Sun position

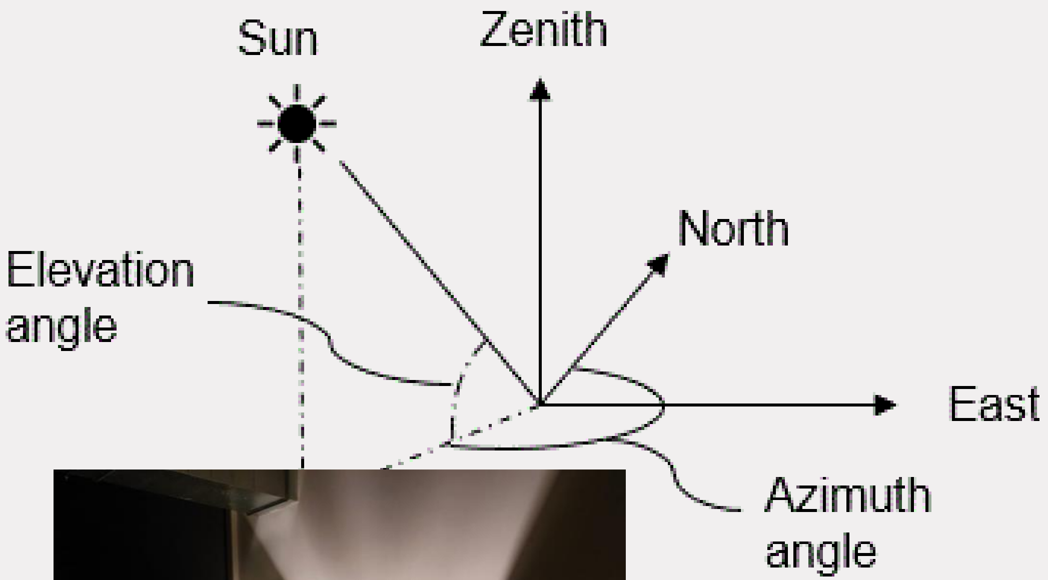
Sun position

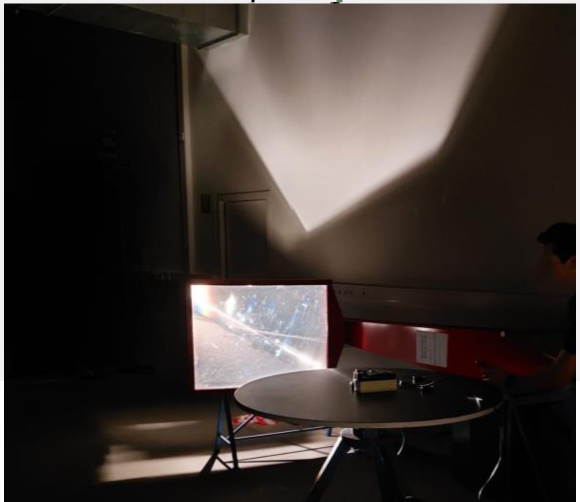
Sun position:

- Sun elevation angle γ_S
- Sun azimuth angle α_S

Depends on:

- Geographical latitude φ_B
- Sun declination δ_S
- Hour angle τ_S





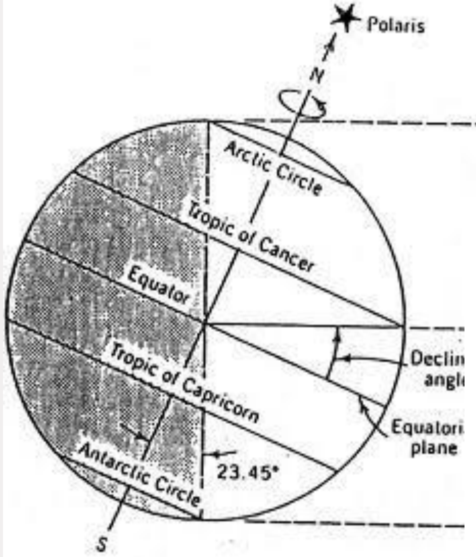
Sun position

Sun position:

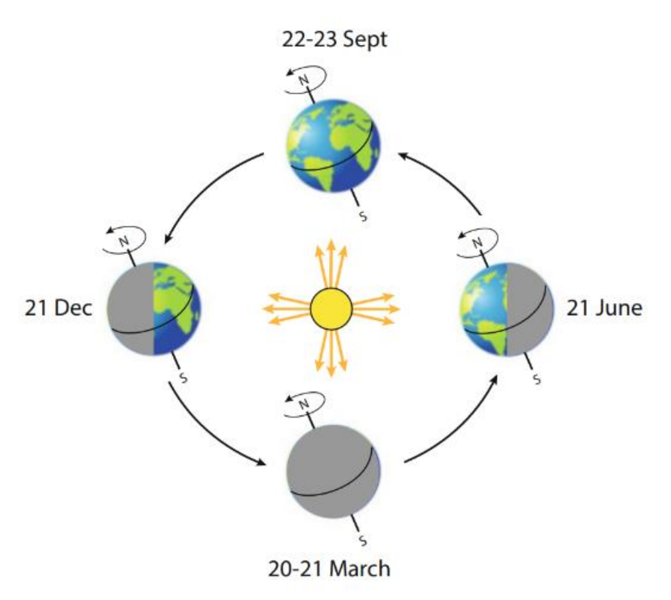
- Sun elevation angle γ_S
- Sun azimuth angle α_S

Depends on:

- Geographical latitude φ_B
- **Sun declination δ_S**
- Hour angle τ_S



The **earth's equator is tilted** 23.45 degrees with respect to the plane of the earth's orbit around the sun, so at various times during the year, as the earth orbits the sun, declination **varies from 23.45 degrees north to 23.45 degrees south.**



Van Bommel. Interior Lighting (2019).

