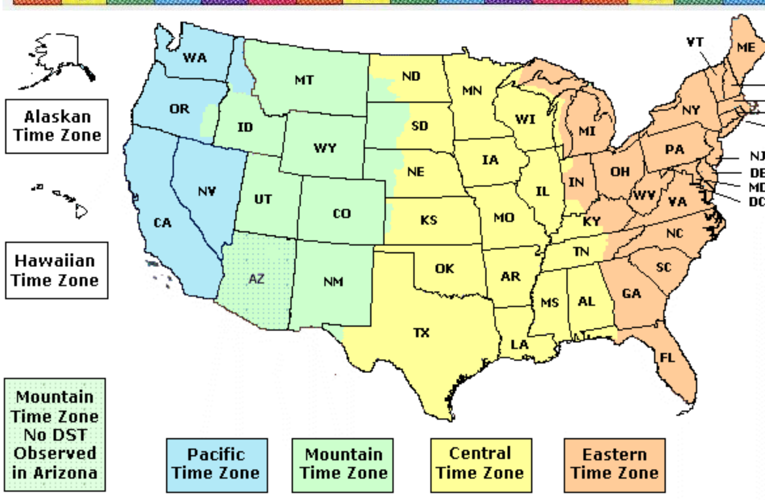
- Print http://en.wikipedia.org/wiki/Geologic_time_scale#Table_of_geologic_time

Geologic time scale, 650 million years ago to the present



Time Zones

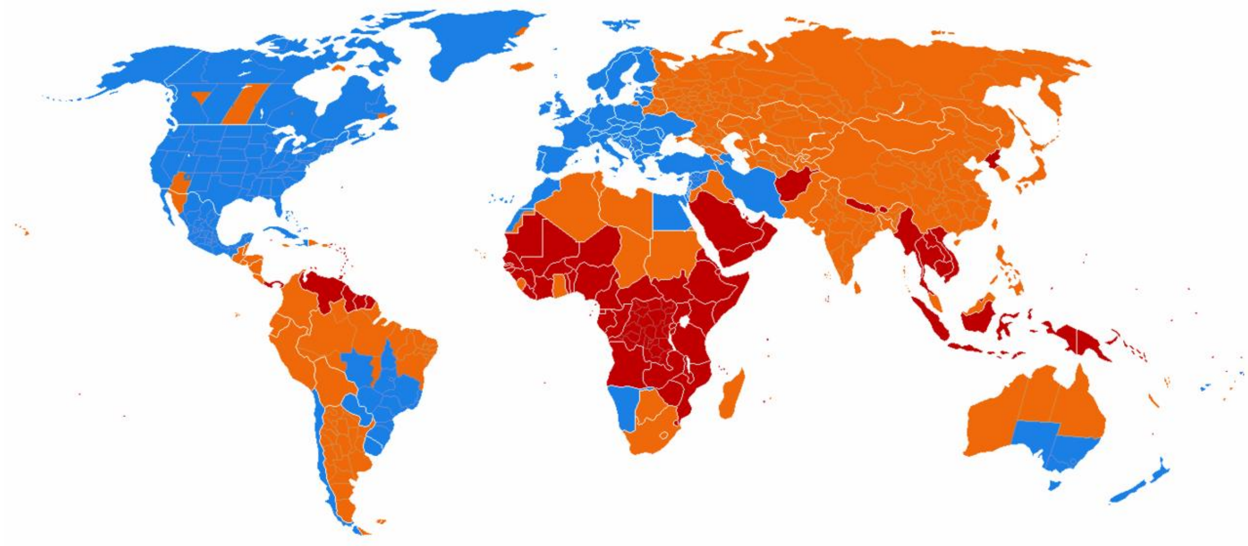
- Given a 24 hour day and 360 degrees of longitude around the earth, it is obvious that the world's 24 time zones have to be 15 degrees wide, on average
- The individual zone boundaries are not straight, however, because they have been adjusted for the convenience and desires of local populations
- 

- 

Arizona is in the Mountain Time Zone and does not observe daylight saving time except in the Navajo Indian Nation. To view the current time in Arizona select from the state menu below.

Daylight Saving Time

- Great video by CGP Grey: https://www.youtube.com/watch?v=84aWtseb2-4
- Modern idea of daylight saving was first proposed in 1895 by George Vernon Hudson
    - Was first implemented by Germany and Austria-Hungary starting on 30 April 1916

- 
    - Blue: DST is used
    - Orange: DST is no longer used
        - Hawaii and Arizona are the only two US states that don't
            - Hawaii because it's sunny all the time so there's no point
            - Arizona because they want less sun to conserve energy
    - Red: DST has never been used
- Daylight Saving Time (United States) 2014 began at 2:00 AM on Sunday, March 9 and ends at 2:00 AM on Sunday, November 2

NIST Time and Frequency Services

- Since 1923, NIST radio station WWV has provided round-the-clock shortwave broadcasts of time and frequency signals
    - WWV's audio signal is also offered by telephone: dial (303) 499-7111 (not toll-free)
    - A sister station, WWVH, was established in 1948 in Hawaii, and its signal can be heard by dialing (808) 335-4363 in Hawaii
- WWVH radio station in Hawaii Broadcast frequencies are 2.5 MHz (megahertz), 5 MHz, 10 MHz, and 15 MHz for both stations, plus 20 MHz on WWV
    - The signal includes UTC time in both voice and coded form; standard carrier frequencies, time intervals and audio tones; information about Atlantic or Pacific storms; geophysical alert data related to radio propagation conditions; and other public service announcements
    - Accuracies of one millisecond (one thousandth of a second) can be obtained from these broadcasts if one corrects for the distance from the stations (near Ft. Collins, Colorado, and Kauai, Hawaii) to the receiver
    - The telephone services provide time signals accurate to 30 milliseconds or better, which is the maximum delay in cross-country telephone lines
- In 1956, low-frequency station WWVB, which offers greater accuracy than WWV or WWVH, began broadcasting at 60 kilohertz
    - The broadcast power for WWVB was increased in 1999 from about 10 kilowatts to 50 kilowatts, providing much improved signal strength and coverage to most of the North American continent

    - This has stimulated commercial development of a wide range of inexpensive radio-controlled clocks and watches for general consumer use
- Time signals are an important byproduct of the Global Positioning System (GPS), and indeed this has become the premier satellite source for time signals
    - The time scale operated by the USNO serves as reference for GPS, but it is important to note that the time scales of NIST and USNO are highly coordinated (that is, synchronized to well within 100 nanoseconds, or 100 billionths of a second)
    - Thus, signals provided by either NIST or USNO can be considered as traceable to both institutions
    - The agreements and coordination of time between these two institutions are important to the country, since they simplify the process of achieving legal traceability when regulations require it
- Official U.S. Government time, as provided by NIST and USNO, is available on the Internet at http://www.time.gov
    - NIST also offers an Internet Time Service (ITS) and an Automated Computer Time Service (ACTS) that allow setting of computer and other clocks through the Internet or over standard commercial telephone lines

