Julian day

"Julian date" redirects here. For dates in the Julian calendar, see Julian calendar. For day of year, see Ordinal date. For the comic book character Julian Gregory Day, see Calendar Man.
Not to be confused with Julian year (astronomy).

Julian day is the continuous count of days since the beginning of the Julian Period used primarily by astronomers.

The **Julian Day Number** (**JDN**) is the integer assigned to a whole solar day in the Julian day count starting from noon Greenwich Mean Time, with Julian day number 0 assigned to the day starting at noon on January 1, 4713 BC, proleptic Julian calendar (November 24, 4714 BC, in the proleptic Gregorian calendar),[1] a date at which three multi-year cycles started and which preceded any historical dates.[2] For example, the Julian day number for the day starting at 12:00 UT on January 1, 2000, was 2,451,545.[3]

The **Julian date** (**JD**) of any instant is the Julian day number for the preceding noon in Greenwich Mean Time plus the fraction of the day since that instant. Julian dates are expressed as a Julian day number with a decimal fraction added.[4] For example, the Julian Date for 00:30:00.0 UT January 1, 2013, is 2,456,293.520833.[5]

The **Julian Period** is a chronological interval of 7980 years beginning 4713 BC. It has been used by historians since its introduction in 1583 to convert between different calendars. 2015 is year 6728 of the current Julian Period. The next Julian Period begins in the year 3268 AD.

Contents

Terminology

The term *Julian date* may also refer, outside of astronomy, to the day-of-year number (more properly, the ordinal date) in the Gregorian calendar, especially in computer programming, the military and the food industry,[6]— or it may refer to dates in the Julian calendar. For example, if a given "Julian date" is "October 5, 1582", this means that date in the Julian calendar (which was October 15, 1582, in the Gregorian calendar — the date it was established). Outside of an astronomical or historical context, if a given "Julian date" is "40", this most likely means the fortieth day of a given Gregorian year, namely February 9. But the potential for mistaking a "Julian date" of "40" to mean an astronomical Julian Day Number (or even to mean the year 40 AD in the Julian calendar, or even to mean a duration of 40 astronomical Julian years) is justification for preferring the terms "ordinal date" or "day-of-year" instead. In contexts where a "Julian date" means simply an ordinal date, calendars of a Gregorian year with formatting for ordinal dates are often called "*Julian calendars*",[6] in spite of the potential for misinterpreting this as meaning that the calendars are of years in the Julian calendar system.

Historical Julian dates were recorded relative to GMT or Ephemeris Time, but the International Astronomical Union now recommends that Julian dates be specified in Terrestrial Time, and that when necessary to specify Julian dates using a different time scale, that the time scale used be indicated when required, such as JD(UT1). The fraction of the day is found by converting the number of hours, minutes, and seconds after noon into the equivalent decimal fraction. Time intervals calculated from differences of Julian Dates specified in non-uniform time scales, such as Coordinated Universal Time (UTC), may need to be corrected for changes in time scales (e.g. leap seconds).[4]

Variants

Because the starting point or reference epoch is so long ago, numbers in the Julian day can be quite large and cumbersome. A more recent starting point is sometimes used, for instance by dropping the leading digits, in order to fit into limited computer memory with an adequate amount of precision. In the following table, times are given in 24-hour notation.

In the table below, *Epoch* refers to the point in time used to set the origin (usually zero, but (1) where explicitly indicated) of the alternative convention being discussed in that row. The date given is a Gregorian calendar date if it is October 15, 1582, or later, but a Julian calendar date if it is earlier. JD stands for Julian Date. 0h is 00:00 midnight, 12h is 12:00 noon, UT unless otherwise specified.