Sun position

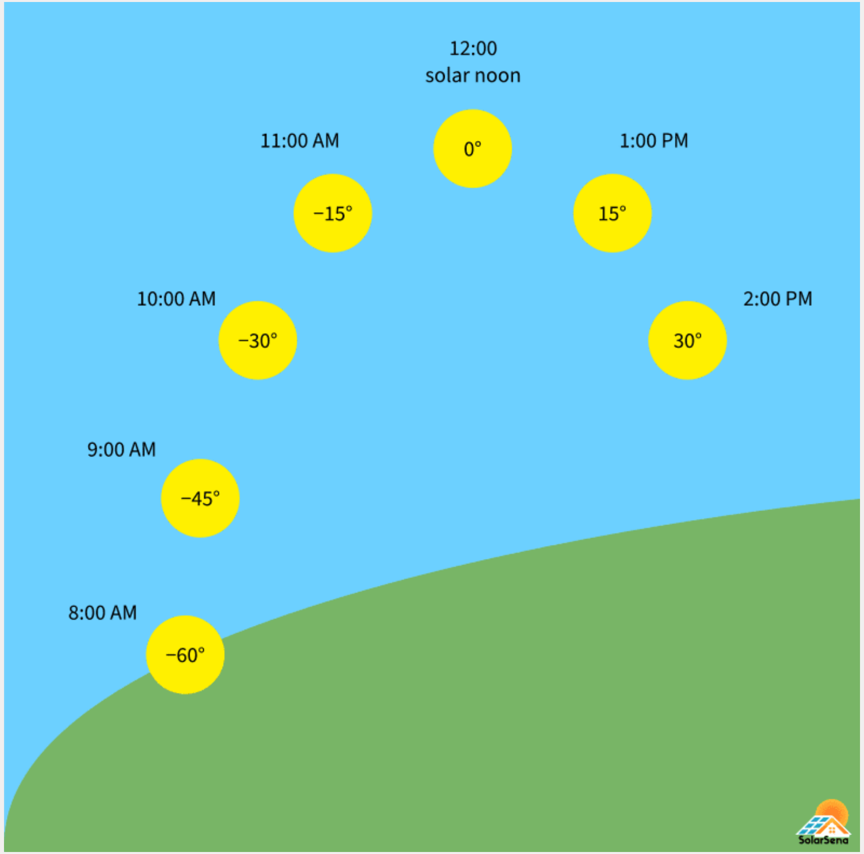
Sun position:

- Sun elevation angle γ_S
- Sun azimuth angle α_S

Depends on:

- Geographical latitude φ_B
- Sun declination δ_S
- **Hour angle $\boldsymbol{\tau_S}$**

The hour angle is the angular displacement of the sun east or west of the local meridian due to **rotation of the earth on its axis** at 15° per hour with **morning being negative and afternoon being positive**.



Sun position | Calculation

$$\gamma_S = \arcsin(\cos\varphi_B \cdot \cos\delta_S \cdot \cos\tau_S + \sin\varphi_B \cdot \sin\delta_S)$$

$$\alpha_S = \begin{cases} 180° - \arccos\left(\dfrac{\sin\gamma_S \cdot \sin\varphi_B - \sin\delta_S}{\cos\gamma_S \cdot \cos\varphi_B}\right) & for\ TST\ \leq 12.00\ h \\ 180° + \arccos\left(\dfrac{\sin\gamma_S \cdot \sin\varphi_B - \sin\delta_S}{\cos\gamma_S \cdot \cos\varphi_B}\right) & for\ TST > 12.00\ h \end{cases}$$

φ_B: Geographical latitude

δ_S: Sun declination

τ_S: Hour angle

TST: True Solar Time

North α_S=0°

East α_S=90°

South α_S=180°

West α_S=270°

Sun position | Calculation

Geographical latitude φ_B of Eindhoven: 51.4°

https://www.fonq.nl/product/city-shapes-skyline-eindhoven-klein/354910/

Sun position | Calculation

The sun declination δ_S can be approximated by Fourier series:

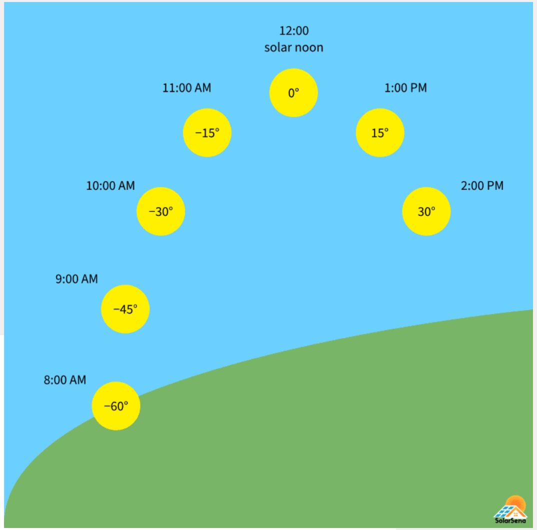
$$\delta_S\,(J) = 0.3948 - 23.2559 \times \cos(J' + 9.1°) - 0.3915 \times \cos(2 \times J' + 5.4°) - 0.1764 \times \cos(3 \times J' + 26°)$$

