

Longitude

Longitude (ⁱ/ˈlɒndʒɪtʃuːd/ or ⁱ/ˈlɒndʒɪtuːd/, Australian and British also ⁱ/ˈlɒnɡɪtʃuːd/),^{[1][2]} is a geographic coordinate that specifies the east-west position of a point on the Earth's surface. It is an angular measurement, usually expressed in degrees and denoted by the Greek letter lambda (λ). Meridians (lines running from the North Pole to the South Pole) connect points with the same longitude. By convention, one of these, the Prime Meridian, which passes through the Royal Observatory, Greenwich, England, was allocated the position of zero degrees longitude. The longitude of other places is measured as the angle east or west from the Prime Meridian, ranging from 0° at the Prime Meridian to +180° eastward and −180° westward. Specifically, it is the angle between a plane containing the Prime Meridian and a plane containing the North Pole, South Pole and the location in question. (This forms a right-handed coordinate system with the *z* axis (right hand thumb) pointing from the Earth's center toward the North Pole and the *x* axis (right hand index finger) extending from Earth's center through the equator at the Prime Meridian.)

A location's north–south position along a meridian is given by its latitude, which is approximately the angle between the local vertical and the plane of the Equator

If the Earth were perfectly spherical and homogeneous, then the longitude at a point would be equal to the angle between a vertical north–south plane through that point and the plane of the Greenwich meridian. Everywhere on Earth the vertical north–south plane would contain the Earth's axis. But the Earth is not homogeneous, and has mountains—which have gravity and so can shift the vertical plane away from the Earth's axis. The vertical north–south plane still intersects the plane of the Greenwich meridian at some angle; that angle is the astronomical longitude, calculated from star observations. The longitude shown on maps and GPS devices is the angle between the Greenwich plane and a not-quite-vertical plane through the point; the not-quite-vertical plane is perpendicular to the surface of the spheroid chosen to approximate the Earth's sea-level surface, rather than perpendicular to the sea-level surface itself.



A graticule on the Earth as a sphere or an ellipsoid. The lines from pole to pole are lines of constant longitude, or **meridians**. The circles parallel to the equator are lines of constant latitude, or **parallels**. The graticule shows the latitude and longitude of points on the surface. In this example meridians are spaced at 6° intervals and parallels at 4° intervals.

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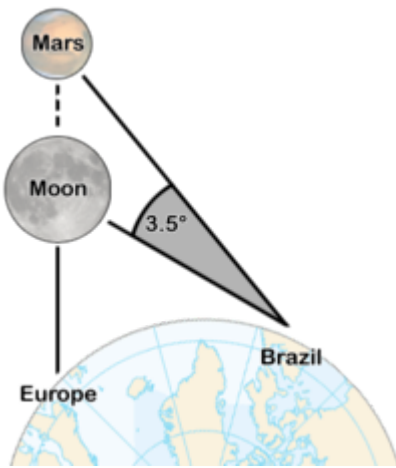
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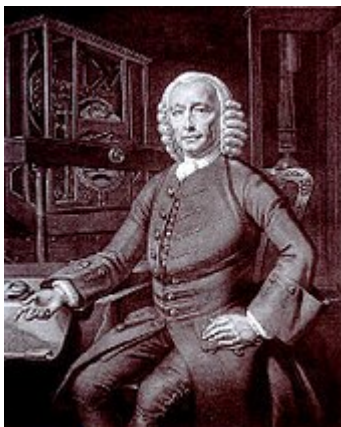
Amerigo Vespucci's means of determining longitude

The measurement of longitude is important both to cartography and for ocean navigation. Mariners and explorers for most of history struggled to determine longitude. Finding a method of determining longitude took centuries, resulting in the history of longitude recording the effort of some of the greatest scientific minds.

Latitude was calculated by observing with quadrant or astrolabe the altitude of the sun or of charted stars above the horizon, but longitude is harder

Amerigo Vespucci was perhaps the first European to proffer a solution, after devoting a great deal of time and energy studying the problem during his sojourns in the New World:

As to longitude, I declare that I found so much difficulty in determining it that I was put to great pains to ascertain the east-west distance I had covered. The final result of my labours was that I found nothing better to do than to watch for and take observations at night of the conjunction of one planet with another, and especially of the conjunction of the moon with the other planets, because the moon is swifter in her course than any other planet. I compared my observations with an almanac. After I had made experiments many nights, one night, the twenty-third of August 1499, there was a conjunction of the moon with Mars, which according to the almanac was to occur at midnight or a half hour before. I found that...at midnight Mars's position was three and a half degrees to the east.^[3]



