

CHAPTER 24

Time (1)

Time systems, planetary orbits, the seasons, and the measurement of days and years in aviation navigation.



Solar & Sidereal Time



Kepler's Laws



Seasons & Solstices



Hour Angle & GHA

Why Pilots Study Time

There are two primary applications for aviation time knowledge:

Standard Time: Different countries operate different local times. You must know how to determine the standard time in any country you operate to or through.

Sunrise/Sunset: You must be able to calculate when it gets light or dark at your destination — particularly if the aerodrome lacks lighting equipment.

Planetary Orbits and Kepler's Laws

The solar system consists of the Sun and its major planets, including Earth. The shape and mechanics of planetary orbits are governed by Kepler's three laws.

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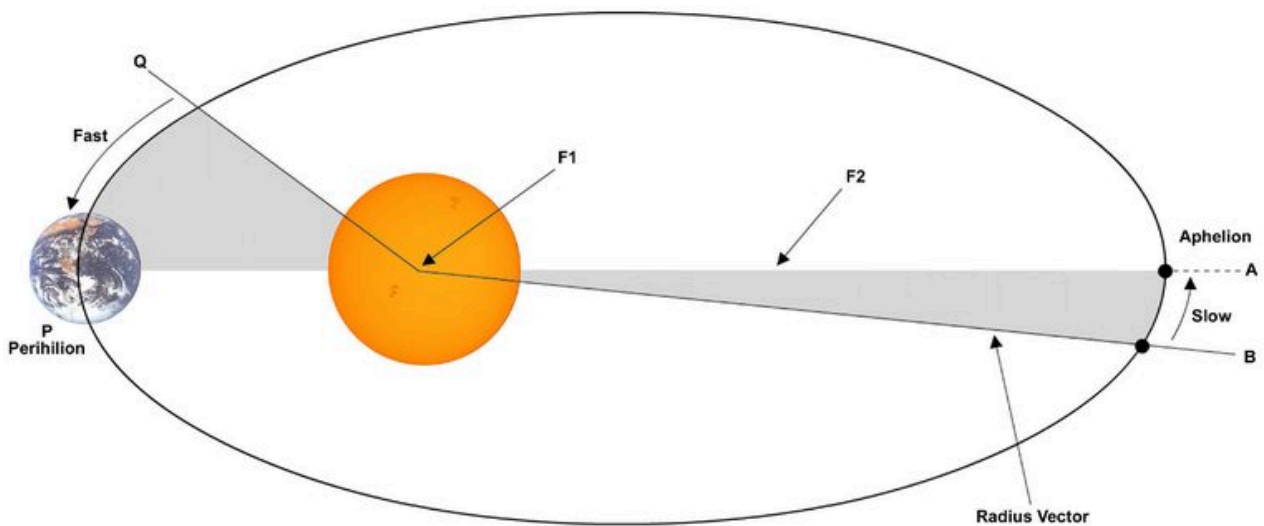


Figure 1 — Elliptical planetary orbit showing Sun at focal point $F1$, perihelion (P) and aphelion (A)

Kepler's First Law — Shape of the Orbit

A planet travels around the Sun in an **elliptical orbit**. The Sun is at one of the two foci of the ellipse ($F1$). The planet's two extreme positions are:

- **Perihelion (P)** — closest point to the Sun. Occurs around **4 January**. Distance ≈ 91.4 million statute miles.
- **Aphelion (A)** — furthest point from the Sun. Occurs around **4 July**. Distance ≈ 94.6 million statute miles.

