

# Time

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**Time** is the indefinite continued progress of existence and events that occur in apparently irreversible succession from the past through the present to the future.<sup>[1][2][3]</sup> Time is a component quantity of various measurements used to sequence events, to compare the duration of events or the intervals between them, and to quantify rates of change of quantities in material reality or in the conscious experience.<sup>[4][5][6][7]</sup> Time is often referred to as the **fourth dimension**, along with the three spatial dimensions.<sup>[8]</sup>

Time has long been an important subject of study in religion, philosophy, and science, but defining it in a manner applicable to all fields without circularity has consistently eluded scholars.<sup>[2][6][7][9][10][11]</sup> Nevertheless, diverse fields such as business, industry, sports, the sciences, and the performing arts all incorporate some notion of time into their respective measuring systems.<sup>[12][13][14]</sup> Two contrasting viewpoints on time divide prominent philosophers. One view is that time is part of the fundamental structure of the universe—a dimension independent of events, in which events occur in sequence. Isaac Newton subscribed to this realist view, and hence it is sometimes referred to as Newtonian time.<sup>[15][16]</sup> The opposing view is that *time* does not refer to any kind of "container" that events and objects "move through", nor to any entity that "flows", but that it is instead part of a fundamental intellectual structure (together with space and number) within which humans sequence and compare events. This second view, in the tradition of Gottfried Leibniz<sup>[17]</sup> and Immanuel Kant,<sup>[18][19]</sup> holds that *time* is neither an event nor a thing, and thus is not itself measurable nor can it be travelled.

Time in physics is unambiguously operationally defined as "what a clock reads".<sup>[6][17][20]</sup> Time is one of the seven fundamental physical quantities in both the International System of Units and International System of Quantities. Time is used to define other quantities—such as velocity—so defining time in terms of such



The flow of sand in an hourglass can be used to measure the passage of time. It also concretely represents the present as being between the past and the future.

quantities would result in circularity of definition.<sup>[21]</sup> An operational definition of time, wherein one says that observing a certain number of repetitions of one or another standard cyclical event (such as the passage of a free-swinging pendulum) constitutes one standard unit such as the second, is highly useful in the conduct of both advanced experiments and everyday affairs of life. The operational definition leaves aside the question whether there is something called time, apart from the counting activity just mentioned, that flows and that can be measured. Investigations of a single continuum called spacetime bring questions about space into questions about time, questions that have their roots in the works of early students of natural philosophy.

Furthermore, it may be that there is a subjective component to time, but whether or not time itself is "felt", as a sensation, or is a judgment, is a matter of debate.<sup>[2][6][7][22][23]</sup>

Temporal measurement has occupied scientists and technologists, and was a prime motivation in navigation and astronomy. Periodic events and periodic motion have long served as standards for units of time. Examples include the apparent motion of the sun across the sky, the phases of the moon, the swing of a pendulum, and the beat of a heart. Currently, the international unit of time, the second, is defined by measuring the electronic transition frequency of caesium atoms (see below). Time is also of significant social importance, having economic value ("time is money") as well as personal value, due to an awareness of the limited time in each day and in human life spans.

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## Temporal measurement and history

Generally speaking, methods of temporal measurement, or chronometry, take two distinct forms: the calendar, a mathematical tool for organising intervals of time,<sup>[24]</sup> and the clock, a physical mechanism that counts the passage of time. In day-to-day life, the clock is consulted for periods less than a day whereas the calendar is

consulted for periods longer than a day. Increasingly, personal electronic devices display both calendars and clocks simultaneously. The number (as on a clock dial or calendar) that marks the occurrence of a specified event as to hour or date is obtained by counting from a fiducial epoch—a central reference point.

## **History of the calendar**

Artifacts from the Paleolithic suggest that the moon was used to reckon time as early as 6,000 years ago.<sup>[25]</sup> Lunar calendars were among the first to appear, either 12 or 13 lunar months (either 354 or 384 days). Without intercalation to add days or months to some years, seasons quickly drift in a calendar based solely on twelve lunar months. Lunisolar calendars have a thirteenth month added to some years to make up for the difference between a full year (now known to be about 365.24 days) and a year of just twelve lunar months. The numbers twelve and thirteen came to feature prominently in many cultures, at least partly due to this relationship of months to years. Other early forms of calendars originated in Mesoamerica, particularly in ancient Mayan civilization. These calendars were religiously and astronomically based, with 18 months in a year and 20 days in a month, plus five epagemonal days at the end of the year.<sup>[26]</sup>

The reforms of Julius Caesar in 45 BC put the Roman world on a solar calendar. This Julian calendar was faulty in that its intercalation still allowed the astronomical solstices and equinoxes to advance against it by about 11 minutes per year. Pope Gregory XIII introduced a correction in 1582; the Gregorian calendar was only slowly adopted by different nations over a period of centuries, but it is now the most commonly used calendar around the world, by far.

During the French Revolution, a new clock and calendar were invented in attempt to de-Christianize time and create a more rational system in order to replace the Gregorian calendar. The French Republican Calendar's days consisted of ten hours of a hundred minutes of a hundred seconds, which marked a deviation from the 12-based duodecimal system used in many other devices by many cultures. The system was later abolished in 1806.<sup>[27]</sup>

## **History of time measurement devices**

A large variety of devices has been invented to measure time. The study of these devices is called horology.

An Egyptian device that dates to c.1500 BC, similar in shape to a bent T-square, measured the passage of time from the shadow cast by its crossbar on a nonlinear rule. The T was oriented eastward in the mornings. At noon, the device was turned around so that it could cast its shadow in the evening direction.<sup>[28]</sup>



Horizontal sundial in Taganrog

A sundial uses a gnomon to cast a shadow on a set of markings calibrated to the hour. The position of the shadow marks the hour in local time. The idea to separate the day into smaller parts is credited to Egyptians because of their sundials, which operated on a duodecimal system. The importance of the number 12 is due the number of lunar cycles in a year and the number of stars used to count the passage of night.<sup>[29]</sup>



An old kitchen clock

The most precise timekeeping device of the ancient world was the water clock, or *clepsydra*, one of which was found in the tomb of Egyptian pharaoh Amenhotep I (1525–1504 BC). They could be used to measure the hours even at night, but required manual upkeep to replenish the flow of water. The Ancient Greeks and the people from Chaldea (southeastern Mesopotamia) regularly maintained timekeeping records as an essential part of their astronomical observations. Arab inventors and engineers in particular made improvements on the use of water clocks up to the Middle Ages.<sup>[30]</sup> In the 11th century, Chinese inventors and engineers invented the first mechanical clocks driven by an escapement mechanism.



A contemporary quartz watch, 2007

The hourglass uses the flow of sand to measure the flow of time. They were used in navigation. Ferdinand Magellan used 18 glasses on each ship for his circumnavigation of the globe (1522).<sup>[31]</sup> Incense sticks and candles were, and are, commonly used to measure time in temples and churches across the globe. Waterclocks, and later, mechanical clocks, were used to mark the events of the abbeys and monasteries of the Middle Ages. Richard of Wallingford (1292–1336), abbot of St. Alban's abbey, famously built a mechanical clock as an astronomical

orrery about 1330.<sup>[32][33]</sup> Great advances in accurate time-keeping were made by Galileo Galilei and especially Christiaan Huygens with the invention of pendulum driven clocks along with the invention of the minute hand by Jost Burgi.<sup>[34]</sup>

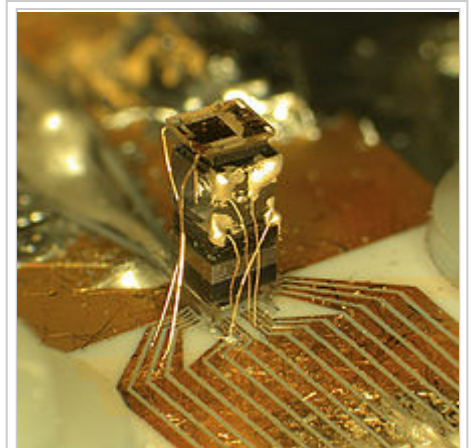
The English word clock probably comes from the Middle Dutch word *klocke* which, in turn, derives from the medieval Latin word *clocca*, which ultimately derives from Celtic and is cognate with French, Latin, and German words that mean bell. The passage of the hours at sea were marked by bells, and denoted the time (see ship's bell). The hours were marked by bells in abbeys as well as at sea.

Clocks can range from watches, to more exotic varieties such as the Clock of the Long Now. They can be driven by a variety of means, including gravity, springs, and various forms of electrical power, and regulated by a variety of means such as a pendulum.

Alarm clocks first appeared in ancient Greece around 250 BC with a water clock that would set off a whistle. This idea was later mechanized by Levi Hutchins and Seth E. Thomas.<sup>[34]</sup>

A chronometer is a portable timekeeper that meets certain precision standards. Initially, the term was used to refer to the marine chronometer, a timepiece used to determine longitude by means of celestial navigation, a precision firstly achieved by John Harrison. More recently, the term has also been applied to the chronometer watch, a watch that meets precision standards set by the Swiss agency COSC.

The most accurate timekeeping devices are atomic clocks, which are accurate to seconds in many millions of years,<sup>[36]</sup> and are used to calibrate other clocks and timekeeping instruments. Atomic clocks use the frequency of electronic transitions in certain atoms to measure the second. One of the most common atoms used is caesium, most modern atomic clocks probe caesium with microwaves to determine the frequency of these electron vibrations.<sup>[37]</sup> Since 1967, the International System of Measurements bases its unit of time, the second, on the properties of caesium atoms. SI defines the second as 9,192,631,770 cycles of the radiation that corresponds to the transition between two electron spin energy levels of the ground state of the  $^{133}\text{Cs}$  atom.



Chip-scale atomic clocks, such as this one unveiled in 2004, are expected to greatly improve GPS location.<sup>[35]</sup>

Today, the Global Positioning System in coordination with the Network Time Protocol can be used to synchronize timekeeping systems across the globe.

In medieval philosophical writings, the **atom** was a unit of time referred to as the smallest possible division of time. The earliest known occurrence in English is in Byrhtferth's *Enchiridion* (a science text) of 1010–1012,<sup>[38]</sup> where it was defined as 1/564 of a *momentum* (1½ minutes),<sup>[39]</sup> and thus equal to 15/94 of a second. It was used in the *computus*, the process of calculating the date of Easter.

As of May 2010, the smallest time interval uncertainty in direct measurements is on the order of 12 attoseconds ( $1.2 \times 10^{-17}$  seconds), about  $3.7 \times 10^{26}$  Planck times.<sup>[40]</sup>

## Units of time

The second (s) is the SI base unit. A minute (min) is 60 seconds in length, and an hour is 60 minutes in length. A day is 24 hours or 86400 seconds in length.

## Definitions and standards

Originally the second was defined as 1/86,400 of the mean solar day, which is the year-average of the solar day, being the time interval between two successive noons, i.e., the time interval between two successive passages of the sun across the meridian. In 1874 the British Association for the Advancement of Science introduced the CGS (centimetre/gramme/second system) combining fundamental units of length, mass and time. This second is "elastic", because tidal friction is slowing the earth's rotation rate. For use in calculating ephemerides of celestial motion, therefore, in 1952 astronomers introduced the "ephemeris second", currently defined as

the fraction 1/31,556,925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time.