John Harrison solved the greatest problem of his day.^[4]

By comparing the positions of the moon and Mars with their anticipated positions, Vespucci was able to crudely deduce his longitude. But this method had several limitations: First, it required the occurrence of a specific astronomical event (in this case, Mars passing through the same right ascension as the moon), and the observer needed to anticipate this event via an astronomical almanac. One needed also to know the precise time, which was difficult to ascertain in foreign lands. Finally, it required a stable viewing platform, rendering the technique useless on the rolling deck of a ship at sea. See Lunar distance (navigation)

In 1612 Galileo Galilei demonstrated that with sufficiently accurate knowledge of the orbits of the moons of Jupiter one could use their positions as a universal clock and this would make possible the determination of longitude, but the method he devised was impracticable for navigators on ships because of their instability.^[5] In 1714 the British government passed the Longitude Act which offered large financial rewards to the first person to demonstrate a practical method for determining the longitude of a ship at sea. These rewards motivated many to search for a solution.

John Harrison, a self-educated English clockmaker, invented the marine chronometer, the key piece in solving the problem of accurately establishing longitude at sea, thus revolutionising and extending the possibility of safe long distance sea travel.^[4] Though the Board of Longitude rewarded John Harrison for his marine chronometer in 1773, chronometers remained very expensive and the lunar distance method continued to be used for decades. Finally, the combination of the availability of marine chronometers and wireless telegraph time signals put an end to the use of lunars in the 20th century

Unlike latitude, which has the equator as a natural starting position, there is no natural starting position for longitude. Therefore, a reference meridian had to be chosen. It was a popular practice to use a nation's capital as the starting point, but other locations were also used. While British cartographers had long used the Greenwich meridian in London, other references were used elsewhere,

including [El Hierro](#), [Rome](#), [Copenhagen](#), [Jerusalem](#), [Saint Petersburg](#), [Pisa](#), [Paris](#), [Philadelphia](#), and [Washington D.C.](#) In 1884 the [International Meridian Conference](#) adopted the Greenwich meridian as the *universal Prime Meridian* or *zero point of longitude*.

Noting and calculating longitude

Longitude is given as an [angular measurement](#) ranging from 0° at the Prime Meridian to $+180^\circ$ eastward and -180° westward. The Greek letter λ (lambda),^{[6][7]} is used to denote the location of a place on Earth east or west of the Prime Meridian.

Each degree of longitude is sub-divided into 60 [minutes](#), each of which is divided into 60 [seconds](#). A longitude is thus specified in [sexagesimal](#) notation as $23^\circ 27' 30''$ E. For higher precision, the seconds are specified with a [decimal fraction](#). An alternative representation uses degrees and minutes, where parts of a minute are expressed in decimal notation with a fraction, thus: $23^\circ 27.5'$ E. Degrees may also be expressed as a decimal fraction: 23.45833° E. For calculations, the angular measure may be converted to [radians](#), so longitude may also be expressed in this manner as a signed fraction of π (pi), or an unsigned fraction of 2π .

For calculations, the West/East suffix is replaced by a negative sign in the [western hemisphere](#). Confusingly, the convention of negative for East is also sometimes seen. The preferred convention—that East is positive—is consistent with a right-handed [Cartesian coordinate system](#), with the North Pole up. A specific longitude may then be combined with a specific latitude (usually positive in the [northern hemisphere](#)) to give a precise position on the Earth's surface.

There is no other physical principle determining longitude directly but with time. Longitude at a point may be determined by calculating the time difference between that at its location and [Coordinated Universal Time](#) (UTC). Since there are 24 hours in a day and 360 degrees in a circle, the sun moves across the sky at a rate of 15 degrees per hour ($360^\circ \div 24 \text{ hours} = 15^\circ \text{ per hour}$). So if the [time zone](#) a person is in is three hours ahead of UTC then that person is near 45° longitude ($3 \text{ hours} \times 15^\circ \text{ per hour} = 45^\circ$). The word *near* is used because the point might not be at the center of the time zone; also the time zones are defined politically, so their centers and boundaries often do not lie on meridians at multiples of 15° . In order to perform this calculation, however, a person needs to have a [chronometer](#) (watch) set to UTC and needs to determine local time by solar or astronomical observation. The details are more complex than described here: see the articles on [Universal Time](#) and on the [equation of time](#) for more details.