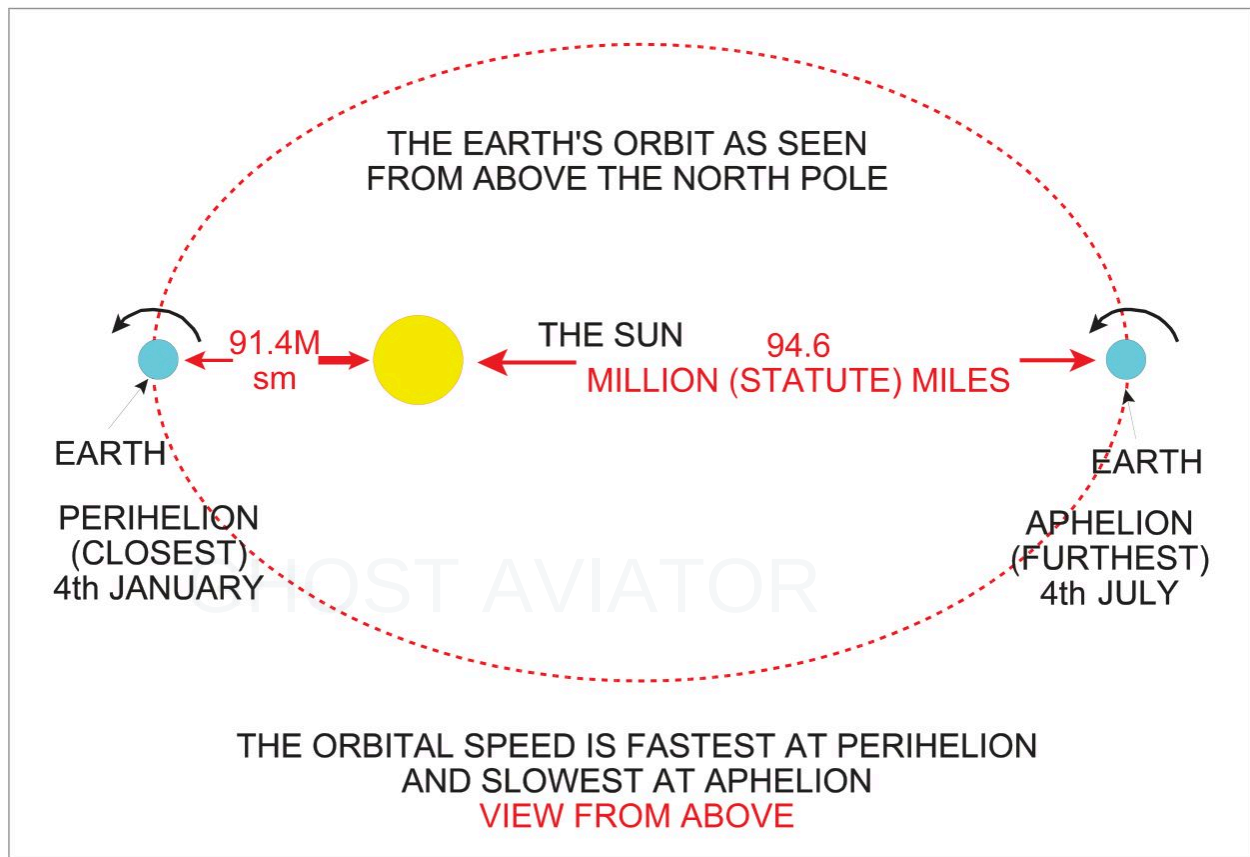


Figure 24.2 Earth orbit

Figure 2 — Kepler's Second Law — equal areas in equal times: radius vector sweeps equal areas ($SBA = SQP$)

Kepler's Second Law — Equal Areas in Equal Times

The radius vector (line from Sun to planet) sweeps out equal areas in equal times. Consequence: the planet moves **fastest near perihelion** and **slowest near aphelion**. This varying orbital speed affects our measurement of a day.

Kepler's Third Law — Period vs. Size

The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit. This determines the length of a year and the relative orbital periods of all planets.

The Seasons

The seasons are **not** caused by the Earth's distance from the Sun (the distance difference only changes solar heat by ~3%). The real cause is the **inclination (tilt) of the Earth's axis**:

The Earth's axis is inclined at 66.5° to its orbital plane — equivalently, 23.5° to the normal (perpendicular) to the orbital plane. This is called the *obliquity of the ecliptic*.

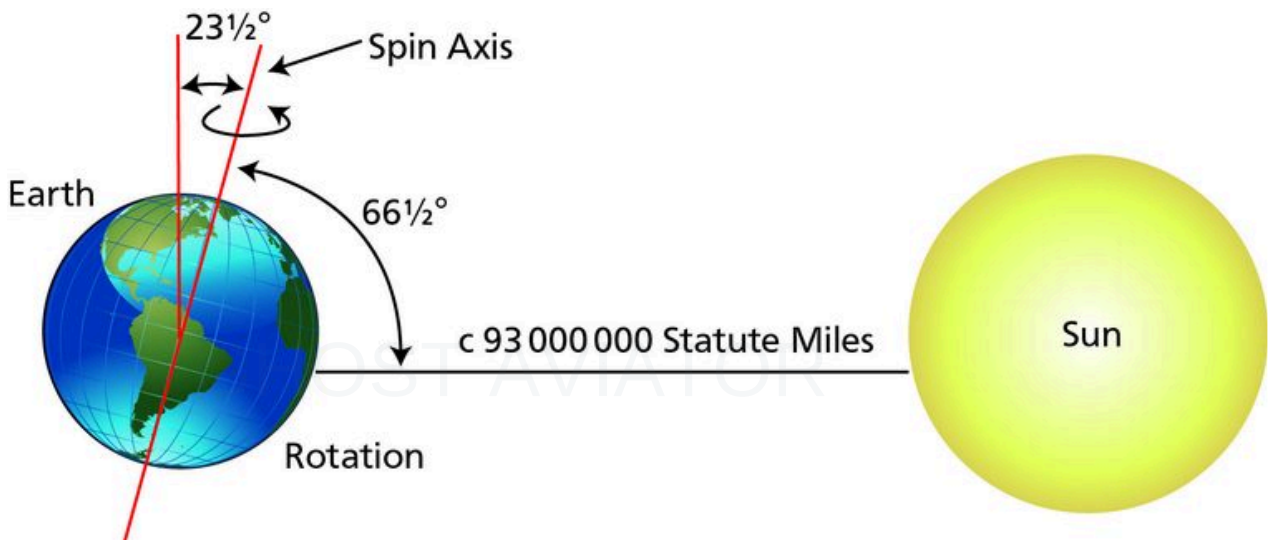


Figure 3 — Earth's orbit showing the tilted axis and changing relationship with the Sun throughout the year