[41]

The CGS system has been superseded by the *Système international*. The SI base unit for time is the SI second. The International System of Quantities, which incorporates the SI, also defines larger units of time equal to fixed integer multiples

of one second (1 s), such as the minute, hour and day. These are not part of the SI, but may be used alongside the SI. Other units of time such as the month and the year are not equal to fixed multiples of 1 s, and instead exhibit significant variations in duration.<sup>[42]</sup>

The official SI definition of the second is as follows:<sup>[42][43]</sup>

The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.

At its 1997 meeting, the CIPM affirmed that this definition refers to a caesium atom in its ground state at a temperature of 0 K.<sup>[42]</sup>

The current definition of the second, coupled with the current definition of the metre, is based on the special theory of relativity, which affirms our spacetime to be a Minkowski space. The definition of the second in mean solar time, however, is unchanged.

## **World time**

While in theory, the concept of a single worldwide universal time-scale may have been conceived of many centuries ago, in practicality the technical ability to create and maintain such a time-scale did not become possible until the mid-19th century. The timescale adopted was Greenwich Mean Time, created in 1847. A few countries have replaced it with Coordinated Universal Time, UTC.

## **History of the development of UTC**

With the advent of the industrial revolution, a greater understanding and agreement on the nature of time itself became increasingly necessary and helpful. In 1847 in Britain, Greenwich Mean Time (GMT) was first created for use by the British railways, the British navy, and the British shipping industry. Using telescopes, GMT was calibrated to the mean solar time at the Royal Observatory, Greenwich in the UK.



As international commerce continued to increase throughout Europe, in order to achieve a more efficiently functioning modern society, an agreed upon, and highly accurate ***international standard*** of time measurement became necessary. In order to find or determine such a time-standard, three steps had to be followed:

1. An internationally agreed upon time-standard had to be defined.
2. This new time-standard then had to be consistently and accurately measured.
3. The new time-standard then had to be freely shared and distributed around the world.

The development of what is now known as UTC time came about historically as an effort which first began as a collaboration between 41 nations, officially agreed to and signed at the International Meridian Conference, in Washington D.C. in 1884. At this conference, the local mean solar time at the Royal Observatory, Greenwich in England was chosen to define the "universal day", counted from 0 hours at Greenwich mean midnight. This agreed with the civil Greenwich Mean Time used on the island of Great Britain since 1847. In contrast astronomical GMT began at mean noon, i.e. astronomical day *X* began at noon of civil day *X*. The purpose of this was to keep one night's observations under one date. The civil system was adopted as of 0 hours (civil) 1 January 1925. Nautical GMT began 24 hours before astronomical GMT, at least until 1805 in the Royal Navy, but persisted much later elsewhere because it was mentioned at the 1884 conference. In 1884, the Greenwich meridian was used for two - thirds of all charts and maps as their Prime Meridian.<sup>[44]</sup>

Among the 41 nations represented at the conference, the advanced time-technologies that had already come into use in Britain were fundamental components of the agreed upon method of arriving at a universal and agreed upon international time. In 1928 Greenwich Mean Time was rebranded for scientific purposes by the International Astronomical Union as Universal Time (UT). This was to avoid confusion with the previous system where the day had begun at noon. As the general public had always begun the day at midnight the timescale continued to be presented to them as Greenwich Mean Time. By 1956, universal time had been split into various versions - UT2, which smoothed for polar motion and seasonal effects, was presented to the public as Greenwich Mean Time. Later, UT1 (which smooths only for polar motion) became the default form of UT used by astronomers and hence the form used in navigation, sunrise and sunset and moonrise and moonset tables where the name Greenwich Mean Time continues to be employed. Greenwich Mean Time is also the preferred method of describing the timescale used by legislators. Even to the present day, UT is still based on an international telescopic system. Observations at the Greenwich Observatory itself

ceased in 1954, though the location is still used as the basis for the coordinate system. Because the rotational period of Earth is not perfectly constant, the duration of a second would vary if calibrated to a telescope-based standard like GMT, where the second is defined as  $1/86\,400$  of the mean solar day.

For the better part of the first century following the "International Meridian Conference," until 1960, the methods and definitions of time-keeping that had been laid out at the conference proved to be adequate to meet time tracking needs of science. Still, with the advent of the "electronic revolution" in the latter half of the 20th century, the technologies that had been available at the time of the Convention of the Metre proved to be in need of further refinement in order to meet the needs of the ever-increasing precision that the "electronic revolution" had begun to require.

### **The ephemeris second**

An invariable second (the "ephemeris second") had been defined, use of which removed the errors in ephemerides resulting from the use of the variable mean solar second as the time argument. In 1960 this ephemeris second was made the basis of the "coordinated universal time" which was being derived from atomic clocks. It is a specified fraction of the mean tropical year as at 1900 and, being based on historical telescope observations, corresponds roughly to the mean solar second of the early nineteenth century.<sup>[45]</sup>

### **The SI second**

In 1967 a further step was taken with the introduction of the SI second, essentially the ephemeris second as measured by atomic clocks and formally defined in atomic terms.<sup>[46]</sup> The SI second (Standard Internationale second) is based directly on the measurement of the atomic-clock observation of the frequency oscillation of caesium atoms. It is the basis of all atomic timescales, e.g. coordinated universal time, GPS time, International Atomic Time, etc. Atomic clocks do not measure nuclear decay rates, which is a common misconception, but rather measure a certain natural vibrational frequency of caesium-133.<sup>[47]</sup> Coordinated universal time is subject to one constraint which does not affect the other atomic timescales. As it has been adopted as the civil timescale by some countries (most countries have opted to retain mean solar time) it is not permitted to deviate from GMT by more than 0.9 second. This is achieved by the occasional insertion of a leap second.

## **Current application of UTC**

Most countries use mean solar time. Australia, Canada (Quebec only), Colombia, France, Germany, New Zealand, Papua New Guinea (Bougainville only), Paraguay, Portugal, Switzerland, the United States and Venezuela use UTC. However, UTC is widely used by the scientific community in countries where mean solar time is official. UTC time is based on the SI second, which was first defined in 1967, and is based on the use of atomic clocks. Some other less used but closely related time-standards include International Atomic Time (TAI), Terrestrial Time, and Barycentric Dynamical Time.

Between 1967 and 1971, UTC was periodically adjusted by fractional amounts of a second in order to adjust and refine for variations in mean solar time, with which it is aligned. After 1 January 1972, UTC time has been defined as being offset from atomic time by a whole number of seconds, changing only when a leap second is added to keep radio - controlled clocks synchronized with the rotation of the Earth.

The Global Positioning System also broadcasts a very precise time signal worldwide, along with instructions for converting GPS time to UTC. GPS-time is based on, and regularly synchronized with or from, UTC-time.

Earth is split up into a number of time zones. Most time zones are exactly one hour apart, and by convention compute their local time as an offset from GMT. For example, time zones at sea are based on GMT. In many locations (but not at sea) these offsets vary twice yearly due to daylight saving time transitions.

## **Time conversions**

These conversions are accurate at the millisecond level for time systems involving earth rotation (UT1 & TT). Conversions between atomic time systems (TAI, GPS, and UTC) are accurate at the microsecond level.

System	Description	UT1	UTC	TT	TAI	GPS
UT1	Mean Solar Time	UT1	$UTC = UT1 - DUT1$	$TT = UT1 + 32.184\text{ s} + LS - DUT1$	$TAI = UT1 - DUT1 + LS$	$GPS = UT1 - DUT1 + LS - 19\text{ s}$
UTC	Civil Time	$UT1 = UTC + DUT1$	UTC	$TT = UTC + 32.184\text{ s} + LS$	$TAI = UTC + LS$	$GPS = UTC + LS - 19\text{ s}$
TT	Terrestrial (Ephemeris) Time	$UT1 = TT - 32.184\text{ s} - LS + DUT1$	$UTC = TT - 32.184\text{ s} - LS$	TT	$TAI = TT - 32.184\text{ s}$	$GPS = TT - 51.184\text{ s}$
TAI	Atomic Time	$UT1 = TAI + DUT1 - LS$	$UTC = TAI - LS$	$TT = TAI + 32.184\text{ s}$	TAI	$GPS = TAI - 19\text{ s}$
GPS	GPS Time	$UT1 = GPS + DUT1 - LS + 19\text{ s}$	$UTC = GPS - LS + 19\text{ s}$	$TT = GPS + 51.184\text{ s}$	$TAI = GPS + 19\text{ s}$	GPS

Definitions:

1. LS = TAI - UTC = Leap Seconds from <http://maia.usno.navy.mil/ser7/tai-utc.dat>
2. DUT1 = UT1 - UTC from <http://maia.usno.navy.mil/ser7/ser7.dat> or <http://maia.usno.navy.mil/search/search.html>

## Sidereal time

Sidereal time is the measurement of time relative to a distant star (instead of solar time that is relative to the sun). It is used in astronomy to predict when a star will be overhead. Due to the orbit of the earth around the sun a sidereal day is about 4 minutes (1/366th) less than a solar day.

## Chronology

Another form of time measurement consists of studying the past. Events in the past can be ordered in a sequence (creating a chronology), and can be put into chronological groups (periodization). One of the most important systems of periodization is the geologic time scale, which is a system of periodizing the events that shaped the Earth and its life. Chronology, periodization, and interpretation of the past are together known as the study of history.

## Time-like concepts: terminology

The term "time" is generally used for many close but different concepts, including:

- instant<sup>[48]</sup> as an object—one point on the time axes. Being an object, it has no value;
- time interval<sup>[49]</sup> as an object—part of the time axes limited by two instants. Being an object, it has no value;
- date<sup>[50]</sup> as a quantity characterising an instant. As a quantity, it has a value which may be expressed in a variety of ways, for example "2014-04-26T09:42:36,75" in ISO standard format, or more colloquially such as "today, 9:42 a.m.";
- duration<sup>[51]</sup> as a quantity characterizing a time interval.<sup>[52]</sup> As a quantity, it has a value, such as a number of minutes, or may be described in terms of the quantities (such as times and dates) of its beginning and end.

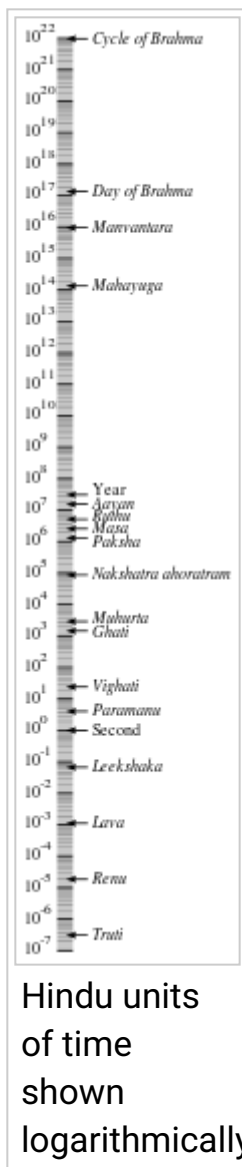
## Religion

### Linear and cyclical time

Ancient cultures such as Incan, Mayan, Hopi, and other Native American Tribes - plus the Babylonians, Ancient Greeks, Hinduism, Buddhism, Jainism, and others - have a concept of a wheel of time: they regard time as cyclical and quantic, consisting of repeating ages that happen to every being of the Universe between birth and extinction.