Calendars

History

- In ancient Rome, a priest observed the sky and announced a new moon cycle to the king. For centuries afterward, Romans referred to the first day of each new month as Kalends (from their word calare, which means "to proclaim”)
    - The word calendar derived from this custom
- 20,000 years ago: Ice-age hunters in Europe scratched lines and gouged holes in sticks and bones, possibly counting the days between phases of the moon
- 5,000 years ago: Sumerians in the Tigris-Euphrates valley (in today’s Iraq) had a calendar that divided the year into 30 day months, day into 12 periods, and periods into 30 parts
- 4,000 years ago: Stonehenge was built in England
    - We have no written records, but its alignments show its purposes apparently included the determination of seasonal or celestial events, such as lunar eclipses, solstices and so on
- The earliest Egyptian calendar was based on the moon's cycles
    - Later the Egyptians realized that the "Dog Star" in Canis Major, which we call Sirius, rose next to the sun every 365 days, about when the annual inundation of the Nile began
    - Egyptians then devised a 365 day calendar that seems to have begun around 3100 BC, which thus seems to be one of the earliest years recorded in history
- Before 2000 BCE, the Babylonians (in today's Iraq) used a year of 12 alternating 29 day and 30 day lunar months, giving a 354 day year
- Mayans of Central America relied not only on the Sun and Moon, but also the planet Venus, to establish 260 day and 365 day calendars
    - This culture and its related predecessors spread across Central America between 2600 BCE and 1500 CE, reaching their apex between 250 and 900 CE
    - They left celestial-cycle records indicating their belief that the creation of the world

occurred in 3114 BCE
    - Their calendars later became portions of the great Aztec calendar stones
- Before today's Gregorian calendar was adopted, the older Julian calendar was used
    - It was introduced in 46 BC
    - It was close to the actual length of the year, but the Julian calendar was not so perfect that it didn't slowly shift off track over the following centuries
    - But, hundreds of years later, monks were the only ones with any free time for scholarly pursuits, and they were discouraged from thinking about the matter of "secular time" for any reason beyond figuring out when to observe Easter
        - In the Middle Ages, the study of the measure of time was first viewed as prying too deeply into God's own affairs – and later thought of as a lowly, mechanical study, unworthy of serious contemplation
    - It wasn't until 1582, by which time Caesar's calendar had drifted a full 10 days off course, that Pope Gregory XIII (1502 - 1585) finally reformed the Julian calendar
        - The "new" calendar, as we know it today, was not adopted uniformly across Europe until well into the 18th century

Church Involvement

- Although the Roman Catholic Church once waged a long and bitter war on science and astronomy (particularly condemning Galileo), in general, they were quite involved in astronomy
    - When to celebrate the feast of Christ's resurrection (Easter) had become a bureaucratic crisis in the church
        - Traditionally, Easter fell on the Sunday after the first full moon of spring
        - But by the 12th century, the usual ways to predict that date had gone awry
    - To set a date for Easter Sunday years in advance, and thus reinforce the church's power and unity, popes and ecclesiastical officials had for centuries relied on astronomers, who pondered over old manuscripts and devised instruments that set them at the forefront of the scientific revolution
- How the observatories worked
- The building, dark inside, needed only a small hole in the roof to allow a beam of sunlight to strike the floor below, producing a clear image of the solar disk
    - On each sunny day, the solar image would sweep across the church floor and, exactly at noon, cross a long metal rod that was the observatory's most important and precise part
        - The noon crossings over the course of a year would reach the line's extremities – which usually marked the summer and winter solstices, when the Sun is farthest north and south of the Equator
        - The circuit, among other things, could be used to measure the year's duration with great precision
    - The path on the floor was known as a meridian line, like the north-south meridians of geographers
        - The rod, in keeping with its setting and duties, was often surrounded by rich tile inlays and zodiacal motifs
        - The instruments lost much of their astronomical value around the middle of the 18th century as telescopes began to exceed them in power

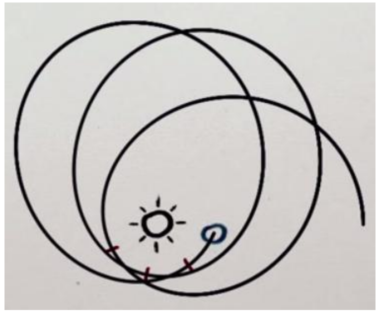
        - But the observatories still played a significant role because the solar timepieces were often used to correct errors in mechanical clocks and even to set time for railroads
- One of the observatories also impressed Charles Dickens, who in his book Pictures from Italy wrote that he found little to like in Bologna except "the Church of San Petronio, where the sunbeams mark the time among the kneeling people"
    - In the book, The Sun in the Church, author Dr. Heilbron, describes his astonishment with seeing the old instruments in Bologna, Italy, at the Basilica of San Petronio
- In the great Basilica of San Petronio, a solar observatory was erected in 1576 by Egnatio Danti, a mathematician and Dominican friar who worked for Cosimo I dei Medici, the Grand Duke of Tuscany, and who advised Pope Gregory on calendar reform
    - Danti was rewarded with a commission to build a solar observatory in the Vatican itself within the Torre dei Venti, or Tower of the Winds
- Among the best known of the rebel observers was Giovanni Cassini, an Italian astronomer who gained fame for discovering moons of Saturn and the gaps in its rings that still bear his name
    - Around 1655, Cassini persuaded the builders of the Basilica of San Petronio that they should include a major upgrade of Danti's old meridian line, making it larger and far more accurate, its entry hole for daylight moved up to be some 90 feet high, atop a lofty vault
    - Cassini used the observatory to investigate the "orbit" of the Sun, quietly suggesting that it actually stood still while the Earth moved
- Cassini decided to use his observations to try to confirm the theories of Johannes Kepler, the German astronomer who had proposed in 1609 that the planets moved in elliptical orbits not the circles that Copernicus had envisioned
    - If true, that meant the Earth over the course of a year would pull slightly closer and farther away from the Sun
    - At least in theory, Cassini's observatory could test Kepler's idea, since the Sun's projected disk on the cathedral floor would shrink slightly as the distance grew and would expand as the gap lessened
    - Such an experiment could also address whether there was any merit to the ancient system of Ptolemy, some interpretations of which had the Earth moving around the Sun in an eccentric circular orbit
    - Ptolemy's Sun at its closest approach moved closer to the Earth than Kepler's Sun did, in theory making the expected solar image larger and the correctness of the rival theories easy to distinguish
- For the experiment to succeed, Cassini could tolerate measurement errors no greater than 0.3 inches in the Sun's projected face, which ranged from 5 to 33 inches wide, depending on the time of year
    - No telescope of the day could achieve that precision
    - The experiment was run around 1655, and after much trial and error, succeeded
    - Cassini and his Jesuit allies confirmed Kepler's version of the Copernican theory
- Between 1655 and 1736, astronomers used the solar observatory at San Petronio to make 4,500 observations, aiding substantially the tide of scientific advance

Current

- Our present civilization has adopted a 365 day solar calendar with a leap year occurring every fourth year (except century years not evenly divisible by 400)
    - A year is approximately 365.24 days and one complete orbit of Earth around the Sun
    - A month is approximately 29.53 days and one complete orbit of the Moon around the Earth
- Tropical year: the time from one fixed point, such as a solstice or equinox, to the next
    - The time it takes for the Earth's axis to come back to the same angle relative to the sun
    - Length is currently 365.242190 days, but it varies
        - Around 1900 its length was 365.242196 days
        - Around 2100 it will be 365.242184 days
    - These numbers are averages
        - The actual length of a particular year may vary by several minutes due to the influence of the gravitational force from other planets
- Synodic month: the time from one new moon to the next
    - Length is currently 29.5305889 days, but it varies
        - Around 1900 its length was 29.5305886 days
        - Around 2100 it will be 29.5305891 days
    - These numbers are averages
        - The time between two new moons may vary by several hours due to a number of factors, including changes in the gravitational force from the sun, and the moon's orbital inclination
- The length of the tropical year is not a multiple of the length of the synodic month
    - This means that with 12 months per year, the relationship between our month and the moon cannot be maintained
    - However, 19 tropical years is 234.997 synodic months, which is very close to an integer
        - So every 19 years the phases of the moon fall on the same dates (if it were not for the skewness introduced by leap years)
        - Nineteen years is called a Metonic cycle (after Meton, an astronomer from Athens in the 5th century B.C.E.)