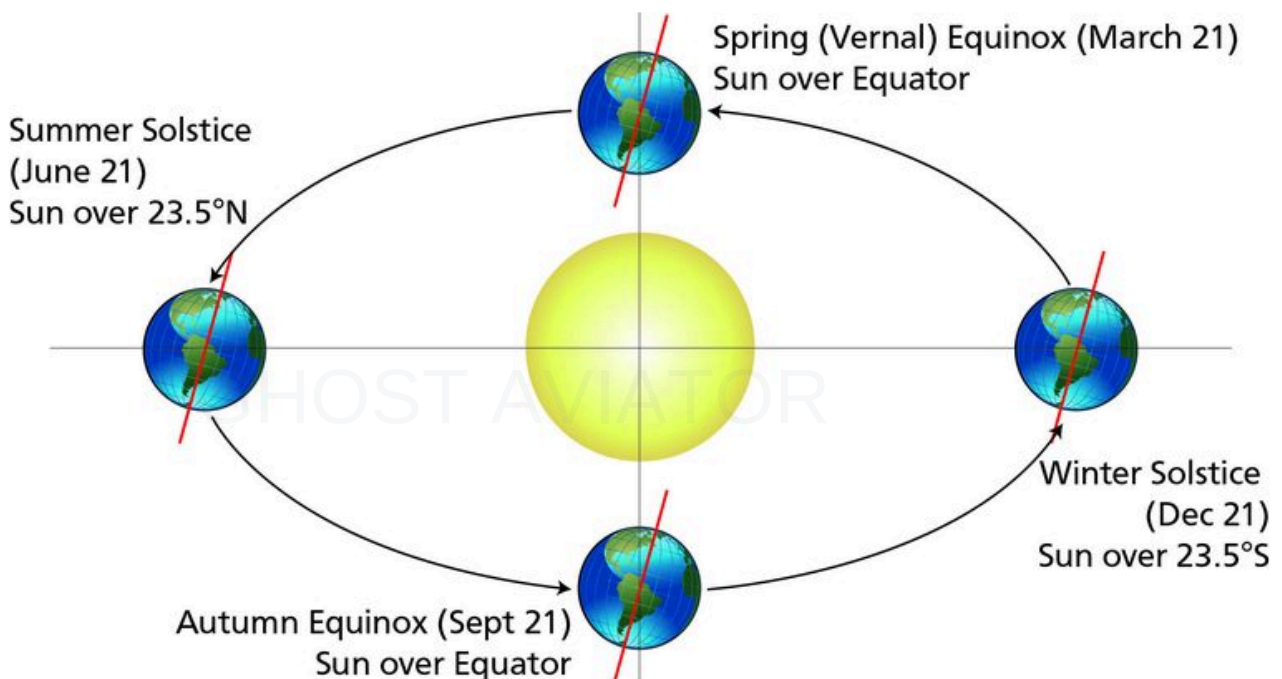


Figure 4 — The four seasons showing Earth's position at equinoxes and solstices



Summer Solstice (~21 June)



Winter Solstice (~21 December)

Sun overhead $23\frac{1}{2}^{\circ}\text{N}$ (Tropic of Cancer)
NH: Summer Solstice | SH: Winter Solstice
Longest day in NH, longest night in SH

Sun overhead $23\frac{1}{2}^{\circ}\text{S}$ (Tropic of Capricorn)
NH: Winter Solstice | SH: Summer Solstice
Longest night in NH, longest day in SH

Vernal (Spring) Equinox (~21 March)

Sun crosses Equator **South** → **North**
NH: Spring Equinox | SH: Autumn Equinox
Equal day and night worldwide

Autumnal Equinox (~21 September)

Sun crosses Equator **North** → **South**
NH: Autumn Equinox | SH: Spring Equinox
Equal day and night worldwide