In general, the Islamic and Judeo-Christian world-view regards time as linear<sup>[53]</sup> and directional,<sup>[54]</sup> beginning with the act of creation by God. The traditional Christian view sees time ending, teleologically,<sup>[55]</sup> with the eschatological end of the present order of things, the "end time".

In the Old Testament book Ecclesiastes, traditionally ascribed to Solomon (970–928 BC), time (as the Hebrew word עֵדָן, זמן *'iddan(time) zēman(season)* is often translated) was traditionally regarded as a medium for the passage of predestined events. (Another word, זמן "זמān" *zamān*, meant *time fit for an event*, and is used as the modern Arabic, Persian, and Hebrew equivalent to the English word "time".)



## Time in Greek mythology

The Greek language denotes two distinct principles, Chronos and Kairos. The former refers to numeric, or chronological, time. The latter, literally "the right or opportune moment", relates specifically to metaphysical or Divine time. In theology, Kairos is qualitative, as opposed to quantitative.

In Greek mythology, Chronos (Ancient Greek: Χρόνος) is identified as the Personification of Time. His name in Greek means "time" and is alternatively spelled Chronus (Latin spelling) or Khronos. Chronos is usually portrayed as an old, wise man with a long, gray beard, such as "Father Time". Some English words whose etymological root is khronos/chronos include *chronology*, *chronometer*, *chronic*, *anachronism*, *synchronise*, and *chronicle*.

## Time in Kabbalah

According to Kabbalists, "time" is a paradox<sup>[56]</sup> and an illusion.<sup>[57]</sup> Both the future and the past are recognised to be combined and simultaneously present.

## Philosophy

Two distinct viewpoints on time divide many prominent philosophers. One view is that time is part of the fundamental structure of the universe, a dimension in which events occur in sequence. Sir Isaac Newton subscribed to this realist view, and hence it is sometimes referred to as Newtonian time.<sup>[16]</sup> An opposing view is that *time* does not refer to any kind of actually existing dimension that events and objects "move through", nor to any entity that "flows", but that it is instead an intellectual concept (together with space and number) that enables humans to sequence and compare events.<sup>[58]</sup> This second view, in the tradition of Gottfried Leibniz<sup>[17]</sup> and Immanuel Kant,<sup>[18][19]</sup> holds that space and time "do not exist in and of themselves, but ... are the product of the way we represent things", because we can know objects only as they appear to us.

The *Vedas*, the earliest texts on Indian philosophy and Hindu philosophy dating back to the late 2nd millennium BC, describe ancient Hindu cosmology, in which the universe goes through repeated cycles of creation, destruction and rebirth, with each cycle lasting 4,320 million years.<sup>[59]</sup> Ancient Greek philosophers, including Parmenides and Heraclitus, wrote essays on the nature of time.<sup>[60]</sup> Plato, in the

*Timaeus*, identified time with the period of motion of the heavenly bodies. Aristotle, in Book IV of his *Physica* defined time as 'number of movement in respect of the before and after'.<sup>[61]</sup>

In Book 11 of his *Confessions*, St. Augustine of Hippo ruminates on the nature of time, asking, "What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not." He begins to define time by what it is not rather than what it is,<sup>[62]</sup> an approach similar to that taken in other negative definitions. However, Augustine ends up calling time a "distention" of the mind (Confessions 11.26) by which we simultaneously grasp the past in memory, the present by attention, and the future by expectation.

In contrast to ancient Greek philosophers who believed that the universe had an infinite past with no beginning, medieval philosophers and theologians developed the concept of the universe having a finite past with a beginning. This view is shared by Abrahamic faiths as they believe time started by creation, therefore the only thing being infinite is God and everything else, including time, is finite.

Isaac Newton believed in absolute space and absolute time; Leibniz believed that time and space are relational.<sup>[63]</sup> The differences between Leibniz's and Newton's interpretations came to a head in the famous Leibniz–Clarke correspondence.

Immanuel Kant, in the *Critique of Pure Reason*, described time as an *a priori* intuition that allows us (together with the other *a priori* intuition, space) to comprehend sense experience.<sup>[64]</sup>

With Kant, neither space nor time are conceived as substances, but rather both are elements of a systematic mental framework that necessarily structures the experiences of any rational agent, or observing subject. Kant thought of time as a fundamental part of an abstract conceptual framework, together with space and number, within which we sequence events, quantify their duration, and compare the motions of objects. In this view, *time* does not refer to any kind of entity that "flows," that objects "move through," or that is a "container" for events. Spatial measurements are used to quantify the extent of and distances between objects, and temporal

“ Time is not an empirical concept. For neither co-existence nor succession would be perceived by us, if the representation of time did not exist as a foundation *a priori*. Without this presupposition we could not represent to ourselves that things exist together at one and the same time, or at different times, that is, contemporaneously, or in succession. ”

Immanuel Kant, *Critique of Pure Reason* (1781), trans. Vasilis

measurements are used to quantify the durations of and between events. Time was designated by Kant as the purest possible schema of a pure concept or category.

Politis (London: Dent., 1991), p.54.

Henri Bergson believed that time was neither a real homogeneous medium nor a mental construct, but possesses what he referred to as *Duration*. Duration, in Bergson's view, was creativity and memory as an essential component of reality.<sup>[65]</sup>

According to Martin Heidegger we do not exist inside time, we *are* time. Hence, the relationship to the past is a present awareness of *having been*, which allows the past to exist in the present. The relationship to the future is the state of anticipating a potential possibility, task, or engagement. It is related to the human propensity for caring and being concerned, which causes "being ahead of oneself" when thinking of a pending occurrence. Therefore, this concern for a potential occurrence also allows the future to exist in the present. The present becomes an experience, which is qualitative instead of quantitative. Heidegger seems to think this is the way that a linear relationship with time, or temporal existence, is broken or transcended.<sup>[66]</sup> We are not stuck in sequential time. We are able to remember the past and project into the future—we have a kind of random access to our representation of temporal existence; we can, in our thoughts, step out of (ecstasis) sequential time.<sup>[67]</sup>

## Time as "unreal"

In 5th century BC Greece, Antiphon the Sophist, in a fragment preserved from his chief work *On Truth*, held that: "*Time is not a reality (hypostasis), but a concept (noêma) or a measure (metron)*." Parmenides went further, maintaining that time, motion, and change were illusions, leading to the paradoxes of his follower Zeno.<sup>[68]</sup> Time as an illusion is also a common theme in Buddhist thought.<sup>[69][70]</sup>

J. M. E. McTaggart's 1908 *The Unreality of Time* argues that, since every event has the characteristic of being both present and not present (i.e., future or past), that time is a self-contradictory idea (see also The flow of time).

These arguments often center on what it means for something to be *unreal*. Modern physicists generally believe that time is as *real* as space—though others, such as Julian Barbour in his book *The End of Time*, argue that quantum equations of the universe take their true form when expressed in the timeless realm containing every possible *now* or momentary configuration of the universe, called 'platonias' by Barbour.<sup>[71]</sup>



A modern philosophical theory called presentism views the past and the future as human-mind interpretations of movement instead of real parts of time (or "dimensions") which coexist with the present. This theory rejects the existence of all direct interaction with the past or the future, holding only the present as tangible. This is one of the philosophical arguments against time travel. This contrasts with eternalism (all time: present, past and future, is real) and the growing block theory (the present and the past are real, but the future is not).

## Physical definition

Until Einstein's reinterpretation of the physical concepts associated with time and space, time was considered to be the same everywhere in the universe, with all observers measuring the same time interval for any event.<sup>[72]</sup> Non-relativistic classical mechanics is based on this Newtonian idea of time.

Einstein, in his special theory of relativity,<sup>[73]</sup> postulated the constancy and finiteness of the speed of light for all observers. He showed that this postulate, together with a reasonable definition for what it means for two events to be simultaneous, requires that distances appear compressed and time intervals appear lengthened for events associated with objects in motion relative to an inertial observer.

The theory of special relativity finds a convenient formulation in Minkowski spacetime, a mathematical structure that combines three dimensions of space with a single dimension of time. In this formalism, distances in space can be measured by how long light takes to travel that distance, e.g., a light-year is a measure of distance, and a meter is now defined in terms of how far light travels in a certain amount of time. Two events in Minkowski spacetime are separated by an *invariant interval*, which can be either space-like, light-like, or time-like. Events that have a time-like separation cannot be simultaneous in any frame of reference, there must be a temporal component (and possibly a spatial one) to their separation. Events that have a space-like separation will be simultaneous in some frame of reference, and there is no frame of reference in which they do not have a spatial separation. Different observers may calculate different distances and different time intervals between two events, but the *invariant interval* between the events is independent of the observer (and his velocity).

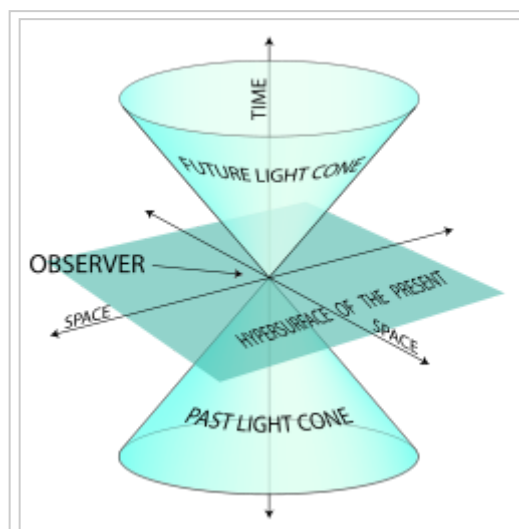
## Classical mechanics

In non-relativistic classical mechanics, Newton's concept of "relative, apparent, and common time" can be used in the formulation of a prescription for the synchronization of clocks. Events seen by two different observers in motion relative to each other produce a mathematical concept of time that works sufficiently well for describing the everyday phenomena of most people's experience. In the late nineteenth century, physicists encountered problems with the classical understanding of time, in connection with the behavior of electricity and magnetism. Einstein resolved these problems by invoking a method of synchronizing clocks using the constant, finite speed of light as the maximum signal velocity. This led directly to the result that observers in motion relative to one another measure different elapsed times for the same event.

## Spacetime

Time has historically been closely related with space, the two together merging into spacetime in Einstein's special relativity and general relativity. According to these theories, the concept of time depends on the spatial reference frame of the observer, and the human perception as well as the measurement by instruments such as clocks are different for observers in relative motion. For example, if a spaceship carrying a clock flies through space at (very nearly) the speed of light, its crew does not notice a change in the speed of time on board their vessel because everything traveling at the same speed slows down at the same rate (including the clock, the crew's thought processes, and the functions of their bodies). However, to a stationary observer watching the spaceship fly by, the spaceship appears flattened in the direction it is traveling and the clock on board the spaceship appears to move very slowly.