Name	Epoch	Calculation	Current value	Notes
Julian Date	12h Jan 1, 4713 BC		**2457308.58472**	
Reduced JD	12h Nov 16, 1858	JD − 2400000	**57308.58472**	[7][8]
Modified JD	0h Nov 17, 1858	JD − 2400000.5	**57308.08472**	Introduced by SAO in 1957
Truncated JD	0h May 24, 1968	floor (JD − 2440000.5)	**17308**	Introduced by NASA in 1979
Dublin JD	12h Dec 31, 1899	JD − 2415020	**42288.58472**	Introduced by the IAU in 1955
Lilian date	Oct 15, 1582[9]	floor (JD − 2299159.5)	**158149**	Count of days of the Gregorian calendar
Rata Die	Jan 1, 1[9] proleptic Gregorian calendar	floor (JD − 1721424.5)	**735884**	Count of days of the Common Era
Unix Time	0h Jan 1, 1970	(JD − 2440587.5) × 86400	**1444701721**	Count of seconds[10]
Mars Sol Date	12h Dec 29, 1873	(JD − 2405522)/1.02749	**50400.99828**	Count of Martian days

- The **Modified Julian Date** (MJD) was introduced by the Smithsonian Astrophysical Observatory in 1957 to record the orbit of Sputnik via an IBM 704 (36-bit machine) and using only 18 bits until August 7, 2576. MJD is the epoch of OpenVMS, using 63-bit date/time, postponing the next Y2K campaign to July 31, 31086, 02:48:05.47.[11] The MJD has a starting point of midnight on November 17, 1858 and is computed by MJD = JD - 2400000.5 [12]
- The **Truncated Julian Day** (TJD) was introduced by NASA/Goddard in 1979 as part of a parallel grouped binary time code (PB-5) "designed specifically, although not exclusively, for spacecraft applications." TJD was a 4-digit day count from MJD 40000, which was May 24, 1968, represented as a 14-bit binary number. Since this code was limited to four digits, TJD recycled to zero on MJD 50000, or October 10, 1995, "which gives a long ambiguity period of 27.4 years". (NASA codes PB-1—PB-4 used a 3-digit day-of-year count.) Only whole days are represented. Time of day is expressed by a count of seconds of a day, plus optional milliseconds, microseconds and nanoseconds in separate fields. Later PB-5J was introduced which increased the TJD field to 16 bits, allowing values up to 65535, which will occur in the year 2147. There are five digits recorded after TJD 9999.[13][14]
- The **Dublin Julian Date** (DJD) is the number of days that has elapsed since the epoch of the solar and lunar ephemerides used from 1900 through 1983, Newcomb's Tables of the Sun and Ernest W. Brown's *Tables of the Motion of the Moon* (1919). This epoch was noon UT on January 0, 1900, which is the same as noon UT on December 31, 1899. The DJD was defined by the International Astronomical Union at their meeting in Dublin, Ireland, in 1955.[15]

- The Lilian day number is a count of days of the Gregorian calendar and not defined relative to the Julian Date. It is an integer applied to a whole day; day 1 was October 15, 1582, which was the day the Gregorian calendar went into effect. The original paper defining it makes no mention of the time zone, and no mention of time-of-day.[16] It was named for Aloysius Lilius, the principal author of the Gregorian calendar.[17]
- Rata Die is a system used in Rexx, Go and Microsoft .NET. It uses the local timezone, and day 1 is January 1, 1, that is, the first day of the Christian or Common Era in the proleptic Gregorian calendar.[18]

The Heliocentric Julian Day (HJD) is the same as the Julian day, but adjusted to the frame of reference of the Sun, and thus can differ from the Julian day by as much as 8.3 minutes (498 seconds), that being the time it takes the Sun's light to reach Earth.

To illustrate the ambiguity that could arise, consider the two separate astronomical measurements of an astronomical object from the earth: Assume that three objects — the Earth, the Sun, and the astronomical object targeted, that is whose distance is to be measured — happen to be in a straight line for both measures. However, for the first measurement, the Earth is between the Sun and the targeted object, and for the second, the Earth is on the opposite side of the Sun from that object. Then, the two measurements would differ by about 1000 light-seconds: For the first measurement, the Earth is roughly 500 light seconds closer to the target than the Sun, and roughly 500 light seconds further from the target astronomical object than the Sun for the second measure.

An error of about 1000 light-seconds is over 1% of a light-day, which can be a significant error when measuring temporal phenomena for short period astronomical objects over long time intervals. To clarify this issue, the ordinary Julian day is sometimes referred to as the **Geocentric Julian Day** (GJD) in order to distinguish it from HJD.