Numbers and Issues

- There are 3 ways to measure a year
    - Tropical year: the mean interval between vernal equinoxes
        - Corresponds to the cycle of the seasons
        - Our calendar year is linked to the tropical year as measured between two March equinoxes, as originally established by Caesar and Sosigenes
    - Sidereal year: the amount of time we come back and see the same stars rising behind the sun
        - In the year 2000, the length of the Tropical Year = 365.24219 days, and the length of the Sidereal Year = 365.2564
        - Another term for the hour angle of the vernal equinox
    - Anomalistic year: closest approaches by the Earth

- 

- The following expression, based on the orbital elements of Laskar (1986), is used for calculating the length of the tropical year
  - $365.2421896698 - 0.00000615359\,T - 7.29 * 10^{-10}\,T^2 + 2.64 * 10^{-10}\,T^3$ days
  - Where $T = \frac{JD - 2451545.0}{36525}$ and JD is the Julian day number
  - However, the interval from a particular vernal equinox to the next may vary from this mean by several minutes
- The following expression for the synodic month is based on the lunar theory of Chapront-Touze' and Chapront (1988):
  - $29.5305888531 + 0.00000021621\,T - 3.64 * 10^{-10}\,T^2$ days
  - Where $T = \frac{JD - 2451545.0}{36525}$ and JD is the Julian day number
  - Any particular phase cycle may vary from the mean by up to seven hours
- In the preceding formulas, T is measured in Julian centuries of Terrestrial Dynamical Time (TDT), which is independent of the variable rotation of the Earth
  - Thus, the lengths of the tropical year and synodic month are here defined in days of 86400 seconds of International Atomic Time (TAI)
- A calendar year of an integral number of days cannot be perfectly synchronized to the tropical year
  - Approximate synchronization of calendar months with the lunar phases requires a complex sequence of months of 29 and 30 days
  - For convenience it is common to speak of a lunar year of twelve synodic months, or 354.36707 days
- Three distinct types of calendars have resulted from this situation
  - Solar calendars, of which the Gregorian calendar in its civil usage is an example, are designed to maintain synchrony with the tropical year
    - To do so, days are intercalated (forming leap years) to increase the average length of the calendar year
  - Lunar calendars (like the Islamic calendar) follow the lunar phase cycle without regard for the tropical year
    - Thus the months of the Islamic calendar systematically shift with respect to the months of the Gregorian calendar
  - Lunisolar calendars have a sequence of months based on the lunar phase cycle, but every few years a whole month is intercalated to bring the calendar back in phase with the tropical year
    - The Hebrew and Chinese calendars are examples of this type of calendar

Holidays

American Federal Holidays

- New Year's Day: January 1
  - The celebration of this holiday begins the night before, when Americans gather to wish each other a happy and prosperous coming year
- Martin Luther King, Jr. Day: third Monday in January
- Washington's Birthday (Presidents' Day): third Monday of February
- Memorial Day: last Monday of May
  - It originally honored the people killed in the American Civil War, but has become a day on which the American dead of all wars are remembered
- Independence Day: July 4
  - Commemorates July 4, 1776
- Labor Day: first Monday of September
- Columbus Day: second Monday in October
  - The day commemorates October 12, 1492, when Italian navigator Christopher Columbus landed in the New World
  - The holiday was first proclaimed in 1937 by President Franklin D. Roosevelt
- Veterans Day: November 11
  - Originally called Armistice Day and established to honor Americans who had served in World War I
  - Now honors veterans of all wars in which the U.S. has fought
  - Veterans' organizations hold parades, and the president places a wreath on the Tomb of the Unknowns at Arlington National Cemetery in Virginia
- Thanksgiving Day: fourth Thursday in November
  - First Thanksgiving was in 1621
- Christmas Day: December 25
  - Christian holiday marking the birth of the Christ Child

American Other Holidays

- Groundhog Day: February 2
  - Has been celebrated since 1887
  - On Groundhog Day, crowds gather in Punxsutawney, Pennsylvania, to see if groundhog Punxsutawney Phil sees his shadow after emerging from his burrow, thus predicting six more weeks of winter weather
- Valentine's Day: February 14
  - The day was named after an early Christian martyr
- St. Patrick's Day: March 17
  - Death day of St. Patrick, patron saint of Ireland
- April Fool's Day: April 1
- Earth Day: April 22
  - First celebrated in 1970 in the United States
- National Arbor Day: last Friday in April
  - Started by President Richard Nixon in 1970
  - The observance began in 1872, when Nebraska settlers and homesteaders were urged to plant trees on the largely treeless plains

- Mother's Day: second Sunday of May
    - President Woodrow Wilson issued a proclamation in 1914 that started the holiday
        - He asked Americans to give a public expression of reverence to mothers on this day
    - Carnations have come to represent Mother's Day, following President William McKinley's habit of always wearing a white carnation, his mother's favorite flower
- Flag Day: June 14
    - Presidentially proclaimed observance since 1916
- Father's Day: third Sunday of June
    - Began in 1909 in Spokane, Washington, when a daughter requested a special day to honor her father, a Civil War veteran who raised his children after his wife died
    - The first presidential proclamation honoring fathers was issued in 1966 by President Lyndon Johnson
- Patriot Day and National Day of Service and Remembrance: September 11
    - In remembrance of September 11, 2001
- Halloween: October 31
- Pearl Harbor Remembrance Day: December 7
    - In 1994, Congress designated this national observance to honor the more than 2,400 military service personnel who died on this date in 1941

NJ State Holidays

- Replace with your own state
- New Year's Day
- Martin Luther King Jr. Day
- Presidents Day
- Good Friday (April 3, 2015): the Friday before Easter
    - Commemorates the Crucifixion, which is retold during services from the Gospel according to St. John
    - A feature in Roman Catholic churches is the Liturgy of the Passion; there is no Consecration, the Host having been consecrated the previous day
    - The eating of hot-cross buns on this day is said to have started in England
- Memorial Day
- Independence Day
- Labor Day
- Columbus Day
- Election Day: first Tuesday after the first Monday in November
    - Since 1845, by act of Congress
- Veteran's Day
- Thanksgiving Day
- Christmas Day

Other Holidays

- Epiphany: 12th day after Christmas
    - Commemorates the manifestation of Jesus Christ to the Gentiles, as represented by the Magi, the baptism of Jesus, and the miracle of the wine at the marriage feast at Cana