On the other hand, the crew on board the spaceship also perceives the observer as slowed down and flattened along the spaceship's direction of travel, because both are moving at very nearly the speed of light relative to each other. Because the outside universe appears flattened to the spaceship, the crew perceives themselves as quickly traveling between regions of space that (to the stationary observer) are many light years apart. This is reconciled by the fact that the crew's

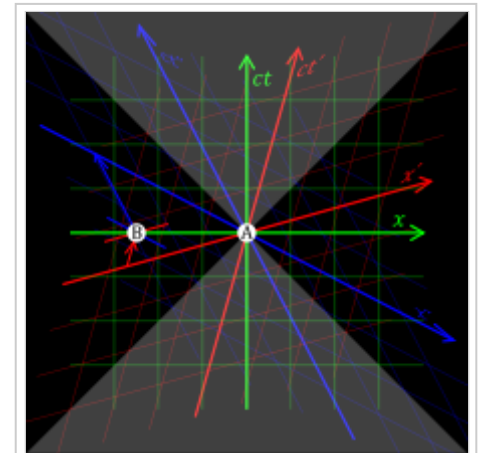


Two-dimensional space depicted in three-dimensional spacetime. The past and future light cones are absolute, the "present" is a relative concept different for observers in relative motion.

perception of time is different from the stationary observer's; what seems like seconds to the crew might be hundreds of years to the stationary observer. In either case, however, causality remains unchanged: the past is the set of events that can send light signals to an entity and the future is the set of events to which an entity can send light signals.<sup>[74][75][76]</sup>

## Time dilation

Einstein showed in his thought experiments that people travelling at different speeds, while agreeing on cause and effect, measure different time separations between events, and can even observe different chronological orderings between non-causally related events. Though these effects are typically minute in the human experience, the effect becomes much more pronounced for objects moving at speeds approaching the speed of light. Many subatomic particles exist for only a fixed fraction of a second in a lab relatively at rest, but some that travel close to the speed of light can be measured to travel farther and survive much longer than expected (a muon is one example). According to the special theory of relativity, in the high-speed particle's frame of reference, it exists, on the average, for a standard amount of time known as its mean lifetime, and the distance it travels in that time is zero, because its velocity is zero. Relative to a frame of reference at rest, time seems to "slow down" for the particle. Relative to the high-speed particle, distances seem to shorten. Einstein showed how both temporal and spatial dimensions can be altered (or "warped") by high-speed motion.



Relativity of simultaneity: Event B is simultaneous with A in the green reference frame, but it occurred before in the blue frame, and occurs later in the red frame.

Einstein (*The Meaning of Relativity*): "Two events taking place at the points A and B of a system K are simultaneous if they appear at the same instant when observed from the middle point, M, of the interval AB. Time is then defined as the ensemble of the indications of similar clocks, at rest relative to K, which register the same simultaneously."

Einstein wrote in his book, *Relativity*, that simultaneity is also relative, i.e., two events that appear simultaneous to an observer in a particular inertial reference frame need not be judged as simultaneous by a second observer in a different

inertial frame of reference.

## Relativistic time versus Newtonian time

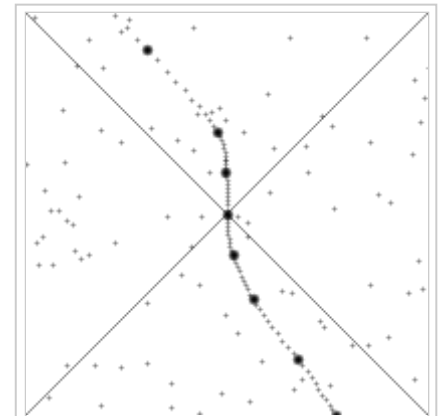
The animations visualise the different treatments of time in the Newtonian and the relativistic descriptions. At the heart of these differences are the Galilean and Lorentz transformations applicable in the Newtonian and relativistic theories, respectively.

In the figures, the vertical direction indicates time. The horizontal direction indicates distance (only one spatial dimension is taken into account), and the thick dashed curve is the spacetime trajectory ("world line") of the observer. The small dots indicate specific (past and future) events in spacetime.

The slope of the world line (deviation from being vertical) gives the relative velocity to the observer. Note how in both pictures the view of spacetime changes when the observer accelerates.

In the Newtonian description these changes are such that *time* is absolute:<sup>[77]</sup> the movements of the observer do not influence whether an event occurs in the 'now' (i.e., whether an event passes the horizontal line through the observer).

However, in the relativistic description the *observability of events* is absolute: the movements of the observer do not influence whether an event passes the "light cone" of the observer. Notice that with the change from a Newtonian to a relativistic description, the concept of *absolute time* is no longer applicable: events move up-and-down in the figure depending on the acceleration of the observer.



Views of spacetime along the world line of a rapidly accelerating observer in a relativistic universe. The events ("dots") that pass the two diagonal lines in the bottom half of the image (the past light cone of the observer in the origin) are the events visible to the observer.

## Arrow of time

Time appears to have a direction—the past lies behind, fixed and immutable, while the future lies ahead and is not necessarily fixed. Yet for the most part the laws of physics do not specify an arrow of time, and allow any process to proceed both forward and in reverse. This is generally a consequence of time being modelled by

a parameter in the system being analysed, where there is no "proper time": the direction of the arrow of time is sometimes arbitrary. Examples of this include the cosmological arrow of time, which points away from the Big Bang, CPT symmetry, and the radiative arrow of time, caused by light only travelling forwards in time (see light cone). In particle physics, the violation of CP symmetry implies that there should be a small counterbalancing time asymmetry to preserve CPT symmetry as stated above. The standard description of measurement in quantum mechanics is also time asymmetric (see Measurement in quantum mechanics). The second law of thermodynamics states that entropy must increase over time (see Entropy). This can be in either direction - Brian Greene theorizes that, according to the equations, the change in entropy occurs symmetrically whether going forward or backward in time. So entropy tends to increase in either direction, and our current low-entropy universe is a statistical aberration, in the similar manner as tossing a coin often enough that eventually heads will result ten times in a row. However, this theory is not supported empirically in local experiment.<sup>[78]</sup>

## Quantized time

Time quantization is a hypothetical concept. In the modern established physical theories (the Standard Model of Particles and Interactions and General Relativity) time is not quantized.

Planck time ( $\sim 5.4 \times 10^{-44}$  seconds) is the unit of time in the system of natural units known as Planck units. Current established physical theories are believed to fail at this time scale, and many physicists expect that the Planck time might be the smallest unit of time that could ever be measured, even in principle. Tentative physical theories that describe this time scale exist; see for instance loop quantum gravity.

## Time travel

Time travel is the concept of moving backwards or forwards to different points in time, in a manner analogous to moving through space, and different from the normal "flow" of time to an earthbound observer. In this view, all points in time (including future times) "persist" in some way. Time travel has been a plot device in fiction since the 19th century. Travelling backwards in time has never been verified, presents many theoretical problems, and may be an impossibility.<sup>[79]</sup> Any technological device, whether fictional or hypothetical, that is used to achieve time travel is known as a time machine.

A central problem with time travel to the past is the violation of causality; should an effect precede its cause, it would give rise to the possibility of a temporal paradox. Some interpretations of time travel resolve this by accepting the possibility of travel between branch points, parallel realities, or universes.

Another solution to the problem of causality-based temporal paradoxes is that such paradoxes cannot arise simply because they have not arisen. As illustrated in numerous works of fiction, free will either ceases to exist in the past or the outcomes of such decisions are predetermined. As such, it would not be possible to enact the grandfather paradox because it is a historical fact that your grandfather was not killed before his child (your parent) was conceived. This view doesn't simply hold that history is an unchangeable constant, but that any change made by a hypothetical future time traveller would already have happened in his or her past, resulting in the reality that the traveller moves from. More elaboration on this view can be found in the Novikov self-consistency principle.

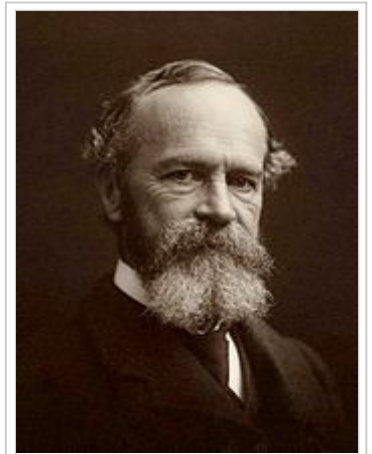
## Time perception

The specious present refers to the time duration wherein one's perceptions are considered to be in the present. The experienced present is said to be 'specious' in that, unlike the objective present, it is an interval and not a durationless instant. The term *specious present* was first introduced by the psychologist E.R. Clay, and later developed by William James.<sup>[80]</sup>

## Biopsychology

The brain's judgment of time is known to be a highly distributed system, including at least the cerebral cortex, cerebellum and basal ganglia as its components. One particular component, the suprachiasmatic nuclei, is responsible for the circadian (or daily) rhythm, while other cell clusters appear capable of shorter-range (ultradian) timekeeping.

Psychoactive drugs can impair the judgment of time. Stimulants can lead both humans and rats to overestimate time intervals,<sup>[81][82]</sup> while depressants can have the opposite effect.<sup>[83]</sup> The level of activity in the brain of neurotransmitters such as dopamine and norepinephrine may be the reason for this.<sup>[84]</sup> Such chemicals will



Philosopher and psychologist William James

either excite or inhibit the firing of neurons in the brain, with a greater firing rate allowing the brain to register the occurrence of more events within a given interval (speed up time) and a decreased firing rate reducing the brain's capacity to distinguish events occurring within a given interval (slow down time).<sup>[85]</sup>

Mental chronometry is the use of response time in perceptual-motor tasks to infer the content, duration, and temporal sequencing of cognitive operations.

## **Development of awareness and understanding of time in children**

Children's expanding cognitive abilities allow them to understand time more clearly. Two- and three-year-olds' understanding of time is mainly limited to "now and not now." Five- and six-year-olds can grasp the ideas of past, present, and future. Seven- to ten-year-olds can use clocks and calendars.<sup>[86]</sup>

## **Alterations**

In addition to psychoactive drugs, judgments of time can be altered by temporal illusions (like the kappa effect),<sup>[87]</sup> age,<sup>[88]</sup> and hypnosis.<sup>[89]</sup> The sense of time is impaired in some people with neurological diseases such as Parkinson's disease and attention deficit disorder.

Psychologists assert that time seems to go faster with age, but the literature on this age-related perception of time remains controversial.<sup>[90]</sup> Those who support this notion argue that young people, having more excitatory neurotransmitters, are able to cope with faster external events.<sup>[85]</sup>

## **Use of time**

In sociology and anthropology, time discipline is the general name given to social and economic rules, conventions, customs, and expectations governing the measurement of time, the social currency and awareness of time measurements, and people's expectations concerning the observance of these customs by others. Arlie Russell Hochschild<sup>[91][92]</sup> and Norbert Elias<sup>[93]</sup> have written on the use of time from a sociological perspective.

The use of time is an important issue in understanding human behavior, education, and travel behavior. Time-use research is a developing field of study. The question concerns how time is allocated across a number of activities (such as time spent

at home, at work, shopping, etc.). Time use changes with technology, as the television or the Internet created new opportunities to use time in different ways. However, some aspects of time use are relatively stable over long periods of time, such as the amount of time spent traveling to work, which despite major changes in transport, has been observed to be about 20–30 minutes one-way for a large number of cities over a long period.