History

The *Julian day number* is based on the *Julian Period* proposed by Joseph Scaliger in 1583, at the time of the Gregorian calendar reform, as it is the least common multiple of three calendar cycles used with the Julian calendar:

> 15 (indiction cycle) × 19 (Metonic cycle) × 28 (Solar cycle) = 7980 years

Its epoch falls at the last time when all three cycles (if they are continued backward far enough) were in their first year together — Scaliger chose this because it preceded all historical dates. Years of the Julian Period are counted from this year, 4713 BC, which was chosen to be before any historical record.[19]

> Since it is now certain that every possible combination of the three cyclic numbers finds its place in the Julian Period, it is evident that the first year of the Christian era, which was the 10th year of a Solar Cycle, the 2nd of a Lunar Cycle, and the 4th of a Cycle of Indiction, finds its place within this artificial era, and must answer to that particular year of the period which is characterized by the same cyclic numbers. Hence, to refer the Christian era to the Julian Period is the same thing as to find out what year of that period it is which, when divided by 28 will leave a remainder 10, divided by 19 will leave a remainder 2, and divided by 15 will leave a remainder 4. The solution of this problem belongs to the higher mathematics, by which it is found that the year required is the 4714th of the period in question. Hence Jul. Per. 4714=A.D.1, and consequently Julian Period 4713=B.C.1.[20]

In point of fact, finding the year is a very straightforward arithmetical procedure. See "Calculation" below.

Although many references say that the *Julian* in "Julian Period" refers to Scaliger's father, Julius Scaliger, in the introduction to Book V of his *Opus de Emendatione Temporum* ("Work on the Emendation of Time") he states, "*Iulianum vocavimus: quia ad annum Iulianum dumtaxat accomodata est*", which translates more or less as "We have called it Julian merely because it is accommodated to the Julian year." Thus *Julian* refers to Julius Caesar, who introduced the Julian calendar in 46 BC.

Originally the Julian Period was used only to count years, and the Julian calendar was used to express historical dates within years. In his book *Outlines of Astronomy*, first published in 1849, the astronomer John Herschel added the counting of days elapsed from the beginning of the Julian Period:

> The period thus arising of 7980 Julian years, is called the Julian period, and it has been found so useful, that the most competent authorities have not hesitated to declare that, through its employment, light and order were first introduced into chronology.[21] We owe its invention or revival to Joseph Scaliger, who is said to have received it from the Greeks of Constantinople. The first year of the current Julian period, or that of which the number in each of the three subordinate cycles is 1, was the year 4713 BC, and the noon of the 1st of January of that year, for the meridian of Alexandria, is the chronological epoch, to which all historical eras are most readily and intelligibly referred, by computing the number of integer days intervening between that epoch and the noon (for Alexandria) of the day, which is reckoned to be the first of the particular era in question. The meridian of Alexandria is chosen as that to which Ptolemy refers the commencement of the era of Nabonassar, the basis of all his calculations.[22]

Astronomers adopted Herschel's "days of the Julian period" in the late nineteenth century, but used the meridian of Greenwich instead of Alexandria, after the former was adopted as the Prime Meridian after the International Meridian Conference in Washington in 1884. This has now become the standard system of Julian days numbers.

The French mathematician and astronomer Pierre-Simon Laplace first expressed the time of day as a decimal fraction added to calendar dates in his book, *Traité de Mécanique Céleste*, in 1799.[23] Other astronomers added fractions of the day to the Julian day number to create Julian Dates, which are typically used by astronomers to date astronomical observations, thus eliminating the complications resulting from using standard calendar periods like eras, years, or months. They were first introduced into variable star work by Edward Charles Pickering, of the Harvard College Observatory, in 1890.[24]

Julian days begin at noon because when Herschel recommended them, the astronomical day began at noon. The astronomical day had begun at noon ever since Ptolemy chose to begin the days in his astronomical periods at noon. He chose noon because the transit of the Sun across the observer's meridian occurs at the same apparent time every day of the year, unlike sunrise or sunset, which vary by several hours. Midnight was not even considered because it could not be accurately determined using water clocks. Nevertheless, he double-dated most nighttime observations with both Egyptian days beginning at sunrise and Babylonian days beginning at sunset. This would seem to imply that his choice of noon was *not*, as is sometimes stated, made in order to allow all observations from a given night to be recorded with the same date. When this practice ended in 1925, it was decided to keep Julian days continuous with previous practice.