    - One of the three major Christian festivals, along with Christmas and Easter
    - Epiphany originally marked the beginning of the carnival season preceding Lent, and the evening preceding it is known as Twelfth Night
- Mawlid al-Nabi: 12th day of the month of Rabi I in the Islamic calendar
    - Celebrates the birthday of Muhammad, the founder of Islam
- Chinese New Year (Feb 19, 2015)
- Shrove Tuesday (Mardi Gras): day before Ash Wednesday
    - End of the carnival season, which once began on Epiphany but is now usually celebrated the last three days before Lent
    - In France, the day is known as Mardi Gras (Fat Tuesday), and celebrations are held in several American cities, particularly New Orleans
    - The day is sometimes called Pancake Tuesday by the English because fats, which were prohibited during Lent, had to be used up
- Ash Wednesday: (Feb 18, 2015): seventh Wednesday before Easter and the first day of Lent, which lasts 40 days
- Purim (Feast of Lots): March 5, 2015
    - A day of joy and feasting celebrating the deliverance of the Jews from a massacre planned by the Persian minister Haman
    - The holiday is marked by the reading of the Book of Esther (the Megillah), by the exchange of gifts, and by donations to the poor
- Palm Sunday: the Sunday before Easter to commemorate the entry of Jesus into Jerusalem
- Passover (Pesach): April 4, 2015
    - Commemorates the escape of the Jews from Egypt
    - As the Jews fled, they ate unleavened bread, and from that time the Jews have allowed no leavening in their houses during Passover, bread being replaced by matzoh
- Easter Sunday: April 5, 2015
    - Commemorates the Resurrection of Jesus
    - Celebrated on the first Sunday after the full moon that occurs on or next after the vernal equinox (fixed at March 21) and is therefore celebrated between March 22 and April 25 inclusive
    - This date was fixed by the Council of Nicaea in A.D. 325
- Orthodox Easter (Pascha): April 5, 2015
    - The Orthodox Church uses the Julian calendar when calculating Easter, rather than the more contemporary Gregorian calendar
    - For this reason, Orthodox Easter generally falls on a different date than the Western Christian Easter
- Ascension Day: May 14, 2015
    - The Ascension of Jesus took place in the presence of his apostles 40 days after the Resurrection
    - It is traditionally thought to have occurred on Mount Olivet in Bethany
- Shavuot (Hebrew Pentecost): May 24, 2015
    - This festival, sometimes called the Feast of Weeks, or of Harvest, or of the First Fruits, falls 50 days after Passover and originally celebrated the end of the seven-week grain-harvesting season
    - In later tradition, it also celebrated the giving of the Law to Moses on Mount Sinai

- Pentecost (Whitsunday): June 9, 2015
    - Commemorates the descent of the Holy Ghost upon the apostles 50 days after the Resurrection
    - Whitsunday is believed to have come from "white Sunday," when, among the English, white robes were worn by those baptized on the day
- First Day of Ramadan: June 18, 2015
    - Marks the beginning of a month-long fast that all Muslims must keep during the daylight hours
    - Commemorates the first revelation of the Qur'an.
    - Following the last day of Ramadan, Eid al-Fitr is celebrated on Tues. August 8
- Rosh Hashanah (Jewish New Year): September 14, 2015
    - This day marks the beginning of the Jewish year 5768 and opens the Ten Days of Penitence, which close with Yom Kippur
- Yom Kippur (Day of Atonement): September 23, 2015
    - This day marks the end of the Ten Days of Penitence that began with Rosh Hashanah
    - It is described in Leviticus as a Sabbath of rest, and synagogue services begin the preceding sundown, resume the following morning, and continue to sundown
- Eid al-Adha: September 24, 2015
    - Or the Feast of Sacrifice, commemorates Abraham's willingness to obey God by sacrificing his son
    - Lasting for three days, it concludes the annual Hajj, or pilgrimage to Mecca
    - Muslims worldwide sacrifice a lamb or other animal and distribute the meat to relatives or the needy
- Thanksgiving (Canada): second Monday in October
- Shemini Atzeret (Assembly of the Eighth Day): October 5, 2015
    - This joyous holiday, encompassing Simchat Torah (Rejoicing in the Torah), falls immediately after the seven days of Sukkot
    - It marks the end of the year's weekly readings of the Torah (Five Books of Moses) in the synagogue, and the beginning of the new cycle of reading
- Muharram: October 25, 2015
    - The month of Muharram marks the beginning of the Islamic liturgical year
    - On the tenth day of the month, many Muslims may observe a day of fasting, known as Ashurah
- All Saints' Day: November 1, 2015
    - A Roman Catholic and Anglican holiday celebrating all saints, known and unknown
- First Sunday of Advent: November 29, 2015
    - Season in which the faithful must prepare themselves for the coming, or advent, of the Savior on Christmas
    - The four Sundays before Christmas are marked by special church services
- Hanukkah (Festival of Lights): December 7, 2015
    - This festival was instituted by Judas Maccabaeus in 165 B.C. to celebrate the purification of the Temple of Jerusalem, which had been desecrated three years earlier by Antiochus Epiphanes, who set up a pagan altar and offered sacrifices to Zeus Olympius
    - In Jewish homes, a lamp or candle is lighted on each night of the eight-day festival
- Kwanzaa: December 26, 2015

    - This secular seven-day holiday was created by Black Studies professor Dr. Maulana Karenga in 1966 in the U.S., to reaffirm African values and serve as a communal celebration among African peoples in the diaspora
    - Modeled on first-fruits celebrations, it reflects seven principles, the Nguzo Saba: unity, self-determination, collective work and responsibility, cooperative economics, purpose, creativity, and faith

Solstices and Equinoxes

- For people in the northern hemisphere
    - Winter solstice is the time in December when the sun reaches its southernmost latitude and the shortest day
        - The date is near 21 December
    - Summer solstice is the time in June when the sun reaches its northernmost latitude and the longest day
        - The date is near 21 June
    - Vernal equinox is the time in March when the sun passes the equator moving from the southern to the northern hemisphere
        - The date is near 20 March
    - Autumnal equinox is the time in September when the sun passes the equator moving from the northern to the southern hemisphere
        - The date is near 22 September
    - For people in the southern hemisphere, winter solstice occurs in June, vernal equinox in September, etc.
- The astronomical "tropical year" is frequently defined as the time between, say, two vernal equinoxes, but this is not actually true
    - Currently the time between two vernal equinoxes is slightly greater than the tropical year
    - The reason is that the earth's position in its orbit at the time of solstices and equinoxes shifts slightly each year (taking approximately 21,000 years to move all the way around the orbit)
    - This, combined with the fact that the earth's orbit is not completely circular, causes the equinoxes and solstices to shift with respect to each other
    - The astronomer's mean tropical year is really a somewhat artificial average of the period between the time when the sun is in any given position in the sky with respect to the equinoxes and the next time the sun is in the same position

Leap Years

- Great video by CGP Grey: https://www.youtube.com/watch?v=xX96xng7sAE&feature=kp
- Leap Year Rules
    - Add an extra day every 4 years
    - Skip if it's a new century (1800, 1900, 2000, 2100 are not leap years)
    - Unless the century is divisible by 400 (2000 is a leap year)
    - Using these rules, only 1 day off in about 8,000 years
- 4000-year rule
    - John Herschel (1792-1871) and others suggested that a better approximation to the length of the tropical year would be 365 969/4000 days = 365.24225 days