Time management is the organization of tasks or events by first estimating how much time a task requires and when it must be completed, and adjusting events that would interfere with its completion so it is done in the appropriate amount of time. Calendars and day planners are common examples of time management tools.

A sequence of events, or series of events, is a sequence of items, facts, events, actions, changes, or procedural steps, arranged in time order (chronological order), often with causality relationships among the items.<sup>[94][95][96]</sup> Because of causality, cause precedes effect, or cause and effect may appear together in a single item, but effect never precedes cause. A sequence of events can be presented in text, tables, charts, or timelines. The description of the items or events may include a timestamp. A sequence of events that includes the time along with place or location information to describe a sequential path may be referred to as a world line.

Uses of a sequence of events include stories,<sup>[97]</sup> historical events (chronology), directions and steps in procedures,<sup>[98]</sup> and timetables for scheduling activities. A sequence of events may also be used to help describe processes in science, technology, and medicine. A sequence of events may be focused on past events (e.g., stories, history, chronology), on future events that must be in a predetermined order (e.g., plans, schedules, procedures, timetables), or focused on the observation of past events with the expectation that the events will occur in the future (e.g., processes, projections). The use of a sequence of events occurs in fields as diverse as machines (cam timer), documentaries (*Seconds From Disaster*), law (choice of law), computer simulation (discrete event simulation), and electric power transmission<sup>[99]</sup> (sequence of events recorder). A specific example of a sequence of events is the timeline of the Fukushima Daiichi nuclear disaster.

## **Spatial conceptualization of time**



Although time is regarded as an abstract concept, there is increasing evidence that time is conceptualized in the mind in terms of space.<sup>[100]</sup> That is, instead of thinking about time in a general, abstract way, humans think about time in a spatial way and mentally organize it as such. Using space to think about time allows humans to mentally organize temporal events in a specific way.

This spatial representation of time is often represented in the mind as a Mental Time Line (MTL).<sup>[101]</sup> Using space to think about time allows humans to mentally organize temporal order. These origins are shaped by many environmental factors<sup>[100]</sup>—for example, literacy appears to play a large role in the different types of MTLs, as reading/writing direction provides an everyday temporal orientation that differs from culture to culture.<sup>[101]</sup> In western cultures, the MTL may unfold rightward (with the past on the left and the future on the right) since people read and write from left to right.<sup>[101]</sup> Western calendars also continue this trend by placing the past on the left with the future progressing toward the right. Conversely, Israeli-Hebrew speakers read from right to left, and their MTLs unfold leftward (past on the right with future on the left), and evidence suggests these speakers organize time events in their minds like this as well.<sup>[101]</sup>

This linguistic evidence that abstract concepts are based in spatial concepts also reveals that the way humans mentally organize time events varies across cultures—that is, a certain specific mental organization system is not universal. So, although Western cultures typically associate past events with the left and future events with the right according to a certain MTL, this kind of horizontal, egocentric MTL is not the spatial organization of all cultures. Although most developed nations use an egocentric spatial system, there is recent evidence that some cultures use an allocentric spatialization, often based on environmental features.<sup>[100]</sup>

A recent study of the indigenous Yupno people of Papua New Guinea focused on the directional gestures used when individuals used time-related words.<sup>[100]</sup> When speaking of the past (such as "last year" or "past times"), individuals gestured downhill, where the river of the valley flowed into the ocean. When speaking of the future, they gestured uphill, toward the source of the river. This was common regardless of which direction the person faced, revealing that the Yupno people may use an allocentric MTL, in which time flows uphill.<sup>[100]</sup>

A similar study of the Pormpuraawans, an aboriginal group in Australia, revealed a similar distinction in which when asked to organize photos of a man aging "in order," individuals consistently placed the youngest photos to the east and the oldest photos to the west, regardless of which direction they faced.<sup>[102]</sup> This directly clashed with an American group which consistently organized the photos from left to right. Therefore, this group also appears to have an allocentric MTL, but based on the cardinal directions instead of geographical features.<sup>[102]</sup>

The wide array of distinctions in the way different groups think about time leads to the broader question that different groups may also think about other abstract concepts in different ways as well, such as causality and number.<sup>[100]</sup>

## See also

- Era
- Horology
- International System of Quantities
- Kairos
- List of UTC timing centers
- UTC
- Term (time)

## Books

- *A Brief History of Time* by Stephen Hawking
- *About Time: Einstein's Unfinished Revolution* by Paul Davies
- *From Eternity to Here: The Quest for the Ultimate Theory of Time* by Sean M. Carroll
- *The Discovery of Time* by Stephen Toulmin and June Goodfield
- *A Natural History of Time* by Pascal Richet
- *The Physical Basis of The Direction of Time* by Heinz-Dieter Zeh
- *An Experiment with Time* by John William Dunne
- *Einstein's Dreams* by Alan Lightman
- *Being and Time* by Martin Heidegger
- *Time Reborn* by Lee Smolin



Time's mortal aspect is personified in this bronze statue by Charles van der Stappen

## Organizations

*Leading scholarly organisations for researchers on the history and technology of time and timekeeping*

- Antiquarian Horological Society—AHS (United Kingdom)
- Chronometrophilia (Switzerland)
- Deutsche Gesellschaft für Chronometrie—DGC (Germany)
- National Association of Watch and Clock Collectors—NAWCC (United States)

## **Miscellaneous arts and sciences**

- Anachronism
- Date and time representation by country
- List of cycles
- Network Time Protocol (NTP)
- Nonlinear narrative
- Philosophy of physics
- Rate (mathematics)

## **Miscellaneous units of time**

- Fiscal year
- Half-life
- Hexadecimal time
- Season
- Tithi
- Unit of time
- Unix epoch

## **References**

1. "Oxford Dictionaries:Time" (<http://oxforddictionaries.com/definition/time>). Oxford University Press. 2011. Retrieved 18 May 2017. "The indefinite continued progress of existence and events in the past, present, and future regarded as a whole"

2.
  - "Webster's New World College Dictionary" (<http://www.yourdictionary.com/time>). 2010. Retrieved 9 April 2011. "1.indefinite, unlimited duration in which things are considered as happening in the past, present, or future; every moment there has ever been or ever will be... a system of measuring duration 2.the period between two events or during which something exists, happens, or acts; measured or measurable interval"
  - "The American Heritage Stedman's Medical Dictionary" (<http://dictionary.reference.com/browse/time?r=66>). 2002. Retrieved 9 April 2011. "A duration or relation of events expressed in terms of past, present, and future, and measured in units such as minutes, hours, days, months, or years."
  - "Collins Language.com" (<https://web.archive.org/web/20111002190630/http://www.collinslanguage.com/results.aspx?context=3&reversed=False&action=define&homonym=-1&text=time>). HarperCollins. 2011. Archived from the original (<http://www.collinslanguage.com/results.aspx?context=3&reversed=False&action=define&homonym=-1&text=time>) on 2 October 2011. Retrieved 18 December 2011. "1. The continuous passage of existence in which events pass from a state of potentiality in the future, through the present, to a state of finality in the past. 2. *physics* a quantity measuring duration, usually with reference to a periodic process such as the rotation of the earth or the frequency of electromagnetic radiation emitted from certain atoms. In classical mechanics, time is absolute in the sense that the time of an event is independent of the observer. According to the theory of relativity it depends on the observer's frame of reference. Time is considered as a fourth coordinate required, along with three spatial coordinates, to specify an event."
  - "The American Heritage Science Dictionary @dictionary.com" (<http://dictionary.reference.com/browse/time?r=66>). 2002. Retrieved 9 April 2011. "1. A continuous, measurable quantity in which events occur in a sequence proceeding from the past through the present to the future. 2a. An interval separating two points of this quantity; a duration. 2b. A system or reference frame in which such intervals are measured or such quantities are calculated."
  - "Eric Weisstein's World of Science" (<http://scienceworld.wolfram.com/physics/Time.html>). 2007. Retrieved 9 April 2011. "A quantity used to specify the order in which events occurred and measure the amount by which one event preceded or followed another. In special relativity,  $ct$  (where  $c$  is the speed of light and  $t$  is time), plays the role of a fourth dimension."
3. "Time" (<http://ahdictionary.com/word/search.html?q=time>). *The American Heritage Dictionary of the English Language* (Fourth ed.). Houghton Mifflin Company. 2011. "A nonspatial continuum in which events occur in apparently irreversible succession from the past through the present to the future."
4. Merriam-Webster Dictionary (<http://www.merriam-webster.com/dictionary/time>) the measured or measurable period during which an action, process, or condition exists or continues : duration; a nonspatial continuum which is measured in terms of events that succeed one another from past through present to future

5. Compact Oxford English Dictionary A limited stretch or space of continued existence, as the interval between two successive events or acts, or the period through which an action, condition, or state continues. (1971).
6.
  - "Internet Encyclopedia of Philosophy" (<http://www.iep.utm.edu/time/>). 2010. Retrieved 9 April 2011. "Time is what clocks measure. We use time to place events in sequence one after the other, and we use time to compare how long events last... Among philosophers of physics, the most popular short answer to the question "What is physical time?" is that it is not a substance or object but rather a special system of relations among instantaneous events. This working definition is offered by Adolf Grünbaum who applies the contemporary mathematical theory of continuity to physical processes, and he says time is a linear continuum of instants and is a distinguished one-dimensional sub-space of four-dimensional spacetime."
  - "Dictionary.com Unabridged, based on Random House Dictionary" (<http://dictionary.reference.com/browse/time?r=66>). 2010. Retrieved 9 April 2011. "1. the system of those sequential relations that any event has to any other, as past, present, or future; indefinite and continuous duration regarded as that in which events succeed one another.... 3. (sometimes initial capital letter) a system or method of measuring or reckoning the passage of time: mean time; apparent time; Greenwich Time. 4. a limited period or interval, as between two successive events: a long time.... 14. a particular or definite point in time, as indicated by a clock: What time is it? ... 18. an indefinite, frequently prolonged period or duration in the future: Time will tell if what we have done here today was right."
  - Ivey, Donald G.; Hume, J.N.P. (1974). *Physics* (<https://books.google.com/?id=HrHvAAAAMAAJ&q=%22time+is+what+clocks+measure%22&dq=%22time+is+what+clocks+measure%22>). 1. Ronald Press. p. 65. "Our operational definition of time is that time is what clocks measure."
7. Le Poidevin, Robin (Winter 2004). "The Experience and Perception of Time" (<http://plato.stanford.edu/archives/win2004/entries/time-experience>). In Edward N. Zalta. *The Stanford Encyclopedia of Philosophy*. Retrieved 9 April 2011.
8. "Newton did for time what the Greek geometers did for space, idealized it into an exactly measurable dimension." *About Time: Einstein's Unfinished Revolution*, Paul Davies, p. 31, Simon & Schuster, 1996, ISBN 978-0684818221
9. Sean M Carroll (2009). *From Eternity to Here: The Quest for the Ultimate Theory of Time* (<https://books.google.com/?id=Uak1wtcXrjwC>). Dutton. ISBN 978-0-525-95133-9.
10. Adam Frank, *Cosmology and Culture at the Twilight of the Big Bang*, "the time we imagine for the cosmos and the time we imagined into the human experience turn out to be woven so tightly together that we have lost the ability to see each of them for what it is." p. xv, Free Press, 2011, ISBN 978-1439169599
11. St. Augustine, *Confessions*, Simon & Brown, 2012, ISBN 978-1613823262

