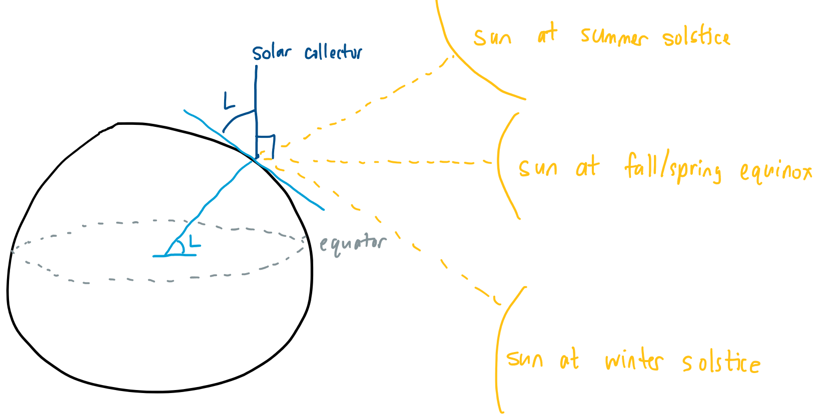
Solar Position

Thursday, February 1, 2024 3:59 PM

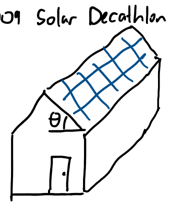
Can we use information from previous lecture to find a good tilt angle for solar collector?



Vancouver: $L = 49.3°$

- Good rule of thumb: tilt toward the equator by an angle L
  - ↳ south in Northern Hemisphere
  - ↳ north in Southern Hemisphere

2009 Solar Decathlon Challenge



e.g. Washington D.C. $L = 38.9°$

tilt angle $\cong 38.9°$

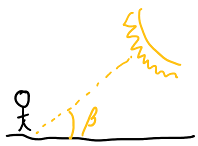
<u>increase</u> tilt angle to optimize for winter

<u>decrease</u> tilt angle to optimize for summer

Solar Noon

- When the sun is directly over the local meridian, i.e. line of longitude

- Recall altitude angle β



- **Altitude Angle at Solar Noon (β_N)**
  - angle between the sun and the local horizon directly beneath the sun

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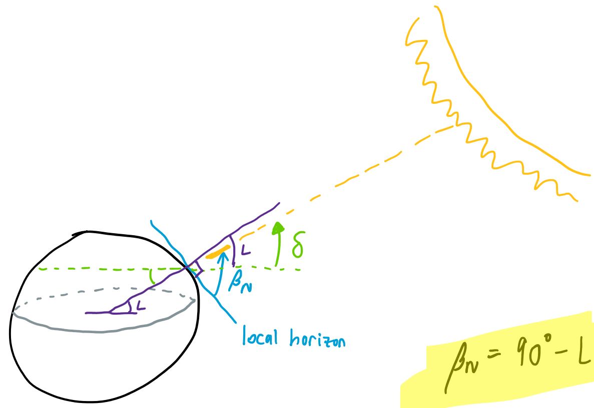


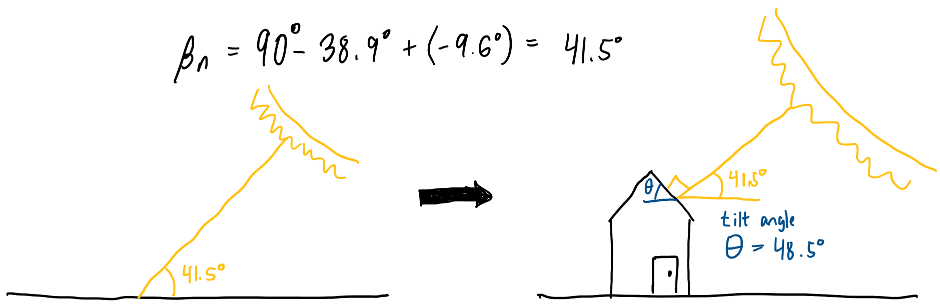
$$\beta_N = 90° - L + \delta$$

- $\boxed{\text{Zenith}}$
  - axis drawn directly overhead at a site
  - perpendicular to local horizon

- E.g. Gable Home from 2009 Solar Decathlon Challenge, Washington D.C.
  - Competition takes place on October 15 → day number $n = 288$

$$\delta = 23.45 \sin\left(\frac{360}{365}(288-81)\right) = -9.6°$$

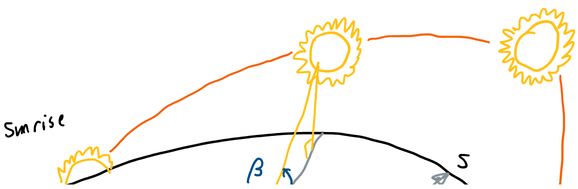
$$\beta_n = 90° - 38.9° + (-9.6°) = 41.5°$$