        - This would dictate 969 leap years every 4000 years, rather than the 970 leap years mandated by the Gregorian calendar
        - This could be achieved by dropping one leap year from the Gregorian calendar every 4000 years, which would make years divisible by 4000 non-leap years
    - This rule has, however, not been officially adopted
- When the Orthodox church in Greece finally decided to switch to the Gregorian calendar in the 1920s, they tried to improve on the Gregorian leap year rules, replacing the "divisible by 400" rule by the following:
    - Every year which when divided by 900 leaves a remainder of 200 or 600 is a leap year
        - This makes 1900, 2100, 2200, 2300, 2500, 2600, 2700, 2800 non-leap years, whereas 2000, 2400, and 2900 are leap years
    - This rule gives 218 leap years every 900 years, which gives us an average year of 365 218/900 days = 365.24222 days, which is certainly more accurate than the official Gregorian number of 365.2425 days
    - However, this rule is not official in Greece
- 24 February is the leap day
- Solar Cycle: a 28-year cycle of the Julian calendar with respect to the week
    - It occurs because leap years occur every 4 years and there are 7 possible days to start a leap year, making a 28 year sequence
    - This cycle also occurs in the Gregorian calendar, but it is interrupted by years such as 1700, 1800, 1900 and 2100, which are divisible by four but which are not leap years
        - This interruption has the effect of skipping 16 years of the solar cycle between February 28 and March 1
        - Because the Gregorian cycle of 400 years has exactly 146,097 days, i.e. exactly 20,871 weeks, one can say that the Gregorian so-called solar cycle lasts 400 years
    - Solar Number of a year = (year + 8) mod 28 + 1
    - In the Julian calendar there is a one-to-one relationship between the Solar Number and the day on which a particular date falls.
- Dominical Letter (Sunday Letter): letter in the range A to G which describes what days of the year are Sundays that is assigned to each ordinary (non-leap) year
    - It works in this manner: Assign the letter A to 1 January, B to 2 Jan, C to 3 Jan, ... G to 7 Jan, A to 8 Jan, B to 9 Jan, and so on, using the letters A to G and omitting the leap day.
    - In a year with Dominical Letter A, all days marked A are Sundays. In a year with Dominical Letter B, all days marked B are Sundays. And so on.
    - Leap years have two Dominical Letters, one which is used from the start of January until the leap day, and another one which is used for the rest of the year.
    - The Dominical Letter of 2006 is A. The Dominical Letters of 2008 will be F and E.
- When can I reuse my year X calendar? (assuming only interested in which dates fall on which days of the week, not in the dates for Easter and other irregular holidays)
    - If year X is a leap year, you can reuse its calendar in year X+28.
    - If year X is the first year after a leap year, you can reuse its calendar in years X+6,

X+17, and X+28.
  - If year X is the second year after a leap year, you can reuse its calendar in years X+11, X+17, and X+28.
  - If year X is the third year after a leap year, you can reuse its calendar in years X+11, X+22, and X+28.
- The rule that every year is divisible by 4 is a leap year was not followed at first
  - So, the leap years are 45 BCE, 42 BCE, 39 BCE, 36 BCE, 33 BCE, 30 BCE, 27 BCE, 24 BCE, 21 BCE, 18 BCE, 15 BCE, 12 BCE, 9 BCE, CE 8, CE 12, and every 4th year from then on

Miscellaneous

- The start of the year
  - When Julius Caesar introduced his calendar in 45 B.C.E., he made 1 January the start of the year, and it was always the date on which the Solar Number and the Golden Number were incremented
    - In 567 CE the council of Tours declared that having the year start on 1 January was an ancient mistake that should be abolished
  - Through the middle ages various New Year dates were used. If an ancient document refers to year X, it may mean any of 7 different periods in our present system:
    - 1 Mar X to 28/29 Feb X+1
    - 1 Jan X to 31 Dec X
    - 1 Jan X-1 to 31 Dec X-1
    - 25 Mar X-1 to 24 Mar X
    - 25 Mar X to 24 Mar X+1
    - Saturday before Easter X to Friday before Easter X+1
    - 25 Dec X-1 to 24 Dec X
  - The Byzantine Empire used a year starting on 1 Sep, but they didn't count years since the birth of Christ, instead they counted years since the creation of the world which they dated to 1 September 5509 BCE
  - Since about 1600 most countries have used 1 January as the first day of the year.
    - Italy and England, however, did not make 1 January official until around 1750 (British Calendar Act of 1751)
    - In England (but not Scotland) three different years were used:
      - The historical year, which started on 1 January
      - The liturgical year, which started on the first Sunday in advent
      - The civil year, which from the 7th to the 12th century started on 25 December, from the 12th century until 1751 started on 25 March, from 1752 started on 1 January
- Origin of the names of the months (in English)

Month	Latin	Origin
January	Januarius	Named after the god Janus.
February	Februarius	Named after Februa, the purification festival.
March	Martius	Named after the god Mars.
April	Aprilis	Named either after the goddess Aphrodite or the Latin word aperire, to open.
May	Maius	Probably named after the goddess Maia.

June	Junius	Probably named after the goddess Juno.
July	Julius	Named after Julius Caesar in 44 B.C.E. Prior to that time its name was Quintilis from the word quintus, fifth, because it was the 5th month in the old Roman calendar.
August	Augustus	Named after emperor Augustus in 8 B.C.E. Prior to that time the name was Sextilis from the word sextus, sixth, because it was the 6th month in the old Roman calendar.
September	September	From the word septem, seven, because it was the 7th month in the old Roman calendar.
October	October	From the word octo, eight, because it was the 8th month in the old Roman calendar.
November	November	From the word novem, nine, because it was the 9th month in the old Roman calendar.
December	December	From the word decem, ten, because it was the 10th month in the old Roman calendar.

- Theory of how Dionysius dated Christ's birth
  - According to the Gospel of Luke (3:1 & 3:23) Jesus was "about thirty years old" shortly after "the fifteenth year of the reign of Tiberius Caesar"
    - Tiberius became emperor in C.E. 14
    - Jesus was born before 4 BCE
  - Dionysius' original task was to calculate an Easter table
    - In the Julian calendar, the dates for Easter repeat every 532 years
    - The first year in Dionysius' Easter tables is CE 532
    - Is it a coincidence that the number 532 appears twice here? Or did Dionysius perhaps fix Jesus' birth year so that his own Easter tables would start exactly at the beginning of the second Easter cycle after Jesus' birth?
- There was no year 0
  - A person who was born in 10 BCE and died in CE 10, would have died at the age of 19, not 20
- Gregorian calendar or the Christian calendar is the one commonly used today
  - Proposed by Aloysius Lilius, a physician from Naples, and adopted by Pope Gregory XIII in accordance with instructions from the Council of Trent (1545-1563) to correct for errors in the older Julian Calendar
  - It was decreed by Pope Gregory XIII in a papal bull, Inter Gravissimas, on February 24, 1582
- How does one count years?
  - In about C.E. 523, the papal chancellor, Bonifatius, asked a monk by the name of Dionysius Exiguus to devise a way to implement the rules from the Nicean council (the so-called "Alexandrine Rules") for general use
  - Dionysius Exiguus (in English known as Denis the Little) was a monk from Scythia, he was a canon in the Roman curia, and his assignment was to prepare calculations of the dates of Easter
    - At that time it was customary to count years since the reign of emperor Diocletian, but in his calculations Dionysius chose to number the years since the birth of Christ, rather than honor the persecutor Diocletian
  - Dionysius (wrongly) fixed Jesus' birth with respect to Diocletian's reign in such a manner that it falls on 25 December 753 AUC (ab urbe condita, i.e., since the