12. Official Baseball Rules, 2011 Edition (2011). "Rules 8.03 and 8.04" ([http://mlb.mlb.com/mlb/downloads/y2011/Official\\_Baseball\\_Rules.pdf](http://mlb.mlb.com/mlb/downloads/y2011/Official_Baseball_Rules.pdf)) (Free PDF download). Major League Baseball. Retrieved 18 May 2017. "Rule 8.03 Such preparatory pitches shall not consume more than one minute of time...Rule 8.04 When the bases are unoccupied, the pitcher shall deliver the ball to the batter within 12 seconds...The 12-second timing starts when the pitcher is in possession of the ball and the batter is in the box, alert to the pitcher. The timing stops when the pitcher releases the ball."
13. "Guinness Book of Baseball World Records" ([http://www.baseball-almanac.com/recbooks/rb\\_guin.shtml](http://www.baseball-almanac.com/recbooks/rb_guin.shtml)). Guinness World Records, Ltd. Retrieved 7 July 2012. "The record for the fastest time for circling the bases is 13.3 seconds, set by Evar Swanson at Columbus, Ohio in 1932...The greatest reliably recorded speed at which a baseball has been pitched is 100.9 mph by Lynn Nolan Ryan (California Angels) at Anaheim Stadium in California on 20 August 1974."
14. Zeigler, Kenneth (2008). *Getting organized at work : 24 lessons to set goals, establish priorities, and manage your time* (<https://books.google.com/?id=acPPD6lCCxcC&printsec=frontcover&dq=Getting+organized+at+work+:+24+lessons+to+set+goals,+establish+priorities,+and+manage+your+time#v=onepage&q=Getting%20organized%20at%20work%20%3A%2024%20lessons%20to%20set%20goals%2C%20establish%20priorities%2C%20and%20manage%20your%20time&f=false>). McGraw-Hill. ISBN 9780071591386. 108 pages.
15. Rynasiewicz, Robert : Johns Hopkins University (12 August 2004). "Newton's Views on Space, Time, and Motion" (<http://plato.stanford.edu/entries/newton-stm/>). *Stanford Encyclopedia of Philosophy*. Stanford University. Retrieved 5 February 2012. "Newton did not regard space and time as genuine substances (as are, paradigmatically, bodies and minds), but rather as real entities with their own manner of existence as necessitated by God's existence ... To paraphrase: Absolute, true, and mathematical time, from its own nature, passes equably without relation to anything external, and thus without reference to any change or way of measuring of time (e.g., the hour, day, month, or year)."
16. Markosian, Ned. "Time" (<http://plato.stanford.edu/entries/time/#3>). In Edward N. Zalta. *The Stanford Encyclopedia of Philosophy (Winter 2002 Edition)*. Retrieved 23 September 2011. "The opposing view, normally referred to either as "Platonism with Respect to Time" or as "Absolutism with Respect to Time", has been defended by Plato, Newton, and others. On this view, time is like an empty container into which events may be placed; but it is a container that exists independently of whether or not anything is placed in it."

17. Burnham, Douglas : Staffordshire University (2006). "Gottfried Wilhelm Leibniz (1646–1716) Metaphysics – 7. Space, Time, and Indiscernibles" (<http://www.iep.utm.edu/leib-met/#H7>). *The Internet Encyclopedia of Philosophy*. Retrieved 9 April 2011. "First of all, Leibniz finds the idea that space and time might be substances or substance-like absurd (see, for example, "Correspondence with Clarke," Leibniz's Fourth Paper, §8ff). In short, an empty space would be a substance with no properties; it will be a substance that even God cannot modify or destroy.... That is, space and time are internal or intrinsic features of the complete concepts of things, not extrinsic.... Leibniz's view has two major implications. First, there is no absolute location in either space or time; location is always the situation of an object or event relative to other objects and events. Second, space and time are not in themselves real (that is, not substances). Space and time are, rather, ideal. Space and time are just metaphysically illegitimate ways of perceiving certain virtual relations between substances. They are phenomena or, strictly speaking, illusions (although they are illusions that are well-founded upon the internal properties of substances).... It is sometimes convenient to think of space and time as something "out there," over and above the entities and their relations to each other, but this convenience must not be confused with reality. Space is nothing but the order of co-existent objects; time nothing but the order of successive events. This is usually called a relational theory of space and time."
18. Matthey, G. J. : UC Davis (22 January 1997). "Critique of Pure Reason, Lecture notes: Philosophy 175 UC Davis" (<https://web.archive.org/web/20050314201600/http://www-philosophy.ucdavis.edu/matthey/kant/TIMELEC.HTM>). Archived from the original (<http://www-philosophy.ucdavis.edu/matthey/kant/TIMELEC.HTM>) on 14 March 2005. Retrieved 9 April 2011. "What is correct in the Leibnizian view was its anti-metaphysical stance. Space and time do not exist in and of themselves, but in some sense are the product of the way we represent things. The[y] are ideal, though not in the sense in which Leibniz thought they are ideal (figments of the imagination). The ideality of space is its mind-dependence: it is only a condition of sensibility.... Kant concluded ... "absolute space is not an object of outer sensation; it is rather a fundamental concept which first of all makes possible all such outer sensation."...Much of the argumentation pertaining to space is applicable, *mutatis mutandis*, to time, so I will not rehearse the arguments. As space is the form of outer intuition, so time is the form of inner intuition.... Kant claimed that time is real, it is "the real form of inner intuition.""

19. McCormick, Matt : California State University, Sacramento (2006). "Immanuel Kant (1724–1804) Metaphysics: 4. Kant's Transcendental Idealism" (<http://www.iep.utm.edu/kantmeta/#H4>). *The Internet Encyclopedia of Philosophy*. Retrieved 9 April 2011.  
"Time, Kant argues, is also necessary as a form or condition of our intuitions of objects. The idea of time itself cannot be gathered from experience because succession and simultaneity of objects, the phenomena that would indicate the passage of time, would be impossible to represent if we did not already possess the capacity to represent objects in time.... Another way to put the point is to say that the fact that the mind of the knower makes the *a priori* contribution does not mean that space and time or the categories are mere figments of the imagination. Kant is an empirical realist about the world we experience; we can know objects as they appear to us. He gives a robust defense of science and the study of the natural world from his argument about the mind's role in making nature. All discursive, rational beings must conceive of the physical world as spatially and temporally unified, he argues."
20. Considine, Douglas M.; Considine, Glenn D. (1985). *Process instruments and controls handbook* (<https://books.google.com/books?id=kt1UAAAAMAAJ>) (3 ed.). McGraw-Hill. pp. 18–61. ISBN 0-07-012436-1.
21. Duff, Okun, Veneziano, *ibid.* p. 3. "There is no well established terminology for the fundamental constants of Nature. ... The absence of accurately defined terms or the uses (i.e., actually misuses) of ill-defined terms lead to confusion and proliferation of wrong statements."
22. Carrol, Sean, Chapter One, Section Two, Plume, 2010. *From Eternity to Here*. ISBN 978-0452296541. "As human beings we 'feel' the passage of time."
23. Lehar, Steve. (2000). The Function of Conscious Experience: An Analogical Paradigm of Perception and Behavior (<http://cns-alumni.bu.edu/~slehar/webstuff/consc1/consc1.html>), *Consciousness and Cognition*.
24. Richards, E. G. (1998). *Mapping Time: The Calendar and its History*. Oxford University Press. pp. 3–5.
25. Rudgley, Richard (1999). *The Lost Civilizations of the Stone Age*. New York: Simon & Schuster. pp. 86–105.
26. Van Stone, Mark. "The Maya Long Count Calendar: An Introduction." *Archaeoastronomy* 24.(2011): 8-11. Academic Search Complete. Web. 20 Feb. 2016.
27. "French Republican Calendar | Chronology." *Encyclopædia Britannica Online*. Encyclopædia Britannica, n.d. Web. 21 Feb. 2016.
28. Barnett, Jo Ellen *Time's Pendulum: The Quest to Capture Time—from Sundials to Atomic Clocks* Plenum, 1998 ISBN 0-306-45787-3 p.28
29. Lombardi, Michael A. "Why Is a Minute Divided into 60 Seconds, an Hour into 60 Minutes, Yet There Are Only 24 Hours in a Day?" *Scientific American*. Springer Nature, 5 Mar. 2007. Web. 21 Feb. 2016.
30. Barnett, *ibid*, p.37
31. Laurence Bergreen, *Over the Edge of the World: Magellan's Terrifying Circumnavigation of the Globe*, HarperCollins Publishers, 2003, hardcover 480 pages, ISBN 0-06-621173-5
32. North, J. (2004) *God's Clockmaker: Richard of Wallingford and the Invention of Time*. Oxbow Books. ISBN 1-85285-451-0



33. Watson, E (1979) "The St Albans Clock of Richard of Wallingford". *Antiquarian Horology* 372–384.
34. "History of Clocks." About.com Inventors. About.com, n.d. Web. 21 Feb. 2016.
35. "NIST Unveils Chip-Scale Atomic Clock" ([https://www.nist.gov/public\\_affairs/releases/miniclock.cfm](https://www.nist.gov/public_affairs/releases/miniclock.cfm)). 27 August 2004. Retrieved 9 June 2011.
36. "New atomic clock can keep time for 200 million years: Super-precise instruments vital to deep space navigation" (<https://web.archive.org/web/20120211190407/http://www.canada.com/vancouversun/news/story.html?id=e24ccfa7-44eb-40b7-8b67-daf8263569ff>). *Vancouver Sun*. 16 February 2008. Archived from the original (<http://www.canada.com/vancouversun/news/story.html?id=e24ccfa7-44eb-40b7-8b67-daf8263569ff>) on 11 February 2012. Retrieved 9 April 2011.
37. "NIST-F1 Cesium Fountain Clock" ([https://www.nist.gov/public\\_affairs/releases/n99-22.cf](https://www.nist.gov/public_affairs/releases/n99-22.cf)). Retrieved 24 July 2015.
38. "Byrhtferth of Ramsey" (<http://search.eb.com/eb/article-9438957>). *Encyclopædia Britannica*. 2008. Retrieved 15 September 2008.
39. "atom", Oxford English Dictionary, Draft Revision September 2008 (contains relevant citations from Byrhtferth's *Enchiridion*)
40. "12 attoseconds is the world record for shortest controllable time" (<http://www.physorg.com/news192909576.html>). 12 May 2010. Retrieved 19 April 2012.
41. *Whitaker's Almanac 2013* (ed. Ruth Northey), London 2012, p 1131, ISBN 978-1-4081-7207-0.
42. Organisation Intergouvernementale de la Convention du Mètre (1998). *The International System of Units (SI), 7th Edition* (<https://web.archive.org/web/20040427205458/http://www1.bipm.org/utis/en/pdf/si-brochure.pdf>) (PDF). Archived from the original (<http://www1.bipm.org/utis/en/pdf/si-brochure.pdf>) (PDF) on 27 April 2004. Retrieved 9 April 2011.
43. "Base unit definitions: Second" (<http://physics.nist.gov/cuu/Units/second.html>). NIST. Retrieved 9 April 2011.
44. Howse 1997, pp. 133-137.
45. "Leap Seconds" (<http://www.webcitation.org/666iH0vl1?url=http://tycho.usno.navy.mil/leapsec.html>). Time Service Department, United States Naval Observatory. Archived from the original (<http://tycho.usno.navy.mil/leapsec.html>) on 12 March 2012. Retrieved 22 November 2015.
46. W Markowitz, RG Hall, L Essen, JVL Parry; Hall; Essen; Parry (1958). "Frequency of cesium in terms of ephemeris time" (<http://www.leapsecond.com/history/1958-PhysRev-v1-n3-Markowitz-Hall-Essen-Parry.pdf>) (PDF). *Physical Review Letters*. **1** (3): 105–107. Bibcode:1958PhRvL...1..105M (<http://adsabs.harvard.edu/abs/1958PhRvL...1..105M>). doi:10.1103/PhysRevLett.1.105 (<https://doi.org/10.1103/PhysRevLett.1.105>).
47. Cesium Atoms at Work (<http://tycho.usno.navy.mil/cesium.html>) Archived (<https://web.archive.org/web/20150223231150/http://tycho.usno.navy.mil/cesium.html>) 23 February 2015 at the Wayback Machine. USNO, downloaded 28 June 2016.
48. IEC 60050-113:2011, item 113-01-08
49. IEC 60050-113:2011, item 113-01-010; ISO 80000-3:2006, item 3-7