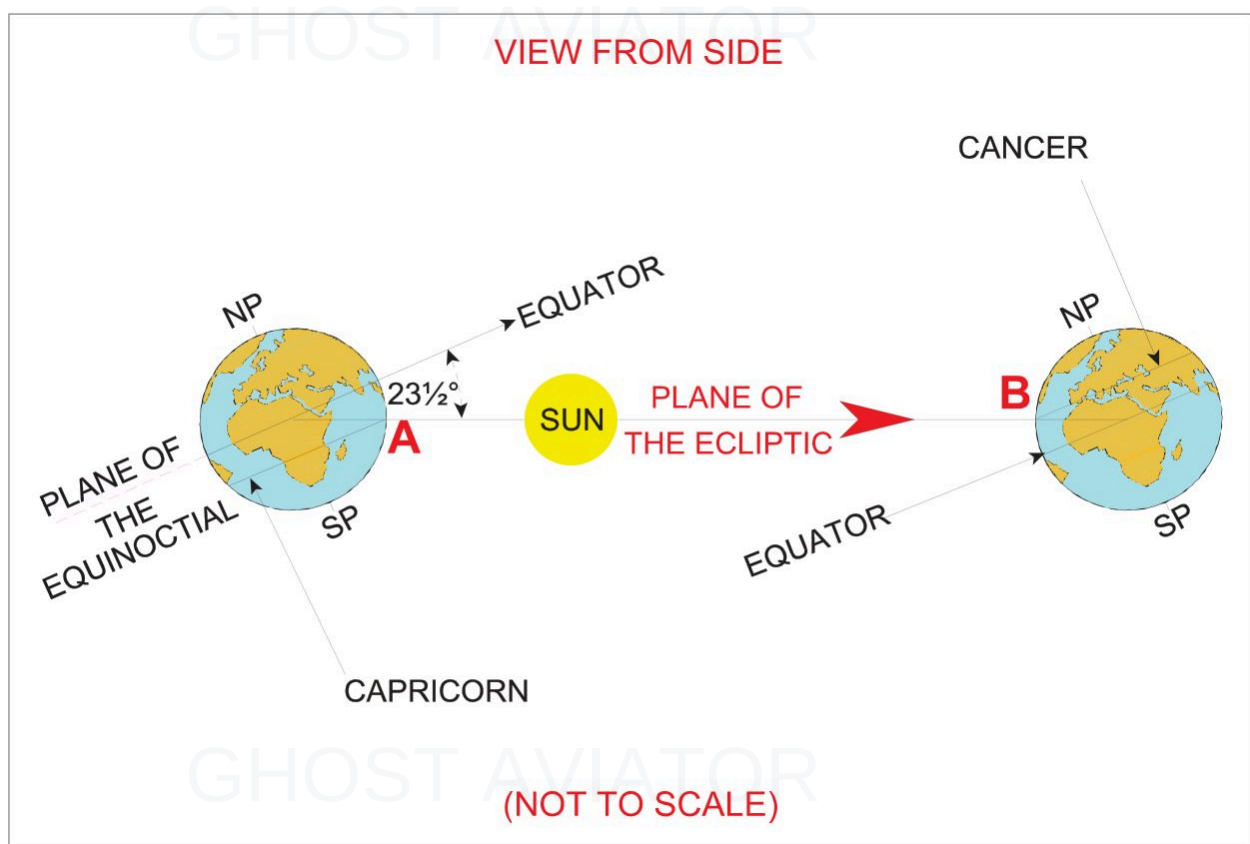


Figure 5 — Earth's orbit viewed from the side, showing the plane of the ecliptic and equinoctial

Declination

The angle the Sun is above or below the Equator is called **Declination**. It is analogous to *latitude* on the Earth. The Sun's declination cycles annually between 23.5°N and 23.5°S .