δ_S: Sun declination

J: Day of the year (Jan 1=1, Dec 31=365)

$$J' = \frac{360° \times J}{365}$$

Sun position | Calculation



The hour angle τ_s can be calculated:

For calculating the sun position, it is necessary to specify the hour angle ω_η

$$\omega_\eta = (12{,}00\,\mathrm{h} - TST) \times 15^o$$

The hour angle ω_η is counted from the meridian as positive towards the afternoon and negative towards the morning. The following then applies for solar altitude

EN 17037: 2018

Sun position | Calculation

The hour angle τ_S can be calculated:

$$\tau_S = \begin{cases} -15° \cdot |(12{:}00h - TST)| \; for \; TST < 12.00 \\ 15° \cdot |(12{:}00h - TST)| \; for \; TST > 12.00 \end{cases}$$

$$TST = LT + \frac{\lambda_B - \lambda_s}{15} + ET$$

$$ET(J) = 0.0066 + 7.3525 \times \cos(J' + 85.9°) + 9.9359 \times \cos(2 \times J' + 108.9°) + 0.3387 \times \cos(3 \times J' + 105.2°)$$

"correction" in minutes

τ_S: Hour angle

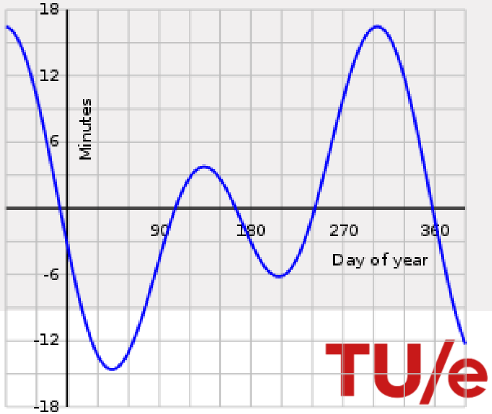
TST: True Solar Time

LT: Local clock Time

λ_B: Geographical longitude

λ_S: Longitude of the standard time meridian (15° in the NL)