50. IEC 60050-113:2011, item 113-01-012: "mark attributed to an instant by means of a specified time scale"
51. IEC 60050-113:2011, item 113-01-013: "range of a time interval (113-01-10)"
52. ISO 80000-3:2006, item 3-7
53. Rust, Eric Charles (1981). *Religion, Revelation and Reason* (<https://books.google.com/books?id=AcSw6GDILVwC>). Mercer University Press. p. 60. ISBN 9780865540583. Retrieved 2015-08-20. "Profane time, as Eliade points out, is linear. As man dwelt increasingly in the profane and a sense of history developed, the desire to escape into the sacred began to drop in the background. The myths, tied up with cyclic time, were not so easily operative. [...] So secular man became content with his linear time. He could not return to cyclic time and re-enter sacred space through its myths. [...] Just here, as Eliade sees it, a new religious structure became available. In the Judaeo-Christian religions - Judaism, Christianity, Islam - history is taken seriously, and linear time is accepted. The cyclic time of the primordial mythical consciousness has been transformed into the time of profane man, but the mythical consciousness remains. It has been historicized. The Christian mythos and its accompanying ritual are bound up, for example, with history and center in authentic history, especially the Christ-event. Sacred space, the Transcendent Presence, is thus opened up to secular man because it meets him where he is, in the linear flow of secular time. The Christian myth gives such time a beginning in creation, a center in the Christ-event, and an end in the final consummation."
54. Betz, Hans Dieter, ed. (2008). *Religion Past & Present: Encyclopedia of Theology and Religion* (<https://books.google.com/books?id=kjIOAQAAMAAJ>). 4: Dev-Ezr (4 ed.). Brill. p. 101. ISBN 9789004146884. Retrieved 2015-08-20. "[...] God produces a creation with a directional time structure [...]."
55. Lundin, Roger; Thiselton, Anthony C.; Walhout, Clarence (1999). *The Promise of Hermeneutics* (<https://books.google.com/books?id=3Y2F6rSq9VMC>). Wm. B. Eerdmans Publishing. p. 121. ISBN 9780802846358. Retrieved 2015-08-20. "We need to note the close ties between teleology, eschatology, and utopia. In Christian theology, the understanding of the teleology of particular actions is ultimately related to the teleology of history in general, which is the concern of eschatology."
56. Hus, Bo'az; Pasi, Marco; Von Stuckrad, Kocku (2011). *Kabbalah and Modernity: Interpretations, Transformations, Adaptations* (<https://books.google.com/books?id=mlGMsLiol7EC>). BRILL. ISBN 9004182845.
57. Wolfson, Elliot R. (2006). *Alef, Mem, Tau: Kabbalistic Musings on Time, Truth, and Death* (<https://books.google.com/books?hl=en&lr=&id=ozhPY2fcNCcC>). University of California Press. p. 111. ISBN 0-520-93231-5. Extract of page 111 (<https://books.google.com/books?hl=en&lr=&id=ozhPY2fcNCcC&pg=PA111>)
58. Navratil, Gerhard (2009). *Research Trends in Geographic Information Science* (<https://books.google.com/books?id=q8w728aa1CkC>). Springer Japan. p. 217. ISBN 3-540-88243-X. Retrieved 9 April 2011.

59. Layton, Robert (1994). *Who needs the past?: indigenous values and archaeology* (<http://books.google.com/books?id=7TPIDL9RdsoC>) (2nd ed.). Routledge. p. 7. ISBN 0-415-09558-1. Retrieved 9 April 2011., Introduction, p. 7 (<https://books.google.com/books?id=7TPIDL9RdsoC&pg=PA7>)
60. Dagobert Runes, *Dictionary of Philosophy*, p. 318
61. Hardie, R. P.; Gaye, R. K. "Physics by Aristotle" (<http://classics.mit.edu//Aristotle/physics.4.iv.html>). MIT. Retrieved 4 May 2014. "*Time then is a kind of number. (Number, we must note, is used in two senses-both of what is counted or the countable and also of that with which we count. Time obviously is what is counted, not that with which we count: there are different kinds of thing.) [...] It is clear, then, that time is 'number of movement in respect of the before and after', and is continuous since it is an attribute of what is continuous.*"
62. Augustine of Hippo. *Confessions* ([http://en.wikisource.org/wiki/Nicene\\_and\\_Post-Nicene\\_Fathers:\\_Series\\_I/Volume\\_I/Confessions/Book\\_XI/Chapter\\_14](http://en.wikisource.org/wiki/Nicene_and_Post-Nicene_Fathers:_Series_I/Volume_I/Confessions/Book_XI/Chapter_14)). Retrieved 9 April 2011. Book 11, Chapter 14.
63. Gottfried Martin, *Kant's Metaphysics and Theory of Science*
64. Kant, Immanuel (1787). *The Critique of Pure Reason, 2nd edition* (<http://ebooks.adelaide.edu.au/k/kant/immanuel/k16p/>). Retrieved 9 April 2011. translated by J. M. D. Meiklejohn, eBooks@Adelaide, 2004
65. Bergson, Henri (1907) *Creative Evolution*. trans. by Arthur Mitchell. Mineola: Dover, 1998.
66. Balslev, Anindita N.; Jitendranath Mohanty (November 1992). *Religion and Time* (<http://books.google.com/?id=y94cKeEVA3sC&printsec=frontcover&dq=Religion+and+time#v=onepage&q=Heidegger&f=false>). Studies in the History of Religions, 54. The Netherlands: Brill Academic Publishers. pp. 53, 54, 55, 56, 57, 58, and 59. ISBN 978-90-04-09583-0.
67. Martin Heidegger (1962). "V". *Being and Time* (<https://books.google.com/?id=S57m5gWOL-MC&pg=PA425&lpg=PA425&dq=heidegger+sequence#v=onepage&q=heidegger%20sequence&f=false>). p. 425. ISBN 978-0-631-19770-6.
68. Harry Foundalis. "You are about to disappear" (<http://www.foundalis.com/phi/WhyTimeFlows.htm>). Retrieved 9 April 2011.
69. Huston, Tom. "Buddhism and the illusion of time" (<http://www.buddhasvillage.com/teachings/time.htm>). Retrieved 9 April 2011.
70. Garfield, Jay L. (1995). *The fundamental wisdom of the middle way: Nāgārjuna's Mūlamadhyamakakārikā* (<https://books.google.com/?id=kfsyfo01IYC&pg=RA1-PR19&dq=The+fundamental+wisdom+of+the+middle+way+time#v=onepage&q&f=false>). New York: Oxford University Press. ISBN 978-0-19-509336-0.
71. "Time is an illusion?" (<http://physicsandphysicists.blogspot.com/2007/03/time-is-illusion.html>). Retrieved 9 April 2011.
72. Herman M. Schwartz, *Introduction to Special Relativity*, McGraw-Hill Book Company, 1968, hardcover 442 pages, see ISBN 0-88275-478-5 (1977 edition), pp. 10–13
73. A. Einstein, H. A. Lorentz, H. Weyl, H. Minkowski, *The Principle of Relativity*, Dover Publications, Inc, 2000, softcover 216 pages, ISBN 0-486-60081-5, See pp. 37–65 for an English translation of Einstein's original 1905 paper.

74. "Albert Einstein's Theory of Relativity" ([https://www.youtube.com/watch?v=ev9zrt\\_\\_lec](https://www.youtube.com/watch?v=ev9zrt__lec)). YouTube. 30 November 2011. Retrieved 24 September 2013.
75. "Time Travel: Einstein's big idea (Theory of Relativity)" (<https://www.youtube.com/watch?v=V7vpw4AH8QQ>). YouTube. 9 January 2007. Retrieved 24 September 2013.
76. Hours, After (11 February 2012). "7 Theories on Time That Would Make Doc Brown's Head Explode" ([http://www.cracked.com/article\\_19659\\_7-theories-time-that-would-make-doc-browns-head-explode.html](http://www.cracked.com/article_19659_7-theories-time-that-would-make-doc-browns-head-explode.html)). Cracked.com. Retrieved 24 September 2013.
77. Knudsen, Jens M.; Hjorth, Poul (2012). *Elements of Newtonian Mechanics* (<https://books.google.com/books?id=rkP1CAAQBAJ>) (illustrated ed.). Springer Science & Business Media. p. 30. ISBN 978-3-642-97599-8. Extract of page 30 (<https://books.google.com/books?id=rkP1CAAQBAJ&pg=PA30>)
78. Greene, Brian (2005). *The Fabric of the Cosmos - Chapter 6: Chance and the Arrow* (<http://books.google.co.uk/books?id=yZujlUD1oAAC>). London.
79. Quznetsov, Gunn (30 March 2010). "Informational Time and Space" (<http://prespacetime.com/index.php/pst/article/view/10>). **1** (2). Retrieved 30 December 2016 – via Prespacetime Journal.
80. Andersen, Holly; Rick Grush (2009). "A brief history of time-consciousness: historical precursors to James and Husserl" (<https://web.archive.org/web/20080216100320/http://mind.ucsd.edu/papers/bhtc/Andersen%26Grush.pdf>) (PDF). **47** (2). *Journal of the History of Philosophy*: 277–307. Archived from the original (<http://mind.ucsd.edu/papers/bhtc/Andersen&Grush.pdf>) (PDF) on 16 February 2008. Retrieved 9 April 2011.
81. Wittmann, M.; Leland DS; Churan J; Paulus MP. (8 October 2007). "Impaired time perception and motor timing in stimulant-dependent subjects" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1997301>). *Drug Alcohol Depend.* **90** (2–3): 183–92. PMC 1997301 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1997301>) . PMID 17434690 (<https://www.ncbi.nlm.nih.gov/pubmed/17434690>). doi:10.1016/j.drugalcdep.2007.03.005 (<https://doi.org/10.1016%2Fj.drugalcdep.2007.03.005>).
82. Cheng, Ruey-Kuang; Macdonald, Christopher J.; Meck, Warren H. (2006). "Differential effects of cocaine and ketamine on time estimation: Implications for neurobiological models of interval timing" (<http://cat.inist.fr/?aModel=afficheN&cpsidt=18303059>) (online abstract). *Pharmacology, biochemistry and behavior.* **85** (1): 114–122. PMID 16920182 (<https://www.ncbi.nlm.nih.gov/pubmed/16920182>). doi:10.1016/j.pbb.2006.07.019 (<https://doi.org/10.1016%2Fj.pbb.2006.07.019>). Retrieved 9 April 2011.
83. Tinklenberg, Jared R.; Walton T. Roth<sup>1</sup>; Bert S. Kopell (January 1976). "Marijuana and ethanol: Differential effects on time perception, heart rate, and subjective response" (<http://www.springerlink.com/content/q1227453r481x439/>). *Psychopharmacology.* **49** (3): 275–279. PMID 826945 (<https://www.ncbi.nlm.nih.gov/pubmed/826945>). doi:10.1007/BF00426830 (<https://doi.org/10.1007%2FBF00426830>). Retrieved 9 April 2011.

