EN671: Solar Energy Conversion Technology

Lecture-5: Solar Radiation Geometry

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✓Geometry, angles and Measurement

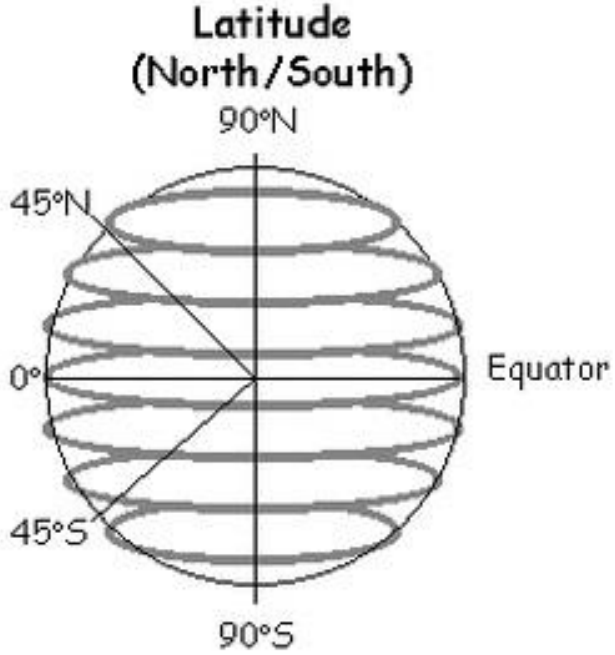
Beam flux and equivalent Beam Flux

- Beam Flux
- Equivalent Beam Flux

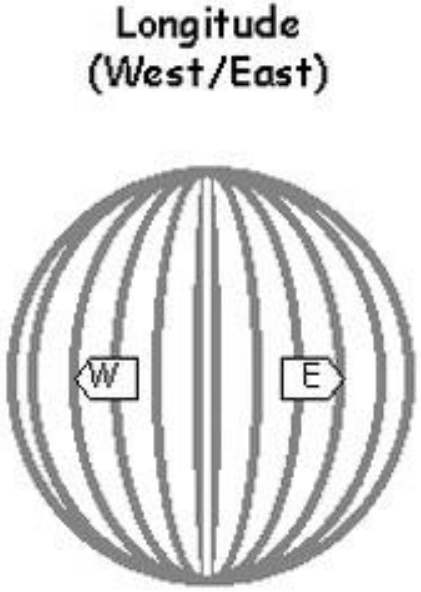
Different angle

- Angle of Incidence (θ)
- Zenith angle (θ_z)
- Latitude (Angle of latitude, ϕ)
- Declination (δ)
- Hour angle (ϖ)
- Altitude angle (α_a)
- Solar Azimuth angle (γ_s
- Slope (tilt angle) (β)
- Surface azimuth angle (γ)

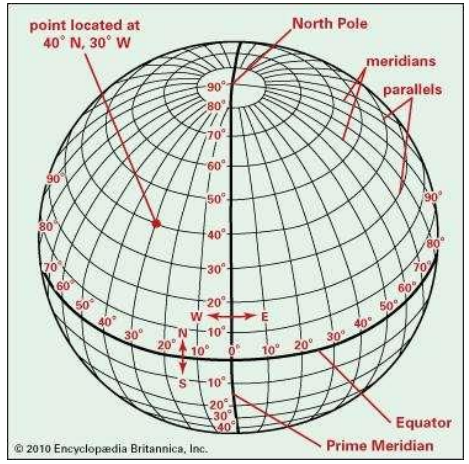
Latitude and Longitude

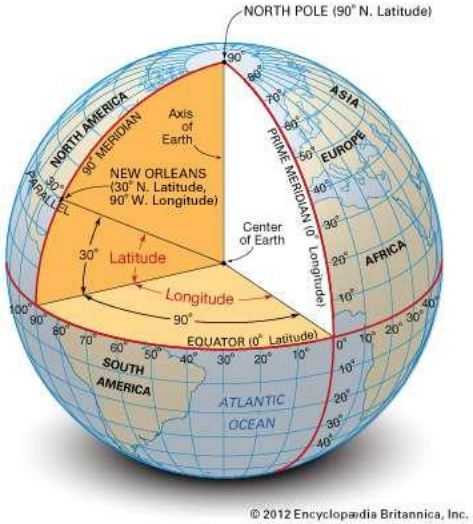


Latitude varies from 0° at the equator to 90° North and South at the poles



Longitude varies from 0° at Greenwich to 180° East and West





Longitude lines are perpendicular and latitude lines are parallel to the equator.