ET: Equation of Time



Sun position | Calculation

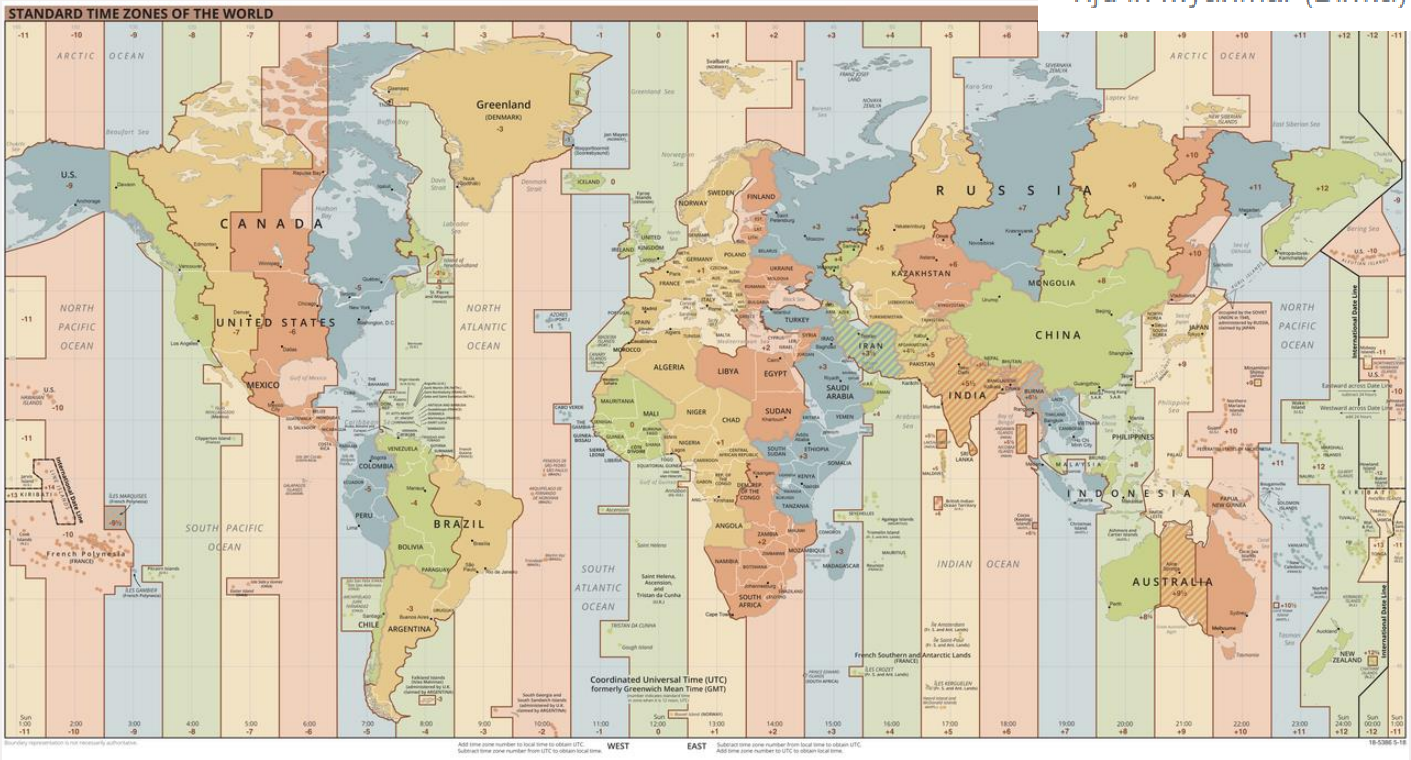
24 hours

What is the width in degrees between two time zones?

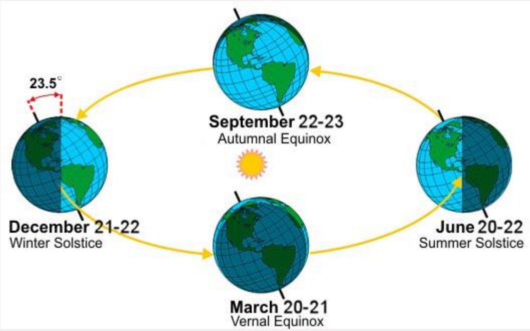
Sun position | Calculation

16:38

vrijdag 24 november 2023 (GMT+6:30)
Tijd in Myanmar (Birma)



Sun position | Calculation



Equation of time

The variation in the length of an apparent solar day is a result of two factors.

1. The Earth's orbit is elliptical—it's a slightly squashed circle, not a perfect circle. When the Earth is closer to the Sun, it travels more quickly along its orbit.
2. The Earth's spin axis is tilted—around the solstices, one of the Earth's poles is leaning toward the Sun. Around the equinoxes, neither pole is leaning toward the Sun.

- Our clocks and watches ignore these differences in the Sun's movement. To these steadily ticking devices, every day is an average day of exactly 24 hours.
- This form of steady, average time is called mean solar time.
- The difference between apparent solar time and mean solar time is called the equation of time.

Sun position | Calculation

Calculate the sun position (γ_S, α_S) in the NL (λ_B = 5°, φ_B = 52°) for today at 3pm.

1. Determine the day of the year

Day = 328

Sun position | Calculation

Calculate the sun position (γ_S, α_S) in the NL (λ_B = 5°, φ_B = 52°) for today at 3pm.

2. Determine the TST

$$J' = \frac{360° \times J}{365}$$

J' = 323.5068

$$ET(J) = 0.0066 + 7.3525 \times \cos(J' + 85.9°) + 9.9359 \times \cos(2 \times J' + 108.9°) + 0.3387 \times \cos(3 \times J' + 105.2°)$$

ET = 13.1756 min

ET = 0.2196 h

$$TST = LT + \frac{\lambda_B - \lambda_S}{15} + ET$$

TST = 14,5529 (14:33)

λ_S: Longitude of the standard time meridian (15°)

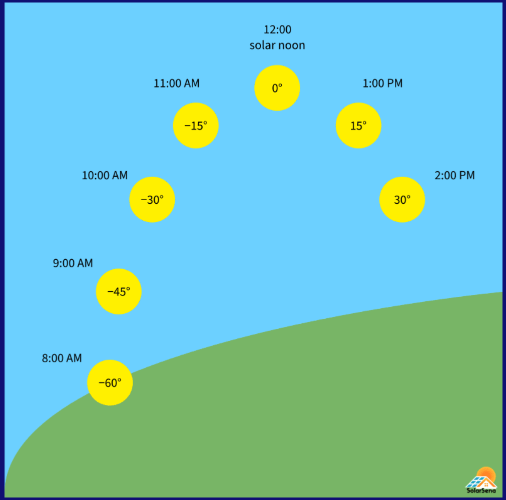
Sun position | Calculation

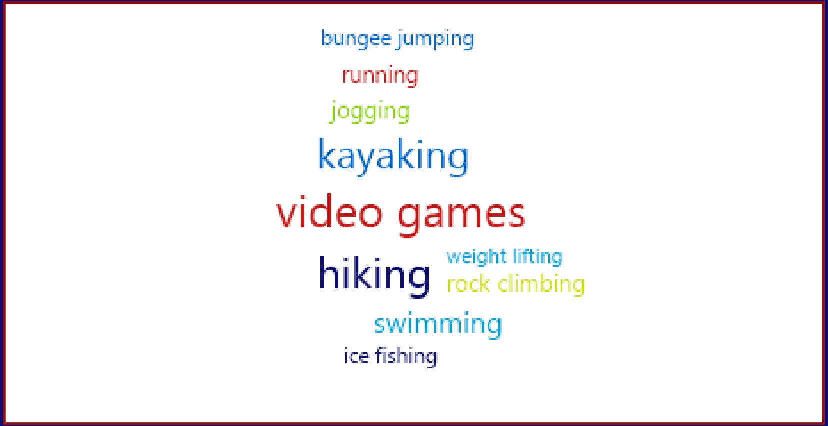
Calculate the sun position (γ_S, α_S) in the NL (λ_B = 5°, φ_B = 52°) for today at 3pm.