84. Arzy, Shahar; Istvan Molnar-Szakacs; Olaf Blanke (18 June 2008). "Self in Time: Imagined Self-Location Influences Neural Activity Related to Mental Time Travel" (<http://www.jneurosci.org/content/28/25/6502.abstract>) (Abstract). *The Journal of Neuroscience*. **28** (25): 6502–6507. PMID 18562621 (<https://www.ncbi.nlm.nih.gov/pubmed/18562621>). doi:10.1523/JNEUROSCI.5712-07.2008 (<https://doi.org/10.1523%2FJNEUROSCI.5712-07.2008>). Retrieved 9 April 2011.
85. Carter, Rita (2009). *The Human Brain Book* (<https://books.google.com/books?id=eCV6cwU3qm0C>). Dorling Kindersley Publishing. pp. 186–187. ISBN 978-0-7566-5441-2.
86. Kennedy-Moore, Eileen (28 March 2014). "Time Management for Kids" (<http://www.psychologytoday.com/blog/growing-friendships/201403/time-management-kids>). Psychology Today. Retrieved 26 April 2014.
87. Wada Y, Masuda T, Noguchi K, 2005, "Temporal illusion called 'kappa effect' in event perception" Perception 34 ECV Abstract Supplement
88. Robert, Adler. "Look how time flies.." (<http://www.newscientist.com/article/mg16422180.900-look-how-time-flies>). Retrieved 9 April 2011.
89. Bowers, Kenneth; Brenneman, HA (January 1979). "Hypnosis and the perception of time" (<http://www.informaworld.com/smpp/content~content=a790232921~db=all>). *International Journal of Clinical and Experimental Hypnosis*. International Journal of Clinical and Experimental Hypnosis. **27** (1): 29–41. PMID 541126 (<https://www.ncbi.nlm.nih.gov/pubmed/541126>). doi:10.1080/00207147908407540 (<https://doi.org/10.1080%2F00207147908407540>).
90. Gruber, Ronald P.; Wagner, Lawrence F.; Block, Richard A. (2000). "Subjective Time Versus Proper (Clock) Time". In Buccheri, R.; Di Gesù, V.; Saniga, Metod. *Studies on the structure of time: from physics to psycho(patho)logy* (<https://books.google.com/books?id=LMSDqsvcxckC>). Springer. p. 54. ISBN 0-306-46439-X. Retrieved 9 April 2011. Extract of page 54 (<https://books.google.com/books?id=LMSDqsvcxckC&pg=PA54>)
91. Russell Hochschild, Arlie (1997). *The time bind: when work becomes home and home becomes work*. New York: Metropolitan Books. ISBN 9780805044713
92. Russell Hochschild, Arlie (20 April 1997). "There's no place like work" (<https://www.nytimes.com/1997/04/20/magazine/there-s-no-place-like-work.html?scp=1&sq=%22there%27s%20no%20place%20like%20work%22&st=cse>). *New York Times Magazine*. The New York Times.
93. Elias, Norbert (1992). *Time: an essay*. Oxford, UK Cambridge, USA: Blackwell. ISBN 9780631157984.
94. "Sequence - Order of Important Events" ([http://www.austinschools.org/curriculum/la/resources/documents/instResources/LA\\_res\\_Seq\\_ORIS\\_Module.pdf](http://www.austinschools.org/curriculum/la/resources/documents/instResources/LA_res_Seq_ORIS_Module.pdf)) (PDF). Austin Independent School District. 2009.
95. "Sequence of Events Worksheets" (<https://web.archive.org/web/20101013032311/http://www.reference.com/motif/Science/sequence-of-events-worksheets>). Reference.com. Archived from the original (<http://www.reference.com/motif/Science/sequence-of-events-worksheets>) on 13 October 2010.
96. Compiled by David Luckham & Roy Schulte. "Event Processing Glossary—Version 2.0" (<http://www.complexevents.com/2011/08/23/event-processing-glossary-version-2-0/>). Complex Event Processing.

97. Richard Nordquist. "narrative" (<http://grammar.about.com/od/mo/g/narrative2term.htm>). About.com.
98. David J. Piasecki. "Inventory Accuracy Glossary" (<http://www.accuracybook.com/glossary.htm>). AccuracyBook.com (OPS Publishing).
99. "Utility Communications Architecture (UCA) glossary" ([http://www.nettedautomation.com/glossary\\_menu/glossary\\_uca.html](http://www.nettedautomation.com/glossary_menu/glossary_uca.html)). NettedAutomation.
100. Núñez, Rafael; Cooperrider, Kensy; Doan, D; Wassmann, Jürg (2012-07-01). "Contours of time: Topographic construals of past, present, and future in the Yupno valley of Papua New Guinea" (<http://www.sciencedirect.com/science/article/pii/S0010027712000571>). *Cognition*. **124** (1): 25–35. doi:10.1016/j.cognition.2012.03.007 (<https://doi.org/10.1016%2Fj.cognition.2012.03.007>).
101. Bottini, Roberto; Crepaldi, Davide; Casasanto, Daniel; Crollen, Virgine; Collignon, Olivier (2015-08-01). "Space and time in the sighted and blind" (<http://www.sciencedirect.com/science/article/pii/S001002771500075X>). *Cognition*. **141**: 67–72. doi:10.1016/j.cognition.2015.04.004 (<https://doi.org/10.1016%2Fj.cognition.2015.04.004>).
102. "Remembrances of Times East" (<http://pss.sagepub.com/content/early/2010/10/19/0956797610386621.full>). *Psychological Science*. PMID 20959511 (<https://www.ncbi.nlm.nih.gov/pubmed/20959511>). Retrieved 2016-12-07.

## Further reading

- Barbour, Julian (1999). *The End of Time: The Next Revolution in Our Understanding of the Universe*. Oxford University Press. ISBN 0-19-514592-5.
- Landes, David (2000). *Revolution in Time*. Harvard University Press. ISBN 0-674-00282-2.
- Das, Tushar Kanti (1990). *The Time Dimension: An Interdisciplinary Guide*. New York: Praeger. ISBN 0-275-92681-8.- Research bibliography
- Davies, Paul (1996). *About Time: Einstein's Unfinished Revolution*. New York: Simon & Schuster Paperbacks. ISBN 0-684-81822-1.
- Feynman, Richard (1994) [1965]. *The Character of Physical Law* (<http://mitpress.mit.edu/catalog/item/default.asp?type=2&tid=5277>). Cambridge (Mass): The MIT Press. pp. 108–126. ISBN 0-262-56003-8.
- Galison, Peter (1992). *Einstein's Clocks and Poincaré's Maps: Empires of Time*. New York: W. W. Norton. ISBN 0-393-02001-0.
- Highfield, Roger (1992). *Arrow of Time: A Voyage through Science to Solve Time's Greatest Mystery*. Random House. ISBN 0-449-90723-6.
- Mermin, N. David (2005). *It's About Time: Understanding Einstein's Relativity* (<http://press.princeton.edu/titles/8112.html>). Princeton University Press. ISBN 0-691-12201-6.
- Penrose, Roger (1999) [1989]. *The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics* (<http://ukcatalogue.oup.com/product/9780192861986.do>). New York: Oxford University Press. pp. 391–417. ISBN 0-19-286198-0. Retrieved 9 April 2011.

- Price, Huw (1996). *Time's Arrow and Archimedes' Point* (<http://sydney.edu.au/time/price/TAAP.html>). Oxford University Press. ISBN 0-19-511798-0. Retrieved 9 April 2011.
- Reichenbach, Hans (1999) [1956]. *The Direction of Time* (<http://store.doverpublications.com/0486409260.html>). New York: Dover. ISBN 0-486-40926-0.
- Stiegler, Bernard, *Technics and Time, 1: The Fault of Epimetheus*
- Quznetsov, Gunn A. (2006). *Logical Foundation of Theoretical Physics*. Nova Sci. Publ. ISBN 1-59454-948-6.
- Whitrow, Gerald J. (1973). *The Nature of Time*. Holt, Rinehart and Wilson (New York).
- Whitrow, Gerald J. (1980). *The Natural Philosophy of Time*. Clarendon Press (Oxford).
- Whitrow, Gerald J. (1988). *Time in History. The evolution of our general awareness of time and temporal perspective*. Oxford University Press. ISBN 0-19-285211-6.
- Rovelli, Carlo (2006). *What is time? What is space?* (<https://web.archive.org/web/20070127102006/http://www.direnzo.it/main.phtml?Language=en&Doc=0001&ISBN=8883231465>). Rome: Di Renzo Editore. ISBN 88-8323-146-5. Archived from the original (<http://www.direnzo.it/main.phtml?Language=en&Doc=0001&ISBN=8883231465>) on 27 January 2007.
- Charlie Gere, (2005) *Art, Time and Technology: Histories of the Disappearing Body*, Berg
- Craig Callendar, *Introducing Time*, Icon Books, 2010, ISBN 978-1848311206
- Benjamin Gal-Or, *Cosmology, Physics and Philosophy*, Springer Verlag, 1981, 1983, 1987, ISBN 0-387-90581-2, ISBN 0-387-96526-2.
- Roberto Mangabeira Unger and Lee Smolin, *The Singular Universe and the Reality of Time*, Cambridge University Press, 2014, ISBN 978-1-107-07406-4.

## External links

- Accurate time vs. PC Clock Difference (<http://www.centralx.com/time/index.en.html>)
- Exploring Time (<http://exploringtime.org/?page=segments>) from Planck Time to the lifespan of the universe
- Different systems of measuring time (<http://tycho.usno.navy.mil/systime.html>)
- 
- Time (<http://www.bbc.co.uk/programmes/p005465z>) on *In Our Time* at the BBC.
- Time (<http://www.iep.utm.edu/time/>) in the *Internet Encyclopedia of Philosophy*, by Bradley Dowden.
- Le Poidevin, Robin (Winter 2004). "The Experience and Perception of Time" (<http://plato.stanford.edu/archives/win2004/entries/time-experience>). In Edward

- N. Zalta. *The Stanford Encyclopedia of Philosophy*. Retrieved 9 April 2011.
- Time at Open Directory (<http://www.dmoz.org/Reference/Time/>)

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