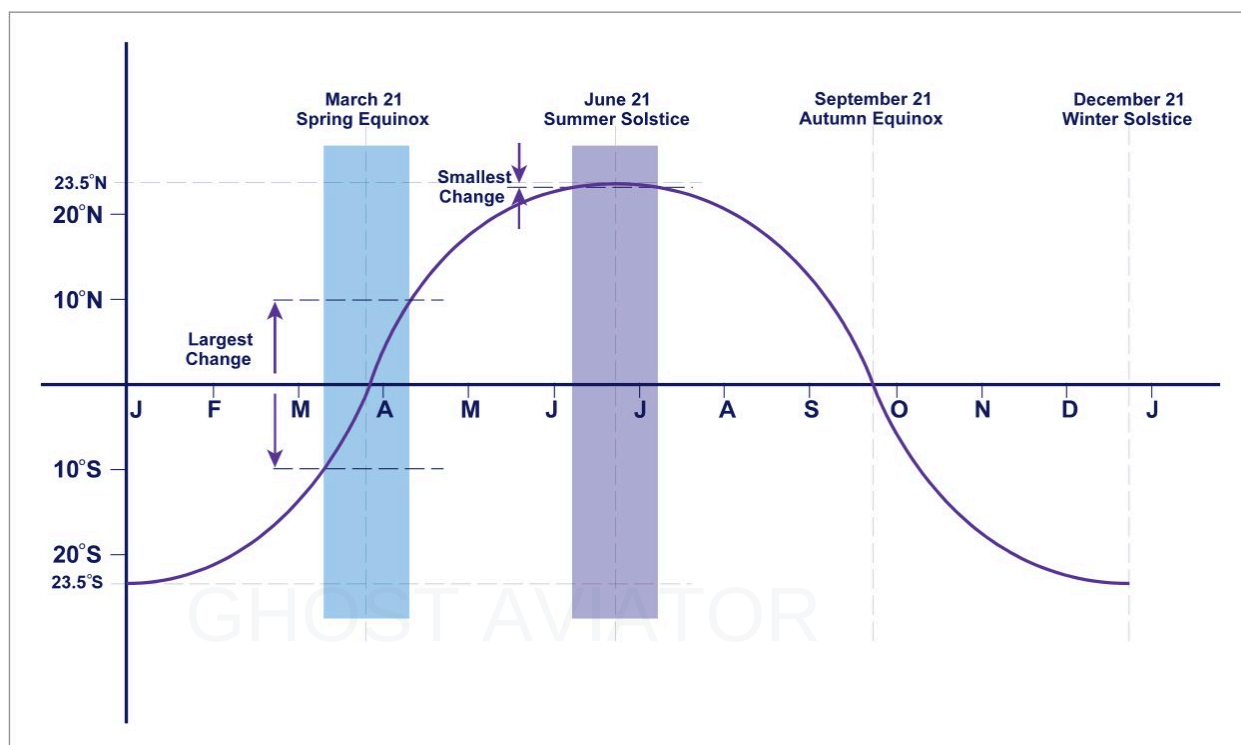


Figure 34.6 — Declination of the Sun

Figure 6 — Annual cycle of the Sun's declination — from 23.5°N at summer solstice to 23.5°S at winter solstice

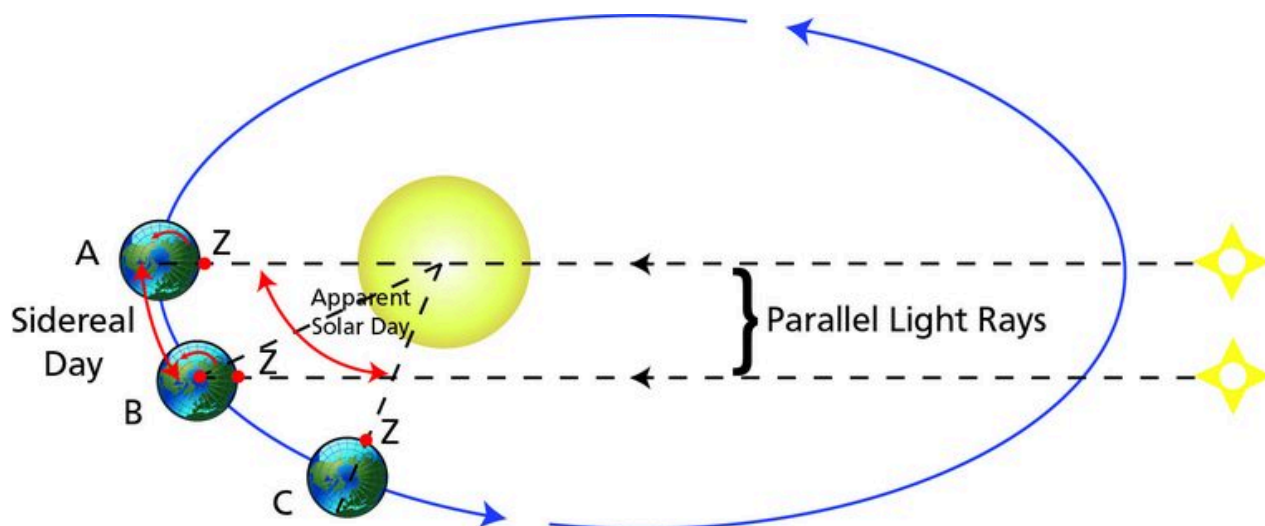
The Plane of the Ecliptic (the Earth's orbital plane) and the Plane of the Equinoctial (the Earth's equatorial plane extended to the sky) are inclined at 23.5° — the obliquity of the ecliptic.

Measurement of Days and Years

A 'day' is the time taken for the Earth to rotate once about its axis, measured against a celestial body. Measurement against a *star* produces a **sidereal** day; against the *Sun*, a **solar** day.

Requirements for a Civil Day

- ✓ **Related to light and darkness** — 1200 hrs must always be roughly midway between sunrise and sunset (solar-based).
- ✓ **Constant length** — must not vary day to day.