3. Determine the hour angle

$$\tau_S = \begin{cases} -15° \cdot |(12{:}00h - TST)| \; for \; TST < 12.00 \\ 15° \cdot |(12{:}00h - TST)| \; for \; TST > 12.00 \end{cases}$$

τ_S =38.2939°





TU/e

Sun position | Calculation

Calculate the sun position (γ_S, α_S) in the NL (λ_B = 5°, φ_B = 52°) for today at 3pm.

4. Determine the sun declination

$$\delta_S\,(J) = 0.3948 - 23.2559 \times \cos(J' + 9.1°) - 0.3915 \times \cos(2 \times J' + 5.4°) - 0.1764 \times \cos(3 \times J' + 26°)$$

δ_S =-20.4227°

Sun declination:
The earth's equator is tilted 23.45 degrees with respect to the plane of the earth's orbit around the sun, so at various times during the year, as the earth orbits the sun, declination varies from 23.45 degrees north to 23.45 degrees south.

Sun position | Calculation

τ_S =38.2939°

δ_S =-20.4227°

(γ_S, α_S) = (10.2448°,216.1678°)

(γ_S, α_S) = (10°,216°)

Calculate the sun position (γ_S, α_S) in the NL (λ_B = 5°, φ_B = 52°) for today at 3pm.

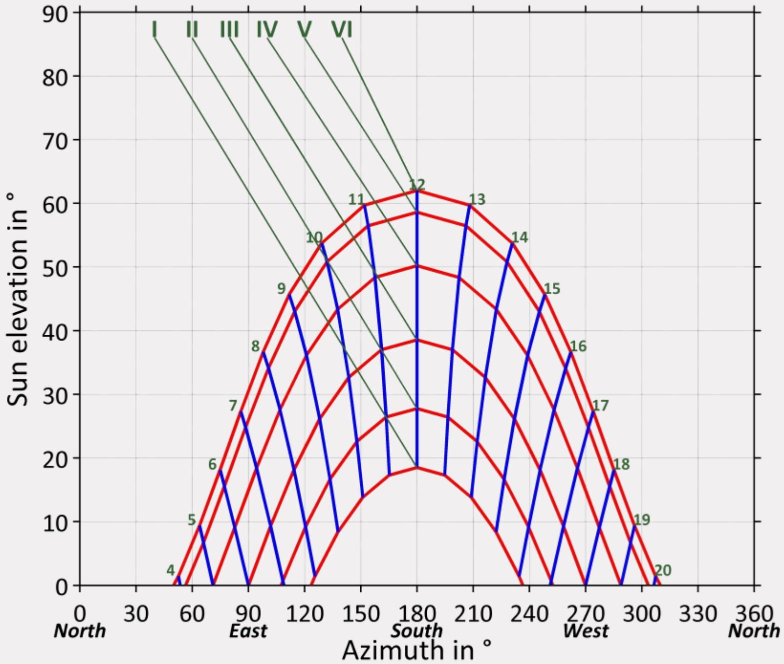
5. Determine the sun position (γS, αS)

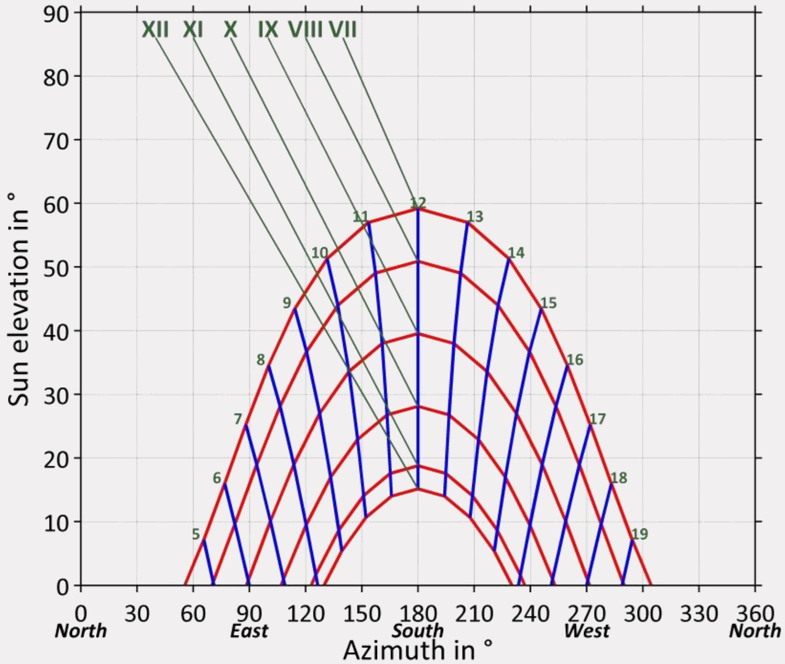
$$\gamma_S = \arcsin(\cos\varphi_B \cdot \cos\delta_S \cdot \cos\tau_S + \sin\varphi_B \cdot \sin\delta_S)$$

$$\alpha_S = \begin{cases} 180° - \arccos\left(\dfrac{\sin\gamma_S \cdot \sin\varphi_B - \sin\delta_S}{\cos\gamma_S \cdot \cos\varphi_B}\right) & for\ TST\ \leq 12.00\ h \\ 180° + \arccos\left(\dfrac{\sin\gamma_S \cdot \sin\varphi_B - \sin\delta_S}{\cos\gamma_S \cdot \cos\varphi_B}\right) & for\ TST > 12.00\ h \end{cases}$$

Practice exercise available!