founding of Rome)
  - Thus, the current era starts with C.E. 1 on 1 January 754 AUC
- When did the 3rd millennium start?
  - The first millennium started in AD 1, so the millennia are counted in this manner:
    - 1st millennium: 1-1000
    - 2nd millennium: 1001-2000
    - 3rd millennium: 2001-3000
  - Thus, the 3rd millennium and, similarly, the 21st century started on 1 Jan 2001.
- ISO 8601: standard on how to write dates, time, and time intervals by the International Organization for Standardization, ISO
  - Dates
    - Calendar date is in year-month-day format
      - Either 1998-12-25 or 19981225
    - Ordinal date is in year, 3-digit day number format
      - Either 1953214 or 1953-214
    - Week date is in year, W, 2-digit-week number, 1-digit week day number (1=Monday, 2=Tuesday, ..., 7=Sunday)
      - Either 1953W317 or 1953-W31-7
  - Time: 24-hour clock
    - 2-digit hour, 2-digit minute, 2-digit second, comma, fraction of a second
      - 140812,35 or 14:08:12,35
    - The time may optionally be followed by a time zone indication
      - For UTC, the time zone indication is the letter Z
      - For other time zones, the indication is a plus or minus followed by the time difference to UTC (plus for times east of Greenwich, minus for times west of Greenwich)
        - 1130+0430 (at a location 4 and a half hours ahead of UTC)
        - 1130-05 (11:30, at a location 5 hours behind of UTC)
  - Date and time indications can be strung together by putting the letter T between them
    - For example, ten minutes to 7 p.m. on 2 August 1953 may be written as:
      - 19530802T185000 or 1953-08-02T18:50:00
  - Time interval
    - Using starting time and ending time:
      - 1998-12-01T12:03/2004-04-02T14:12
    - Using starting time and duration:
      - 1927-03-12T08:04/P1Y4M12DT6H30M9S
  - BC dates
    - The year 1 BC must be written as 0000
    - The year 2 BC must be written as -0001
  - Years of more than 4 digits
    - Must be written with an initial plus sign
    - The year AD 10000 must be written as +10000
  - Cannot write dates in the Julian calendar; Gregorian only
  - Monday is the first day of the week
- The Indiction was used in the middle ages to specify the position of a year in a 15 year

taxation cycle

    - It was introduced by emperor Constantine the Great on 1 September 312 and ceased to be used in 1806
    - Indiction = (year + 2) mod 15 + 1
    - The Indiction has no astronomical significance and did not always follow the calendar year
    - Three different Indictions may be identified:
        - The Pontifical or Roman Indiction, which started on New Year's Day (being either 25 December, 1 January, or 25 March)
        - The Greek or Constantinopolitan Indiction, which started on 1 September
        - The Imperial Indiction or Indiction of Constantine, which started on 24 September

Navigation

- For navigation, Greeks developed latitude and longitude system
    - Latitude was not a problem; longitude was
    - Every degree of longitude corresponds to 4 minutes of time
- 1714: Queen Anne of England offered 20,000 pounds (worth more than $10,000,000 in today's currency) to anyone who could find a way to determine longitude to within half a degree after a voyage to the West Indies
- 1761: John Harrison, a carpenter and self-taught clock-maker, built a marine chronometer with a spring and balance wheel escapement that won the 1714 prize
    - It kept time on board a rolling ship to about one-fifth of a second a day, nearly as well as a pendulum clock could do on land, and 10 times better than required to win the prize
    - Refined Graham's temperature compensation techniques for the pendulum clock and developed new methods for reducing friction
- GPS (Global Positioning System) uses atomic clocks to determine its position
    - Each satellite beams down a signal giving its position and the mean time determined by 4 atomic clocks it carries on board
    - The signal picks up a device to compute latitude and longitude
    - Onboard atomic clocks are accurate to 1 second in 30,000 years

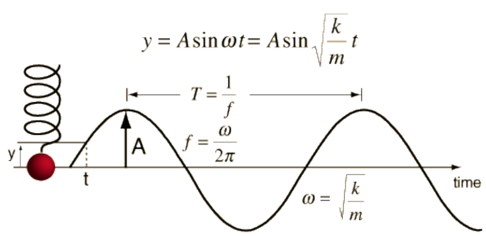
International Date Line

- Although the IDL starts out in the middle of its UTC±12 time zone at both poles, exactly at longitude 180 degrees, for most of its length, it shifts to the east and coincides with the eastern edge of its time zone, which also zigs and zags
    - The bottom line is, this accommodation keeps the island nations of Oceania each on their own clock and calendar
    - Exceptions:
        - Tonga preferred to be at UTC+13 (or UTC-11) for reasons of commerce and convenience
        - Samoa, originally in the UTC-11 time zone, in 2011 "gerrymandered" their time-zone borders to place them in UTC±12
        - The Chatham Islands sets their clocks at UTC+12.75, creating an "orphan" time zone inside UTC±12

        - Fractional time zones are used in 16 locations around the globe
- The rules is that crossing the IDL changes the day and date, but not the time, but there are many exceptions
    - If you cross traveling westward, the day goes forward by one, and the date increases by one
- The IDL does not apply in outer space
    - The International Space Station (ISS), is moving at the astounding speed of 7.7 km/s (4.7 miles/s)
        - That's 5.7 times faster than a speeding bullet
        - The ISS makes one trip around the Earth every 90 minutes
        - So in 24 hours, the occupants experience 32 day and date alternations, and enjoy 16 sunrises and 16 sunsets
    - To keep things simple, their clocks are set to UTC
- Some scientific bases in Antarctica do the same thing as the ISS
    - Others use New Zealand time (UTC±12), as that's a popular embarkation point for travel to Antarctica
    - Since the meridians of longitude converge at the poles, it's possible to walk across multiple time zones on an arbitrarily short hike
    - One kilometer from either pole, time zones are only 262 meters wide. If you were exactly on either pole, you could stand with one foot in all 24 time zones

Physics

Simple Harmonic Motion

- 

- $y = A\sin\omega t = A\sin\sqrt{\frac{k}{m}}t$
- $v = A\omega\cos\omega t$
- $a = -A\omega^2\sin\omega t = -\omega^2 y$
- $E = KE + PE = \frac{1}{2}kA^2$

Special Relativity

- The principle of relativity: The laws of physics don't change, even for objects moving in inertial (constant speed) frames of reference
- The principle of the speed of light: The speed of light is the same for all observers, regardless of their motion relative to the light source
- Lorentz factor: $\gamma = \frac{1}{\sqrt{1-\beta^2}}$
- Time dilation: $t' = \gamma t$
- Length contraction: $l' = \frac{l}{\gamma}$

- Lorentz transformation:
    - $x' = \gamma(x - vt)$
    - $y' = y$
    - $z' = z$
    - $t' = \gamma\left(t - \frac{vx}{c^2}\right)$
- Velocity addition:
    - $V_x' = \frac{V_x - v}{\gamma\left(1 - \frac{V_x v}{c^2}\right)}$
    - $V_y' = \frac{V_y}{\gamma\left(1 - \frac{V_x v}{c^2}\right)}$
    - $V_z' = \frac{V_z}{\gamma\left(1 - \frac{V_x v}{c^2}\right)}$