Note: The movement of the Earth along its orbit has been exaggerated for clarity

Figure 7 — Comparison of sidereal and solar day — Earth must rotate slightly beyond 360° to bring the Sun back to the meridian

Types of Day

Type	Reference	Length	Civil Use?
Sidereal Day	Distant star	23 hrs 56 min 04 sec	No — not related to Sun
Apparent Solar Day	Real/apparent Sun	Varies throughout year	No — variable length
Mean Solar Day	Imaginary mean Sun	24 hrs (exactly, by definition)	☒ YES — the civil day

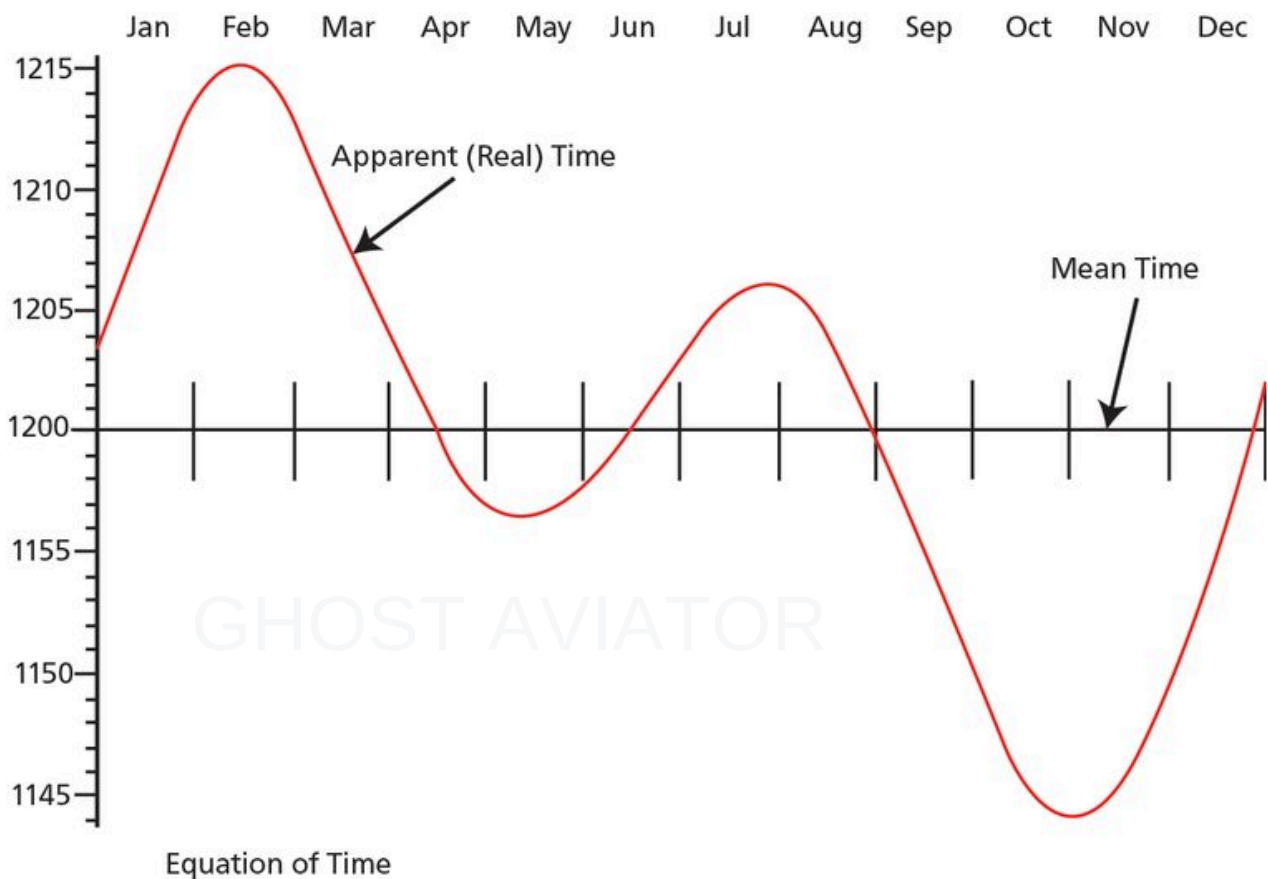


Figure 8 — Earth positions demonstrating why the apparent solar day varies in length throughout the year due to elliptical orbit

The Equation of Time

The difference between *apparent noon* (when the real Sun transits the meridian) and *mean noon* (1200 LMT) is called the **Equation of Time**. It results from the Earth's elliptical orbit and the inclination of the ecliptic.

📌 Maximum values: approximately **+16 minutes in November** and **−14 minutes in February**.

📌 The equation of time is **zero** around the equinoxes and solstices.

Types of Year

Type	Definition	Length
Sidereal Year	Earth's orbit measured against a distant star	365 days 6 hrs

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Tropical Year	One complete cycle of the seasons	365 d 5 h 48.75 min
Calendar Year	Civil year, kept in step with tropical year	Normally 365 days; 366 in leap year

Leap Year Rule

Step 1: Every 4th year is a leap year (366 days).