Calculation

The Julian day number can be calculated using the following formulas (**integer division is used exclusively**, that is, the remainder of all divisions are dropped):

The months (M) January to December are 1 to 12. For the year (Y) astronomical year numbering is used, thus 1 BC is 0, 2 BC is −1, and 4713 BC is −4712. D is the day of the month. JDN *is the Julian Day Number, which pertains to the noon occurring in the corresponding calendar date.*

Converting Julian or Gregorian calendar date to Julian Day Number

The algorithm is valid at least for all positive Julian Day Numbers.[25] The meaning of the variables are explained by the Computer Science Department of the University of Texas at San Antonio.

It is worth noting that this algorithm does not follow the NASA[26] or the US Naval Observatory[27] - the convention in these systems being that the Gregorian calendar did not exist before the date October 15, 1582 (Gregorian). This algorithm effectively back-dates the Gregorian calendar onto the Julian calendar for dates before the introduction of the Gregorian calendar. Thus any calculations made with this formula before October 15, 1582, will not agree with these previous ephemerides.

You must compute first the number of years (y) and months (m) since March 1 −4800 (March 1, 4801 BC):

$$a = \left\lfloor \frac{14 - \text{month}}{12} \right\rfloor$$
$$y = \text{year} + 4800 - a$$
$$m = \text{month} + 12a - 3$$

The value 'a' will be 1 for January and February, and 0 for other months. And 'm' will be 0 for March and 11 for February.

All years in the BC era must be converted to astronomical years, so that 1 BC is year 0, 2 BC is year −1, etc. Convert to a negative number, then increment toward zero.

Then, if starting from a Gregorian calendar date compute (note the floor brackets!):

$$JDN = \text{day} + \left\lfloor \frac{153m + 2}{5} \right\rfloor + 365y + \left\lfloor \frac{y}{4} \right\rfloor - \left\lfloor \frac{y}{100} \right\rfloor + \left\lfloor \frac{y}{400} \right\rfloor - 32045$$

Otherwise, if starting from a Julian calendar date compute:

$$JDN = \text{day} + \left\lfloor \frac{153m + 2}{5} \right\rfloor + 365y + \left\lfloor \frac{y}{4} \right\rfloor - 32083$$

Note: (153m+2)/5 gives the number of days since March 1 and comes from the repetition of days in the month from March in groups of five:

Mar–Jul:	31 30 31 30 31
Aug–Dec:	31 30 31 30 31
Jan–Feb:	31 28

Finding Julian date given Julian day number and time of day

For the full Julian Date (divisions are real numbers):

$$JD = JDN + \tfrac{\text{hour}-12}{24} + \tfrac{\text{minute}}{1440} + \tfrac{\text{second}}{86400}$$

So, for example, January 1, 2000, at 12:00:00 corresponds to JD = 2451545.0

Finding day of week given Julian day number

The US day of the week **W1** can be determined from the Julian Day Number **J** with the expression:

> **W1** = mod(J + 1, 7)[28]

W1	0	1	2	3	4	5	6
Day of the week	Sun	Mon	Tue	Wed	Thu	Fri	Sat

The ISO day of the week **W0** can be determined from the Julian Day Number **J** with the expression:

> **W0** = mod (J, 7) + 1

W0	1	2	3	4	5	6	7
Day of the week	Mon	Tue	Wed	Thu	Fri	Sat	Sun

Julian or Gregorian calendar from Julian day number

This is an algorithm by Richards to convert a Julian Day Number, **J**, to a date in the Gregorian calendar (proleptic, when applicable). Richards does not state which dates the algorithm is valid for.[29] All variables are integer values, and the notation "a div b" indicates integer division, and "mod(a,b)" denotes the modulus operator.

Algorithm parameters for Gregorian calendar

variable	value	variable	value
y	4716	v	3
j	1401	u	5
m	2	s	153
n	12	w	2
r	4	B	274277
p	1461	C	−38

For Julian calendar:

1. $f = \mathbf{J} + j$

For Gregorian calendar:

1. $f = \mathbf{J} + j + (((4 \times \mathbf{J} + B) \text{ div } 146097) \times 3) \text{ div } 4 + C$

For Julian or Gregorian, continue:

2. $e = r \times f + v$
3. $g = \text{mod}(e, p) \text{ div } r$
4. $h = u \times g + w$
5. $\mathbf{D} = (\text{mod}(h, s)) \text{ div } u + 1$
6. $\mathbf{M} = \text{mod}(h \text{ div } s + m, n) + 1$
7. $\mathbf{Y} = (e \text{ div } p) - y + (n + m - \mathbf{M}) \text{ div } n$

D, **M**, and **Y** are the numbers of the day, month, and year respectively.