Eclipses

- Types of solar eclipses
    - Total: dark silhouette of the Moon completely obscures the intensely bright light of the Sun, allowing the much fainter solar corona to be visible
    - Annular: Sun and Moon are exactly in line, but the apparent size of the Moon is smaller than that of the Sun
        - Hence the Sun appears as a very bright ring, or annulus, surrounding the dark disk of the Moon
    - Hybrid: shifts between a total and annular eclipse
    - Partial: Sun and Moon are not exactly in line and the Moon only partially obscures the Sun
- Solar eclipse dates
    - Last total solar eclipse: November 13, 2012
        - Total: Arnhem Land and central Cape York Peninsula, Australia, Kermadec Islands, New Zealand
        - Partial: Australia, New Zealand, Melanesia, Southeastern South America, Southern Pacific, Polynesia, Antarctic Peninsula, West Antarctica, Talos Dome
    - Last hybrid solar eclipse: November 3, 2013
        - Hybrid: Gabon, Republic of the Congo, Democratic Republic of the Congo, Uganda, Kenya, Ethiopia
        - Partial: Eastern America, Eastern Canada, Caribbean, Eastern South America, South Europe, Africa
    - Second last annular solar eclipse: May 10, 2013
        - Annular: Western Australia, Northern Territory and Queensland, Australia, Louisiade Archipelago, Solomon Islands, Kiribati
        - Partial: Australia, New Zealand, Central Pacific, Hawaii, Indonesia
    - Last annular solar eclipse (non-central): April 29, 2014
        - Annular: western Wilkes Land
        - Partial: South Indian Ocean, Australia, east Antarctica
    - Last partial solar eclipse: October 23, 2014
        - Partial: Northern Pacific, North America, Mexico, Eastern Russia
    - Next total solar eclipse: March 20, 2015

        - Total: Faroe Islands, Svalbard, North Atlantic, North Pole
        - Partial: Greenland, Europe, Central Asia, Western Russia
- Total Lunar Eclipse Dates
    - 2014 Oct 08: 10:55 duration
    - 2015 Apr 04: 12:00 duration

Abbreviations

Institutions

- NIST: National Institute of Standards and Technology
- TDT: Terrestrial Dynamical Time
- TAI: International Atomic Time
- ISO: International Organization for Standardization

Eras

- CE: Common Era
- BCE: Before Common Era
- BC: Before Christ
- AD: Anno Domini, Latin for "in the year of the Lord"

Time Zones

- UTC: Coordinated Universal Time
- ACDT (Australian Central Daylight Savings Time): UTC+10:30
- ACST (Australian Central Standard Time): UTC+09:30
- ACT (ASEAN Common Time): UTC+08
- ADT (Atlantic Daylight Time): UTC−03
- AEDT (Australian Eastern Daylight Savings Time): UTC+11
- AEST (Australian Eastern Standard Time): UTC+10
- AFT (Afghanistan Time): UTC+04:30
- AKDT (Alaska Daylight Time): UTC−08
- AKST (Alaska Standard Time): UTC−09
- AMST (Amazon Summer Time (Brazil)): UTC−03
- AMST (Armenia Summer Time): UTC+05
- AMT (Amazon Time (Brazil)): UTC−04
- AMT (Armenia Time): UTC+04
- ART (Argentina Time): UTC−03
- AST (Arabia Standard Time): UTC+03
- AST (Atlantic Standard Time): UTC−04
- AWDT (Australian Western Daylight Time): UTC+09
- AWST (Australian Western Standard Time): UTC+08
- AZOST (Azores Standard Time): UTC−01
- AZT (Azerbaijan Time): UTC+04
- BDT (Brunei Time): UTC+08
- BIOT (British Indian Ocean Time): UTC+06
- BIT (Baker Island Time): UTC−12

- BOT (Bolivia Time): UTC−04
- BRT (Brasilia Time): UTC−03
- BST (Bangladesh Standard Time): UTC+06
- BST (British Summer Time (British Standard Time from Feb 1968 to Oct 1971)): UTC+01
- BTT (Bhutan Time): UTC+06
- CAT (Central Africa Time): UTC+02
- CCT (Cocos Islands Time): UTC+06:30
- CDT (Central Daylight Time (North America)): UTC−05
- CDT (Cuba Daylight Time): UTC−04
- CEDT (Central European Daylight Time): UTC+02
- CEST (Central European Summer Time (Cf. HAEC)): UTC+02
- CET (Central European Time): UTC+01
- CHADT (Chatham Daylight Time): UTC+13:45
- CHAST (Chatham Standard Time): UTC+12:45
- CHOT (Choibalsan): UTC+08
- ChST (Chamorro Standard Time): UTC+10
- CHUT (Chuuk Time): UTC+10
- CIST (Clipperton Island Standard Time): UTC−08
- CIT (Central Indonesia Time): UTC+08
- CKT (Cook Island Time): UTC−10
- CLST (Chile Summer Time): UTC−03
- CLT (Chile Standard Time): UTC−04
- COST (Colombia Summer Time): UTC−04
- COT (Colombia Time): UTC−05
- CST (Central Standard Time (North America)): UTC−06
- CST (China Standard Time): UTC+08
- CST (Central Standard Time (Australia)): UTC+09:30
- CST (Central Summer Time (Australia)): UTC+10:30
- CST (Cuba Standard Time): UTC−05
- CT (China time): UTC+08
- CVT (Cape Verde Time): UTC−01
- CWST (Central Western Standard Time (Australia) unofficial): UTC+08:45
- CXT (Christmas Island Time): UTC+07
- DAVT (Davis Time): UTC+07
- DDUT (Dumont d'Urville Time): UTC+10
- DFT (AIX specific equivalent of Central European Time): UTC+01
- EASST (Easter Island Standard Summer Time): UTC−05
- EAST (Easter Island Standard Time): UTC−06
- EAT (East Africa Time): UTC+03
- ECT (Eastern Caribbean Time (does not recognise DST)): UTC−04
- ECT (Ecuador Time): UTC−05
- EDT (Eastern Daylight Time (North America)): UTC−04
- EEDT (Eastern European Daylight Time): UTC+03
- EEST (Eastern European Summer Time): UTC+03

- EET (Eastern European Time): UTC+02
- EGST (Eastern Greenland Summer Time): UTC+00
- EGT (Eastern Greenland Time): UTC−01
- EIT (Eastern Indonesian Time): UTC+09
- EST (Eastern Standard Time (North America)): UTC−05
- EST (Eastern Standard Time (Australia)): UTC+10
- FET (Further-eastern European Time): UTC+03
- FJT (Fiji Time): UTC+12
- FKST (Falkland Islands Standard Time): UTC−03
- FKST (Falkland Islands Summer Time): UTC−03
- FKT (Falkland Islands Time): UTC−04
- FNT (Fernando de Noronha Time): UTC−02
- GALT (Galapagos Time): UTC−06
- GAMT (Gambier Islands): UTC−09
- GET (Georgia Standard Time): UTC+04
- GFT (French Guiana Time): UTC−03
- GILT (Gilbert Island Time): UTC+12
- GIT (Gambier Island Time): UTC−09
- GMT (Greenwich Mean Time): UTC
- GST (South Georgia and the South Sandwich Islands): UTC−02
- GST (Gulf Standard Time): UTC+04
- GYT (Guyana Time): UTC−04
- HADT (Hawaii-Aleutian Daylight Time): UTC−09
- HAEC (Heure Avancée d'Europe Centrale francised name for CEST): UTC+02
- HAST (Hawaii-Aleutian Standard Time): UTC−10
- HKT (Hong Kong Time): UTC+08
- HMT (Heard and McDonald Islands Time): UTC+05
- HOVT (Khovd Time): UTC+07
- HST (Hawaii Standard Time): UTC−10
- ICT (Indochina Time): UTC+07
- IDT (Israel Daylight Time): UTC+03
- IOT (Indian Ocean Time): UTC+03
- IRDT (Iran Daylight Time): UTC+04:30
- IRKT (Irkutsk Time): UTC+09
- IRST (Iran Standard Time): UTC+03:30
- IST (Indian Standard Time): UTC+05:30
- IST (Irish Standard Time): UTC+01
- IST (Israel Standard Time): UTC+02
- JST (Japan Standard Time): UTC+09
- KGT (Kyrgyzstan time): UTC+06
- KOST (Kosrae Time): UTC+11
- KRAT (Krasnoyarsk Time): UTC+07
- KST (Korea Standard Time): UTC+09
- LHST (Lord Howe Standard Time): UTC+10:30