Sun position | Sun chart

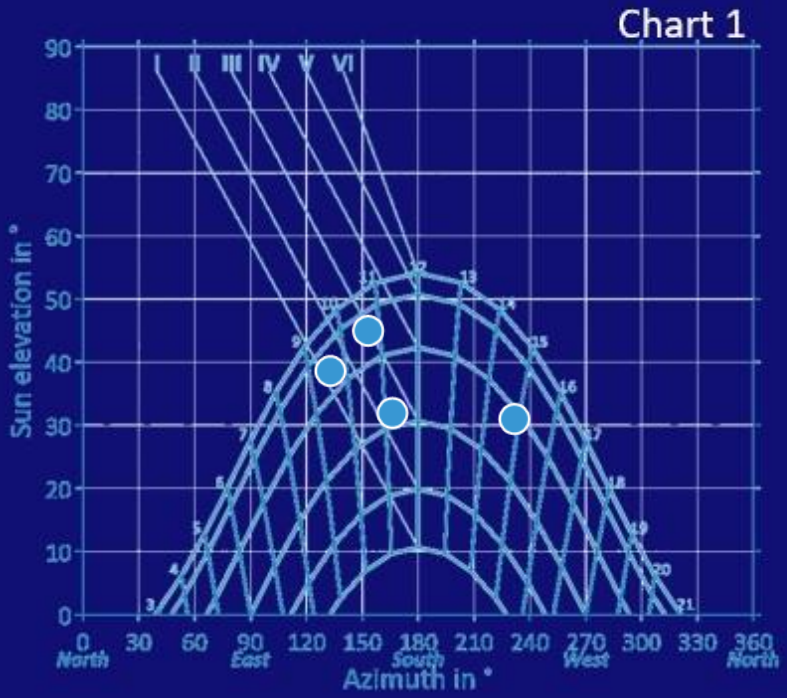




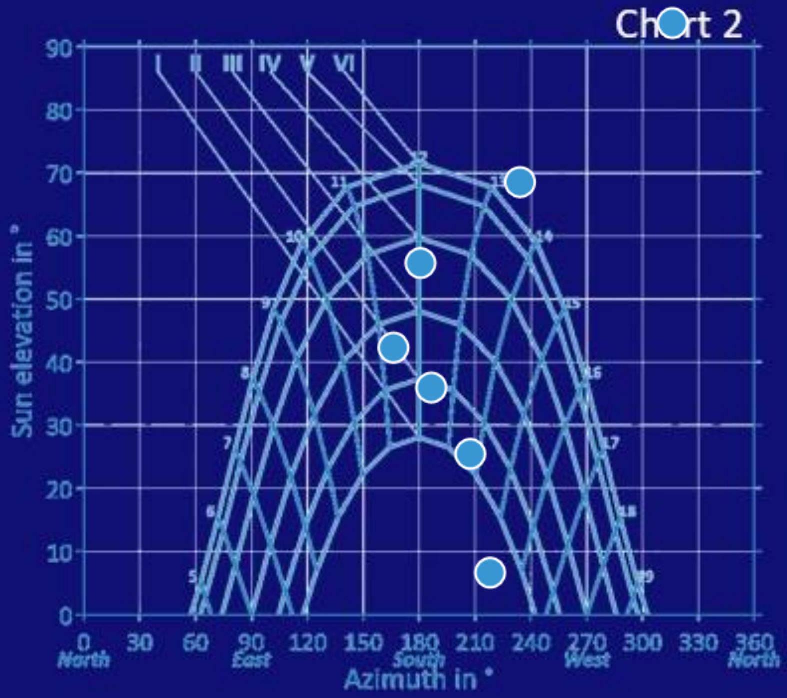
$$\varphi_B(Eindhoven) = 51.4°$$

Sun position | Sun chart

One sun chart belongs to Rome and one to Stockholm. Which chart belongs to Rome?