Step 2: Centennial years (1800, 1900, 2100...) are NOT leap years — unless the first two digits are divisible by 4.

Step 3: Exception to the exception: 1600, 2000, 2400 *are* leap years (16, 20, 24 are divisible by 4).

Hour Angle (GHA / LHA)

Hour Angle is a celestial coordinate that is analogous to **longitude** on Earth. It measures how far westward a celestial body is from a reference meridian.

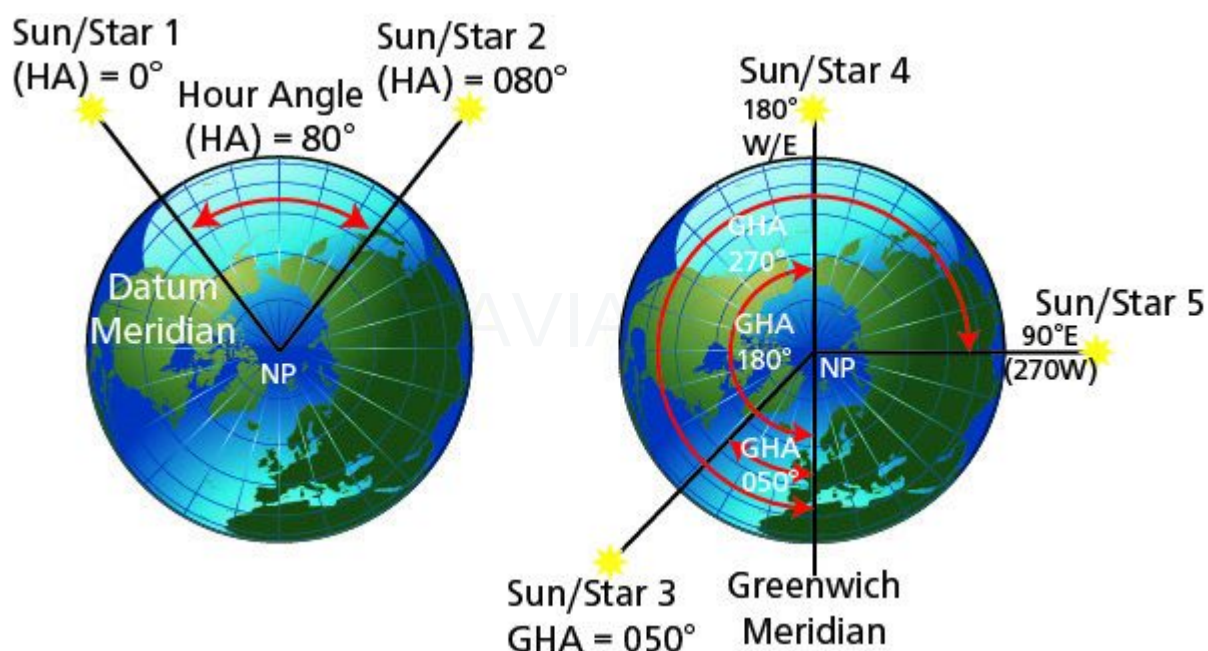


Figure 9 — Hour angle diagram showing GHA measured westward from the Greenwich Meridian to the body's meridian

 **Greenwich Hour Angle (GHA)** — angle measured *westward* from the Greenwich Meridian to the meridian of the body (0° to 360°).

 **Local Hour Angle (LHA)** — angle measured *westward* from the observer's meridian to the body's meridian.

 **Relationship:** $LHA = GHA + \text{East Longitude}$ (or $GHA - \text{West Longitude}$)

Key rule: GHA 220° means the body is 220° west of Greenwich. Converting: $360^\circ - 220^\circ = 140^\circ\text{E}$. The body is transiting the 140°E meridian.

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Practice Questions

▼ Q1. When does perihelion occur?

a) early January

b) mid March

c) early July

d) September 21

Answer: (a) — Perihelion (closest point to Sun) occurs around 4 January.

▼ Q2. When does aphelion occur?

a) early January

b) mid March

c) early July

d) September 21

Answer: (c) — Aphelion (furthest point from Sun) occurs around 4 July.

▼ **Q3. Viewed from the North Celestial Pole (above the North Pole), the Earth orbits the Sun:**

- a) clockwise in a circular orbit
- b) anticlockwise in a circular orbit
- c) clockwise in an elliptical orbit
- d) anticlockwise in an elliptical orbit**

Answer: (d) — Viewed from above the North Pole, Earth's orbit is anticlockwise and elliptical (Kepler's First Law).

▼ **Q4. When do the equinoxes occur?**

- a) December and June
- b) February and November
- c) March and September**
- d) January and July

Answer: (c) — Equinoxes occur approximately 21 March (Spring/Vernal) and 21 September (Autumn).