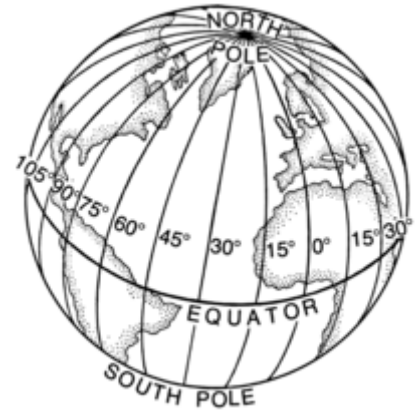
Singularity and discontinuity of longitude

Note that the longitude is [singular](#) at the [Poles](#) and calculations that are sufficiently accurate for other positions, may be inaccurate at or near the Poles. Also the [discontinuity](#) at the $\pm 180^\circ$ meridian must be handled with care in calculations. An example is a calculation of east displacement by subtracting two longitudes, which gives the wrong answer if the two positions are on either side of this meridian. To avoid these complexities, consider replacing latitude and longitude with another [horizontal position representation](#) in calculation.

Plate movement and longitude

The Earth's [tectonic plates](#) move relative to one another in different directions at speeds on the order of 50 to 100mm per year.^[8] So points on the Earth's surface on different plates are always in motion relative to one another. For example, the longitudinal difference between a point on the Equator in Uganda, on the [African Plate](#), and a point on the Equator in Ecuador, on the [South American Plate](#), is increasing by about 0.0014 [arcseconds](#) per year. These tectonic movements likewise affect latitude.

If a [global reference frame](#) (such as [WGS84](#), for example) is used, the longitude of a place on the surface will change from year to year. To minimize this change, when dealing just with points on a single plate, a different reference frame can be used, whose coordinates are fixed to a particular plate, such as [NAD83](#) for North America or [ETRS89](#) for Europe.



Drawing of Earth with longitudes but without latitudes.

Length of a degree of longitude

The length of a degree of longitude (east-west distance) depends only on the radius of a circle of latitude. For a sphere of radius a that radius at latitude ϕ is $a \cos \phi$, and the length of a one-degree (or $\frac{\pi}{180}$ radian) arc along a circle of latitude is

$$\Delta^1_{\text{long}} = \frac{\pi}{180^\circ} a \cos \phi$$

When the Earth is modelled by an ellipsoid this arc length becomes^{[9][10]}

$$\Delta^1_{\text{long}} = \frac{\pi a \cos \phi}{180^\circ \sqrt{1 - e^2 \sin^2 \phi}}$$

where e , the eccentricity of the ellipsoid, is related to the major and minor axes (the equatorial and polar radii respectively) by

$$e^2 = \frac{a^2 - b^2}{a^2}$$

An alternative formula is

$$\Delta^1_{\text{long}} = \frac{\pi}{180^\circ} a \cos \psi \quad \text{where } \tan \psi = \frac{b}{a} \tan \phi$$

$\cos \phi$ decreases from 1 at the equator to 0 at the poles, which measures how circles of latitude shrink from the equator to a point at the pole, so the length of a degree of longitude decreases likewise. This contrasts with the small (1%) increase in the length of a degree of latitude (north-south distance), equator to pole. The table shows both for the WGS84 ellipsoid with $a = 6\,378\,137.0$ m and $b = 6\,356\,752.3142$ m. Note that the distance between two points 1 degree apart on the same circle of latitude, measured along that circle of latitude, is slightly more than the shortest (geodesic) distance between those points (unless on the equator, where these are equal); the difference is less than 0.6 m (2 ft).

A geographical mile is defined to be the length of one minute of arc along the equator (one equatorial minute of longitude), so a degree of longitude along the equator is exactly 60 geographical miles, as there are 60 minutes in a degree.

Longitude on bodies other than Earth

Planetary co-ordinate systems are defined relative to their mean axis of rotation and various definitions of longitude depending on the body. The longitude systems of most of those bodies with observable rigid surfaces have been defined by references to a surface feature such as a crater. The north pole is that pole of rotation that lies on the north side of the invariable plane of the solar system (near the ecliptic). The location of the Prime Meridian as well as the position of body's north pole on the celestial sphere may vary with time due to precession of the axis of rotation of the planet (or satellite). If the position angle of the body's Prime Meridian increases with time, the body has a direct (prograde) rotation; otherwise the rotation is said to be retrograde.

In the absence of other information, the axis of rotation is assumed to be normal to the mean orbital plane; Mercury and most of the satellites are in this category. For many of the satellites, it is assumed that the rotation rate is equal to the mean orbital period. In the case of the giant planets, since their surface features are constantly changing and moving at various rates, the rotation of their magnetic fields is used as a reference instead. In the case of the Sun, even this criterion fails (because its magnetosphere is very complex and does not really rotate in a steady fashion), and an agreed-upon value for the rotation of its equator is used instead.