- LHST (Lord Howe Summer Time): UTC+11
- LINT (Line Islands Time): UTC+14
- MAGT (Magadan Time): UTC+12
- MART (Marquesas Islands Time): UTC−09:30
- MAWT (Mawson Station Time): UTC+05
- MDT (Mountain Daylight Time (North America)): UTC−06
- MET (Middle European Time Same zone as CET): UTC+01
- MEST (Middle European Saving Time Same zone as CEST): UTC+02
- MHT (Marshall Islands): UTC+12
- MIST (Macquarie Island Station Time): UTC+11
- MIT (Marquesas Islands Time): UTC−09:30
- MMT (Myanmar Time): UTC+06:30
- MSK (Moscow Time): UTC+04
- MST (Malaysia Standard Time): UTC+08
- MST (Mountain Standard Time (North America)): UTC−07
- MST (Myanmar Standard Time): UTC+06:30
- MUT (Mauritius Time): UTC+04
- MVT (Maldives Time): UTC+05
- MYT (Malaysia Time): UTC+08
- NCT (New Caledonia Time): UTC+11
- NDT (Newfoundland Daylight Time): UTC−02:30
- NFT (Norfolk Time): UTC+11:30
- NPT (Nepal Time): UTC+05:45
- NST (Newfoundland Standard Time): UTC−03:30
- NT (Newfoundland Time): UTC−03:30
- NUT (Niue Time): UTC−11
- NZDT (New Zealand Daylight Time): UTC+13
- NZST (New Zealand Standard Time): UTC+12
- OMST (Omsk Time): UTC+07
- ORAT (Oral Time): UTC+05
- PDT (Pacific Daylight Time (North America)): UTC−07
- PET (Peru Time): UTC−05
- PETT (Kamchatka Time): UTC+12
- PGT (Papua New Guinea Time): UTC+10
- PHOT (Phoenix Island Time): UTC+13
- PHT (Philippine Time): UTC+08
- PKT (Pakistan Standard Time): UTC+05
- PMDT (Saint Pierre and Miquelon Daylight time): UTC−02
- PMST (Saint Pierre and Miquelon Standard Time): UTC−03
- PONT (Pohnpei Standard Time): UTC+11
- PST (Pacific Standard Time (North America)): UTC−08
- PYST (Paraguay Summer Time (South America)): UTC−03
- PYT (Paraguay Time (South America)): UTC−04
- RET (Réunion Time): UTC+04

- ROTT (Rothera Research Station Time): UTC−03
- SAKT (Sakhalin Island time): UTC+11
- SAMT (Samara Time): UTC+04
- SAST (South African Standard Time): UTC+02
- SBT (Solomon Islands Time): UTC+11
- SCT (Seychelles Time): UTC+04
- SGT (Singapore Time): UTC+08
- SLST (Sri Lanka Time): UTC+05:30
- SRT (Suriname Time): UTC−03
- SST (Samoa Standard Time): UTC−11
- SST (Singapore Standard Time): UTC+08
- SYOT (Showa Station Time): UTC+03
- TAHT (Tahiti Time): UTC−10
- THA (Thailand Standard Time): UTC+07
- TFT (Indian/Kerguelen): UTC+05
- TJT (Tajikistan Time): UTC+05
- TKT (Tokelau Time): UTC+13
- TLT (Timor Leste Time): UTC+09
- TMT (Turkmenistan Time): UTC+05
- TOT (Tonga Time): UTC+13
- TVT (Tuvalu Time): UTC+12
- UCT (Coordinated Universal Time): UTC
- ULAT (Ulaanbaatar Time): UTC+08
- UTC (Coordinated Universal Time): UTC
- UYST (Uruguay Summer Time): UTC−02
- UYT (Uruguay Standard Time): UTC−03
- UZT (Uzbekistan Time): UTC+05
- VET (Venezuelan Standard Time): UTC−04:30
- VLAT (Vladivostok Time): UTC+10
- VOLT (Volgograd Time): UTC+04
- VOST (Vostok Station Time): UTC+06
- VUT (Vanuatu Time): UTC+11
- WAKT (Wake Island Time): UTC+12
- WAST (West Africa Summer Time): UTC+02
- WAT (West Africa Time): UTC+01
- WEDT (Western European Daylight Time): UTC+01
- WEST (Western European Summer Time): UTC+01
- WET (Western European Time): UTC
- WIT (Western Indonesian Time): UTC+07
- WST (Western Standard Time): UTC+08
- YAKT (Yakutsk Time): UTC+10
- YEKT (Yekaterinburg Time): UTC+06
- Z (Zulu Time (Coordinated Universal Time)): UTC

Other

- DST: Daylight Savings Time
- GPS: Global Positioning System
- IDL: International Date Line
- IMC: International Meridian Conference
- ISS: International Space Station

Quotes

- “Time you enjoy wasting is not wasted time.”
  ― Marthe Troly-Curtin, Phrynette Married
- “I wish it need not have happened in my time," said Frodo.
  "So do I," said Gandalf, "and so do all who live to see such times. But that is not for them to decide. All we have to decide is what to do with the time that is given us.”
  ― J.R.R. Tolkien, The Fellowship of the Ring
- “Time flies like an arrow; fruit flies like a banana.”
  ― Anthony G. Oettinger
- “There comes a time when the world gets quiet and the only thing left is your own heart. So you'd better learn the sound of it. Otherwise you'll never understand what it's saying.”
  ― Sarah Dessen, Just Listen
- “How did it get so late so soon?”
  ― Dr. Seuss
- “It has been said, 'time heals all wounds.' I do not agree. The wounds remain. In time, the mind, protecting its sanity, covers them with scar tissue and the pain lessens. But it is never gone.”
  ― Rose Kennedy
- “Yesterday is gone. Tomorrow has not yet come. We have only today. Let us begin.”
  ― Mother Teresa
- “They say I'm old-fashioned, and live in the past, but sometimes I think progress progresses too fast!”
  ― Dr. Seuss
- “Time is the longest distance between two places.”
  ― Tennessee Williams, The Glass Menagerie
- “They always say time changes things, but you actually have to change them yourself.”
  ― Andy Warhol, The Philosophy of Andy Warhol
- “It's being here now that's important. There's no past and there's no future. Time is a very misleading thing. All there is ever, is the now. We can gain experience from the past, but we can't relive it; and we can hope for the future, but we don't know if there is one.”
  ― George Harrison
- “Here we are, trapped in the amber of the moment. There is no why.”
  ― Kurt Vonnegut
- “Unfortunately, the clock is ticking, the hours are going by. The past increases, the future recedes. Possibilities decreasing, regrets mounting.”
  ― Haruki Murakami, Dance Dance Dance
- “It is the time you have wasted for your rose that makes your rose so important.”
  ― Antoine de Saint-Exupéry, The Little Prince

- “Time is an illusion.”
  — Albert Einstein
- “There's never enough time to do all the nothing you want.”
  — Bill Watterson
- “Time is a created thing. To say 'I don't have time,' is like saying, 'I don't want to.”
  — Lao Tzu
- “How did it get so late so soon? It's night before it's afternoon. December is here before it's June. My goodness how the time has flewn. How did it get so late so soon?”
  — Dr. Seuss