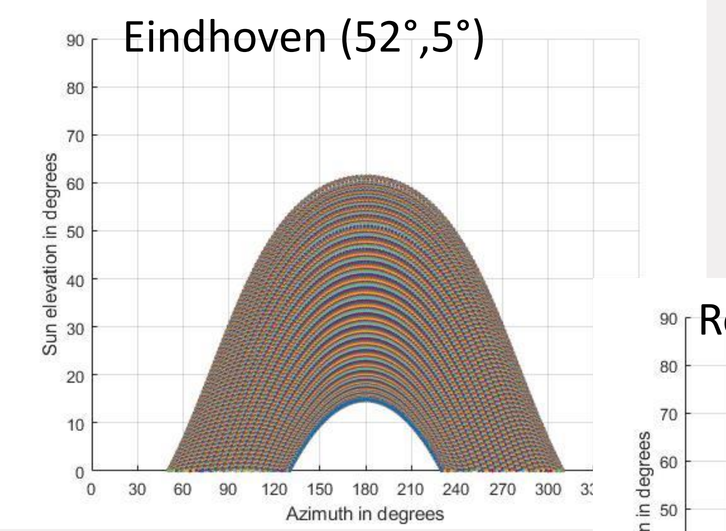


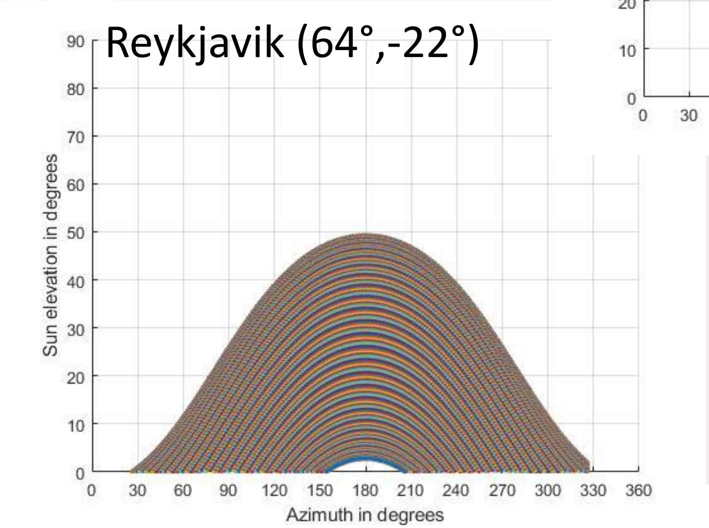
$\varphi_B(Stockholm) = 59.3°$

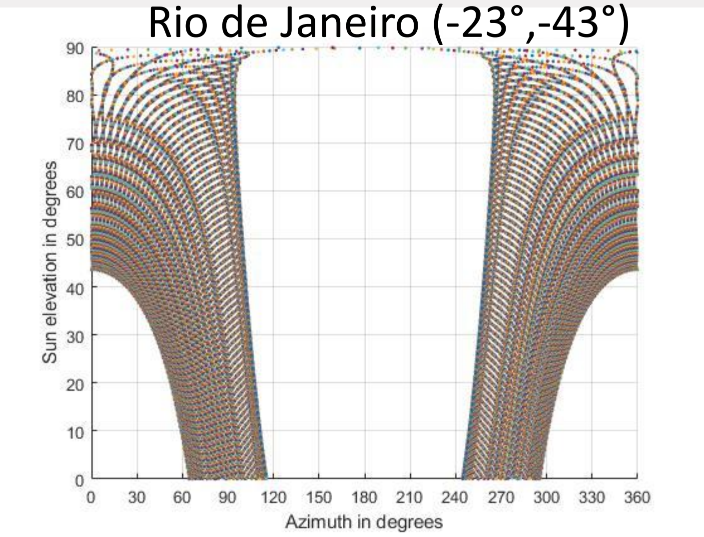


$\varphi_B(Rome) = 41.9°$

Sun position | Sun chart







Sun position | Sunrise and sunset

$$\gamma_S = \arcsin(\cos\varphi_B \cdot \cos\delta_S \cdot \cos\tau_S + \sin\varphi_B \cdot \sin\delta_S)$$

Set $\gamma_S = 0$ and solve for time:

$$t_{sr} = 12 - \frac{\arccos(-\tan\varphi_B \cdot \tan\delta_S)}{15}$$

$$t_{ss} = 12 + \frac{\arccos(-\tan\varphi_B \cdot \tan\delta_S)}{15}$$

$In\ TST!$

φ_B: Geographical latitude

δ_S: Sun declination

τ_S: Hour angle

Sun position | Sunrise and sunset

δ_S =-20.4227°

$t_{ss,TST}$ = 16.5496 h (16:33)

φ_B: Geographical latitude
δ_S: Sun declination
τ_S: Hour angle

At what time (LT) will the sun set in Eindhoven today?

A. 16:00

B. 16:06

C. 16:13

D. 16:28

E. 16:33

$$t_{ss} = 12 + \frac{\arccos(-\tan\varphi_B \cdot \tan\delta_S)}{15}$$

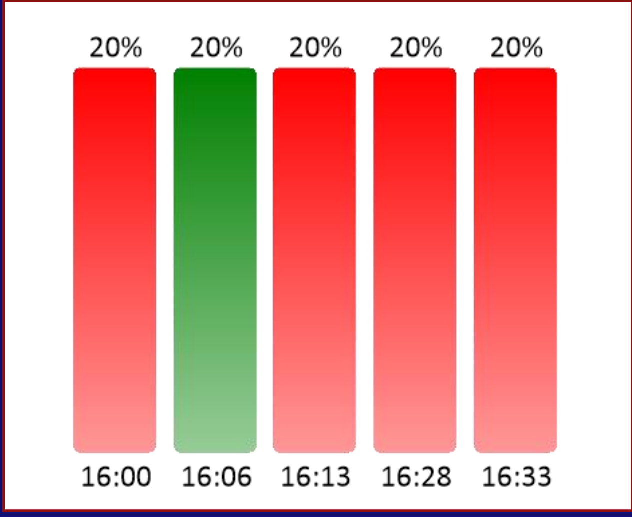
$$TST = LT + \frac{\lambda_B - \lambda_s}{15} + ET$$

λ_S: Longitude of the standard time meridian (15°)