For planetographic longitude, west longitudes (i.e., longitudes measured positively to the west) are used when the rotation is prograde, and east longitudes (i.e., longitudes measured positively to the east) when the rotation is retrograde. In simpler terms, imagine a distant, non-orbiting observer viewing a planet as it rotates. Also suppose that this observer is within the plane of the

ϕ	Δ^1_{lat}	Δ^1_{long}
0°	110.574 km	111.320 km
15°	110.649 km	107.551 km
30°	110.852 km	96.486 km
45°	111.132 km	78.847 km
60°	111.412 km	55.800 km
75°	111.618 km	28.902 km
90°	111.694 km	0.000 km

planet's equator. A point on the Equator that passes directly in front of this observer later in time has a higher planetographic longitude than a point that did so earlier in time.

However, *planetocentric longitude* is always measured positively to the east, regardless of which way the planet rotates. *East* is defined as the counter-clockwise direction around the planet, as seen from above its north pole, and the north pole is whichever pole more closely aligns with the Earth's north pole. Longitudes traditionally have been written using "E" or "W" instead of "+" or "-" to indicate this polarity. For example, the following all mean the same thing:

- -91°
- 91°W
- $+269^{\circ}$
- 269°E .

The reference surfaces for some planets (such as Earth and Mars) are ellipsoids of revolution for which the equatorial radius is larger than the polar radius; in other words, they are oblate spheroids. Smaller bodies (Io, Mimas, etc.) tend to be better approximated by triaxial ellipsoids; however, triaxial ellipsoids would render many computations more complicated, especially those related to map projections. Many projections would lose their elegant and popular properties. For this reason spherical reference surfaces are frequently used in mapping programs.

The modern standard for maps of Mars (since about 2002) is to use planetocentric coordinates. The meridian of Mars is located at Airy-0 crater.^[11]

Tidally-locked bodies have a natural reference longitude passing through the point nearest to their parent body: 0° the center of the primary-facing hemisphere, 90° the center of the leading hemisphere, 180° the center of the anti-primary hemisphere, and 270° the center of the trailing hemisphere.^[12] However, libration due to non-circular orbits or axial tilts causes this point to move around any fixed point on the celestial body like analemma.

See also

- American Practical Navigator
- Cardinal direction
- Ecliptic longitude
- Geodesy
- Geodetic system
- Geographic coordinate system
- Geographical distance
- Geotagging
- Great-circle distance
- History of longitude
- Island of the Day Before
- Latitude
- List of cities by longitude
- Meridian arc
- Natural Area Code
- Navigation
- Orders of magnitude
- Right ascension on celestial sphere
- World Geodetic System

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4. "Longitude clock comes alive"(<http://news.bbc.co.uk/2/hi/science/nature/1864737.stm>) BBC. March 11, 2002.
5. Denny, Mark (2012), *The Science of Navigation: From Dead Reckoning to GPS* (<https://books.google.com/books?id=ttDB6nnTBG8C&pg=PR105>) Johns Hopkins University Press, p. 105 **ISBN 9781421405605** "in 1610, Galileo thought he might win the Spanish longitude prize with his idea of measuring time by observing the moons of Jupiter ... The trouble with the method was in making accurate measurements of the four moons while on the deck of a moving ship at sea. This problem proved intractable, and the method was therefore not adopted"
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7. "λ = Longitude east of Greenwich (for longitude west of Greenwich, use a minus sign)."
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11. *Where is zero degrees longitude on Mars?*(http://www.esa.int/SPECIALS/Mars_Express/SEM0VQV4QWD_0.html) – Copyright 2000 – 2010 © European Space AgencyAll rights reserved.
12. *First map of extraterrestrial planet*(http://www.cfa.harvard.edu/image_archive/2007/31/lores.jpg) – Center of Astrophysics.

External links

- [Resources for determining your latitude and longitude](#)
 - [IAU/IAG Working Group On Cartographic Coordinates and Rotational Elements of the Planets and Satellites](#)
 - "Longitude forged": an essay exposing a hoax solution to the problem of calculating longitude, undetected in Dava Sobel's *Longitude*, from TLS, November 12, 2008.
 - [Board of Longitude Collection, Cambridge Digital Library](#)- complete digital version of the Board's archive
 - [Longitude And Latitude Of Points of Interest](#)
 - [Length Of A Degree Of Latitude And Longitude Calculator](#)
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