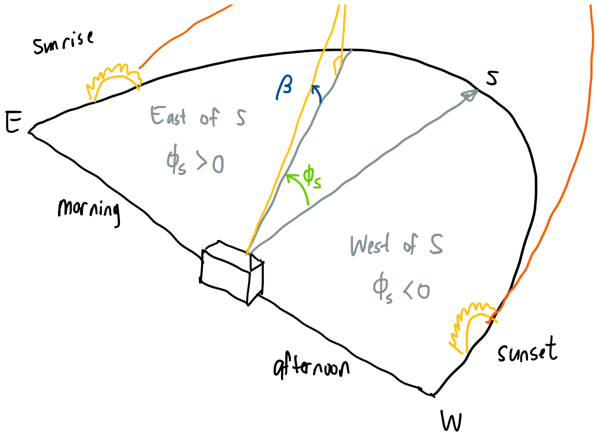
Optimized for October 15th

<u>But we have not considered Earth's rotation</u>

- Now, we describe the location of the sun at any time → altitude angle β
  → azimuth angle ϕ_s



β, ϕ_s depend on



β, ϕ_s depend on
- ↳ day number
- ↳ latitude
- ↳ hour of day

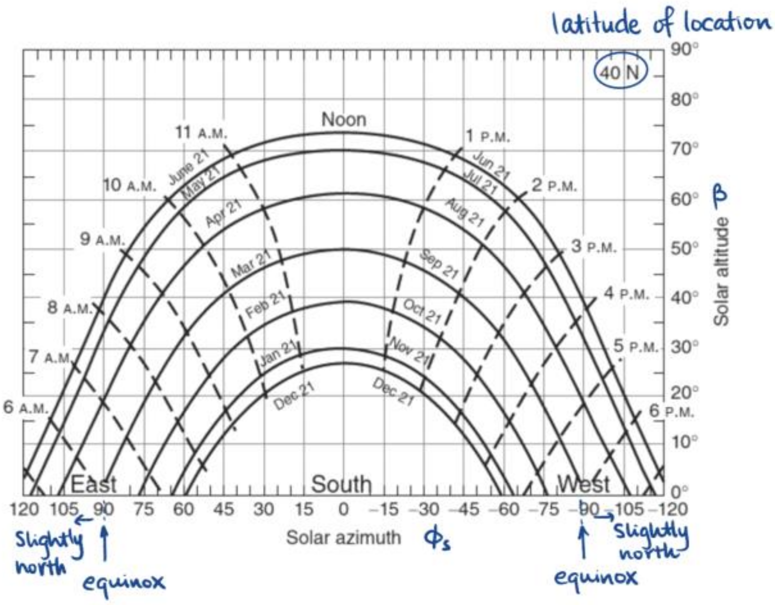
- $\boxed{\text{Hour angle } (H)}$
  - # of degrees the Earth must rotate to have the Sun directly over the local meridian

$$H = \frac{15^\circ}{\text{hour}} \times \text{hours before solar noon}$$

  - Without going through details of derivation,

$$\sin\beta = \cos L \cos\delta \cos H + \sin L \sin\delta$$

$$\sin\phi_s = \frac{\cos\delta \sin H}{\cos\beta}$$



- But: in spring and summer, it is possible to have $\phi_s > 90^\circ$ (early morning) or $\phi_s < -90^\circ$ (evening) but $\sin x = \sin(180^\circ - x)$

➤ We need a test to determine if $|\phi_s| < 90^\circ$ or $|\phi_s| > 90^\circ$

If $\cos H \geq \frac{\tan\delta}{\tan L}$, then $|\phi_s| \leq 90°$. otherwise $|\phi_s| > 90°$

- Example: Find the altitude angle β and azimuth angle ϕ_s for the sun at 3pm Solar time in Boulder, C.O. ($L = 40°$) on summer solstice.

i) $\delta = 23.45°$

ii) $H = 15°(-3) = -45°$ at 3pm solar time

iii) $\sin\beta = \cos(40°)\cos(23.45°)\cos(-45°) + \sin(40°)\sin(23.45°)$

$\beta = 48.83°$

iv) $\sin\phi_s = \frac{\cos(23.45°)\sin(-45°)}{\cos(48.83°)} = -0.9854$

$\phi_s = -80.19°$ OR $260.19° = -99.81°$

80.19° west of south

99.81° west of south

v) The test: $\cos H = \cos(-45°) = 0.707$

$\frac{\tan\delta}{\tan L} = \frac{\tan(23.45°)}{\tan(40°)} = 0.517$

$\cos H > \frac{\tan\delta}{\tan L} \rightarrow |\phi_s| \leq 90° \rightarrow \phi_s = -80.19°$

Summary

n = day number

δ = solar declination angle

$\delta = 23.45°\sin\left(\frac{360}{365}(n-81)\right)$

L = latitude

β_N = altitude angle at solar noon

$\beta_N = 90° - L + \delta$

H = hour angle

$H = 15°/hr \times$ # hrs before solar noon

β = solar altitude angle

ϕ_s = solar azimuth angle