▼ **Q5. When it is the Winter Solstice in the Southern hemisphere, the Declination of the Sun is:**

- a) 0°N/S
- b) $23\frac{1}{2}^{\circ}\text{N}$**
- c) $66\frac{1}{2}^{\circ}\text{N}$

d) $23\frac{1}{2}^{\circ}\text{S}$

Answer: (b) — SH Winter Solstice = NH Summer Solstice (≈ 21 June) $\rightarrow$ Sun overhead Tropic of Cancer $\rightarrow$ Declination $23\frac{1}{2}^{\circ}\text{N}$.

▼ **Q6. In the situation of Question 5, the Sun will be overhead:**

a) the Arctic Circle

b) the Tropic of Capricorn

c) the Equator

d) the Tropic of Cancer

Answer: (d) — At Declination $23\frac{1}{2}^{\circ}\text{N}$, the Sun is directly overhead the Tropic of Cancer.

▼ **Q7. What is the angle between the Equinoctial and the Ecliptic?**

a) $66\frac{1}{2}^{\circ}$

b) $23\frac{1}{2}^{\circ}$

c) varies between $23\frac{1}{2}^{\circ}\text{N}$ and $23\frac{1}{2}^{\circ}\text{S}$

d) varies between $66\frac{1}{2}^{\circ}\text{N}$ and $66\frac{1}{2}^{\circ}\text{S}$

Answer: (b) — The obliquity of the ecliptic (angle between Equatorial plane and Ecliptic plane) is $23\frac{1}{2}^{\circ}$.

▼ **Q8. The declination of a celestial body (the Sun) measured on the Celestial Sphere is analogous to _____ on the Earth?**

a) latitude

b) longitude

c) altitude of the body measured from the sensible horizon

d) co-latitude

Answer: (a) — Declination on the Celestial Sphere is the equivalent of latitude on Earth — both measure angular distance from an equatorial plane.

▼ **Q9. 'The length of daylight/night depends upon the declination of the Sun and the latitude of the observer'. When is the rate of change of the length of daylight greatest?**

a) February/November

b) January/July

c) at the Equinoxes

d) at the Solstices

Answer: (c) — The Sun's declination changes fastest at the Equinoxes (crossing 0°), so the rate of change of daylight length is maximum at the Equinoxes.

▼ **Q10. A sidereal day is:**

a) longer than an apparent solar day

b) longer than a real solar day

c) shorter than an apparent solar day

d) equal to a real solar day

Answer: (c) — A sidereal day (~23h 56m) is shorter than an apparent solar day (~24h) because after one full Earth rotation, the Earth has also moved slightly along its orbit, requiring extra rotation to bring the Sun back to the meridian.

▼ **Q11. The maximum difference between mean noon (1200 LMT) and real/apparent noon occurs in:**

a) January/July

b) March/September

c) November/February

d) December/June

Answer: (c) — The Equation of Time reaches its peak values in November ($\sim +16$ min) and February (~ -14 min).

▼ Q12. The maximum difference between mean time and apparent time is:

a) 21 minutes

b) 16 minutes

c) 30 minutes

d) there is no difference

Answer: (b) — The maximum value of the Equation of Time is approximately 16 minutes (occurring in November).

▼ Q13. What is the length of a Sidereal Year?

a) 365 days

b) 366 days

c) 365 days 6 hrs

d) 365 days 5 hrs 48.75 minutes

Answer: (c) — A Sidereal Year (Earth orbit measured against a distant star) = 365 days 6 hours. The Tropical Year is slightly shorter at 365 d 5 h 48.75 min.

▼ **Q14. The Calendar Year and the Tropical Year are of different lengths, adjusted partly by leap years. Which of the following years will be a leap year?**

a) 2001

b) 2100

c) 2300

d) 2400

Answer: (d) — Centennials are only leap years when the first two digits are divisible by 4. $24 \div 4 = 6$ (exact), so 2400 IS a leap year. 2100, 2200, 2300 are not (21, 22, 23 are not divisible by 4).

▼ **Q15. The Hour Angle (Greenwich Hour Angle) of a celestial body is analogous/equivalent on the Earth to _____?**

a) latitude

b) longitude

c) co-latitude

d) UTC

Answer: (b) — GHA is analogous to longitude — both measure angular distance westward from a reference meridian (Greenwich).

▼ **Q16. A star has a Greenwich Hour Angle (GHA) of 220° . Which meridian is the star transiting (crossing)?**

a) 040W

b) 040E

c) 140W

d) 140E

Answer: (d) — GHA is measured westward from Greenwich. $\text{GHA } 220^\circ\text{W} = 360^\circ - 220^\circ = 140^\circ\text{E}$. The star is transiting the 140°E meridian.

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