ET = 11.556 min

ET = 0.1926 h

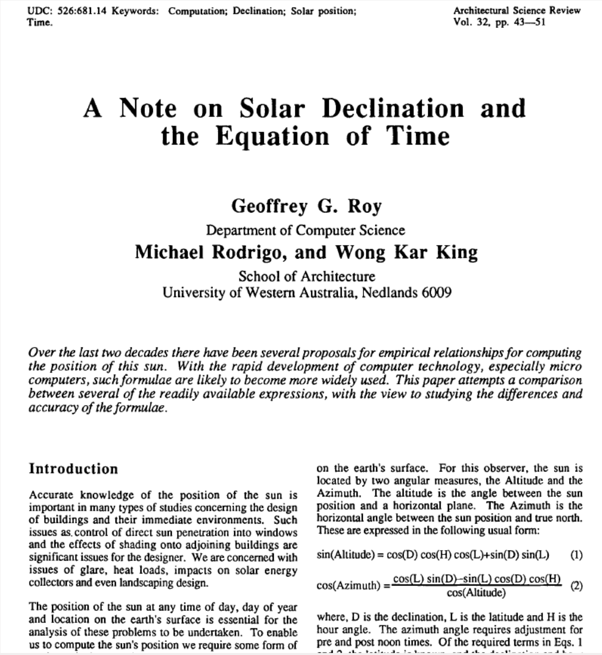
$T_{ss,LT}$ = 16.1025 h (16:06)



Sun position | Sunrise and sunset

Google

- Different equations for ET
- Definition of sun rise/sun set



UDC: 526:681.14 Keywords: Computation; Declination; Solar position; Time.

Architectural Science Review Vol. 32, pp. 43—51

A Note on Solar Declination and the Equation of Time

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Over the last two decades there have been several proposals for empirical relationships for computing the position of this sun. With the rapid development of computer technology, especially micro computers, such formulae are likely to become more widely used. This paper attempts a comparison between several of the readily available expressions, with the view to studying the differences and accuracy of the formulae.

Introduction

Accurate knowledge of the position of the sun is important in many types of studies concerning the design of buildings and their immediate environments. Such issues as control of direct sun penetration into windows and the effects of shading onto adjoining buildings are significant issues for the designer. We are concerned with issues of glare, heat loads, impacts on solar energy collectors and even landscaping design.

The position of the sun at any time of day, day of year and location on the earth's surface is essential for the analysis of these problems to be undertaken. To enable us to compute the sun's position we require some form of

on the earth's surface. For this observer, the sun is located by two angular measures, the Altitude and the Azimuth. The altitude is the angle between the sun position and a horizontal plane. The Azimuth is the horizontal angle between the sun position and true north. These are expressed in the following usual form:

$$\sin(\text{Altitude}) = \cos(D)\cos(H)\cos(L)+\sin(D)\sin(L) \quad (1)$$

$$\cos(\text{Azimuth}) = \frac{\cos(L)\sin(D)-\sin(L)\cos(D)\cos(H)}{\cos(\text{Altitude})} \quad (2)$$

where, D is the declination, L is the latitude and H is the hour angle. The azimuth angle requires adjustment for pre and post noon times. Of the required terms in Eqs. 1

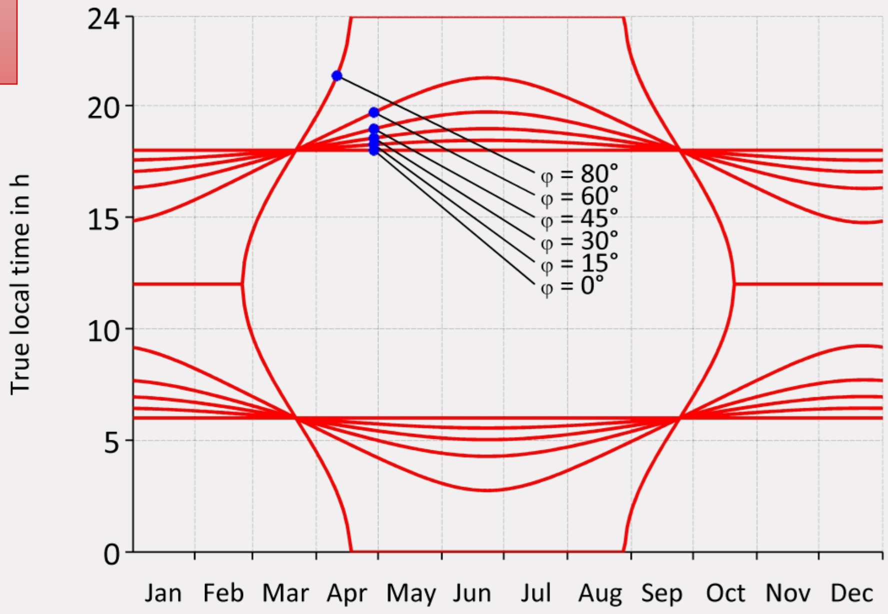
TU/e

Sun position | Daylight duration

$$T_D = t_{ss} - t_{sr} = 2 \cdot \frac{\arccos(-\tan\varphi_B \cdot \tan\delta_S)}{15}$$

$$T_a = \sum_{i=1}^{365} T_{D,i}$$

T_a (Eindhoven) = 4406 hours



Reference material

- EN 17037:2018. Daylight in buildings