Julian Period from indiction, Metonic and solar cycles

Let Y be the year BC or AD and i, m and s respectively its positions in the indiction, Metonic and solar cycles. Divide 6916i + 4200m + 4845s by 7980 and call the remainder r.

> If r>4713, Y = (r - 4713) and is a year AD.
> If r<4714, Y = (4714 - r) and is a year BC.

Example

i = 8, m = 2, s = 8. What is the year?

> (6916 x 8) = 55328; (4200 x 2) = 8400: (4845 x 8) = 38760. 55328 + 8400 + 38760 = 102488.
> 102488/7980 = 12 remainder 6728.
> Y = (6728 - 4713) = AD 2015.[30]

See also

- J2000 - The epoch that starts on JD 2451545.0 (TT), the standard epoch used in astronomy since 1984
- Barycentric Julian Date
- Julian year (astronomy)
- Julian year (calendar)
- Decimal time
- Epoch (reference date)
- Epoch (astronomy)
- Era
- Time
- Time standards
- Ordinal date
- Dual dating
- 5th millennium BC
- Lunation Number (similar concept)
- Zeller's congruence

References

1. Dershowitz & Reingold 2008, 15.
2. Both of these dates are years of the Christian or Common Era (which has no year 0 between 1 BC and 1 AD). Astronomical calculations generally include a year 0, so these dates should be adjusted accordingly (i.e. the year 4713 Before Christ becomes astronomical year number −4712, etc.). In this article, dates before October 15, 1582 are in the (possibly proleptic) Julian calendar and dates on or after October 15, 1582 are in the Gregorian calendar, unless otherwise labelled.
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4. "Resolution B1" 1997.
5. US Naval Observatory 2005
6. USDA Julian date calendar (http://www.dm.usda.gov/procurement/toolkit/docs/calendar.pdf)
7. Hopkins, Jeffrey L. (2013). *Using Commercial Amateur Astronomical Spectrographs*, p. 257, Springer Science & Business Media, ISBN 9783319014425
8. Pallé Pere L., Cesar Esteban. (2014). *Asteroseismology*, p. 185, Cambridge University Press, ISBN 9781107470620
9. This is an epoch starting with day 1 instead of 0
10. *Astronomical almanac for the year 2001*, 2000, p. K2
11. Worsham 1988
12. Winkler n. d.
13. Chi 1979.
14. SPD Toolkit Time Notes 2014.
15. Ransom c. 1988
16. Ohms 1986
17. IBM 2004, "CEEDATE—convert Lilian date to character format" (http://publib.boulder.ibm.com/infocenter/comphelp/v7v91/index.jsp?topic=%2Fcom.ibm.aix.cbl.doc%2Frpsrv06.htm)
18. Dershowitz & Reingold 2008, 10.
19. Richards 2013, pp. 591-592.
20. Edwards, Smith & ben Uziel 1853, p. 82.
21. Ideler 1825, p. 77.
22. Sir J F W Herschel, *Outlines of Astronomy*, London 1858, p. 678, available at [1] (http://books.google.com/books?id=uj0DAAAAQAAJ&pg=PA678).
23. Laplace (http://books.google.com/books?id=QjEVAAAAQAAJ&pg=PA348) 1799, p.349
24. Furness (http://books.google.com/books?id=5jQJAAAAIAAJ&printsec=toc#PPA206,M1) 1988, p. 206.
25. Tøndering 2014.
26. *HORIZONS System* 2013
27. *Julian Date Converter* 2013
28. Richards 2013, pp. 592, 618.
29. Richards 2013, 617–9
30. Robert Heath, *Astronomia accurata; or the royal astronomer and navigator, London 1760, p. 160, available at [2] (http://books.google.co.uk/books?id=1sRNAAAAMAAJ&pg=PA160).*

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