Longitude is the angular distance, in degrees, minutes, and seconds, of a point east or west of the Prime (Greenwich) Meridian. Lines of **longitude** are often referred to as meridians.

-90° to +90°

Declination

Angular displacement of the sun from the plane of the Earh's equator.

-23.45^{o} to $+23.45^{o}$

Hour Angle

The angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15^{o} per hour

-180^{o} to $+180^{o}$

Solar Azimuth Angle and Inclination Angle

Surface Azimuth Angle

Surface orientation	γ (°)
Sloped towards the south	0
Sloped towards the north	180
Sloped towards the east	–90
Sloped towards the west	+90
Sloped toward the southeast	–45
Sloped toward the southwest	+45

-180° to +180°

Slope

$0^o \leq \beta \leq 180^o$

$\beta > 90^o$ Means the surface has a downward-facing components

Solar Radiation Geometry

Solar Radiation Geometry

Special cases

(i) For vertial Surface

(ii) For horizontal surface

(iii) For inclined surface facing due south

(iv) For vertical surface facing due south

(v) For inclined surface facing due north

Sunrise, sunset, Day length

Solar time (passage of time with reference to the position of the Sun in the sky). Two Corrections- (1) Difference between the longitude of a location and the meridian on which the standard time is based (The correction has a magnitude of 4 minutes for every degree difference in longitude). (2) Equation of time correction is due to the fact that the Earth's orbit and rate of rotation are subjected to small variations. The difference in minutes between solar time and standard time defined as:

Solar time/LAT = standard time $\pm$ 4 (L_{st} -L_{loc}) + E

-ve sign eastern hemisphere, +ve western hemisphere

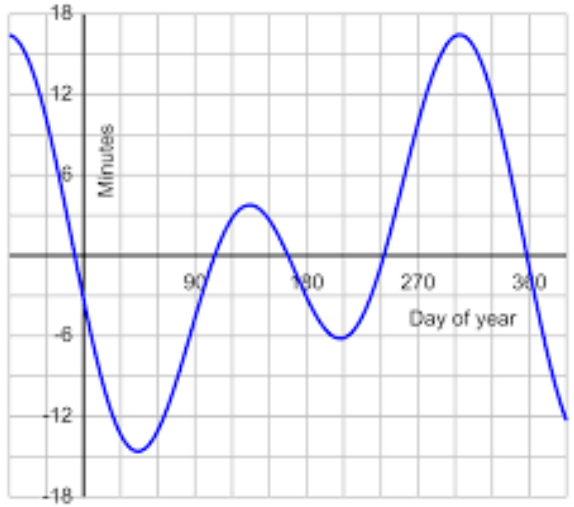
L_{st} : Standard meridian for the local time zone (for India $81^0 44'$)

L_{loc} : Longitude of the location

(longitudes are in degrees west, 0<L<360)

E: Equation of time (minutes)

How to calculate E??



E is in min…as a function of time of year

$$E = 229.2\left(0.000075 + 0.001868\cos B - 0.032077\sin B - 0.014615\cos 2B - 0.04089\sin 2B\right)$$

where $B = (n-1)\times 360/365$, $n = n^{th}$ day of the year

BASIS FOR COMPARISON	LOCAL TIME	STANDARD TIME
Meaning	Local time implies the time of a place determined on the basis of apparent movement of the sun.	Standard time refers to the fixed time for places falling in the same meridian, set in a country by law.
Variations	Changes continuously with the change in longitude.	Remains same for a particular country.
Longitude	Places on the same longitude have same local time.	Places on the same longitude have different standard time.
Reckoned by	Shadow cast by the sun.	Time zones

Local time, expressed in relation to the line of longitude passing through it. It is the time, reckoned on the basis of the meridian running through a particular place. Noon occurs at different times in different meridians. Hence local time varies from region to region.

Standard time is used to mean the reference time for a particular area. It is the local time of the standard meridian passing through the region or country.

Representative day of a month for Solar Radiation calculation

Month	n for ith Day of Month	For Average Day of Month		
		Date	n	δ
January	i	17	17	−20.9
February	$31 + i$	16	47	−13.0
March	$59 + i$	16	75	−2.4
April	$90 + i$	15	105	9.4
May	$120 + i$	15	135	18.8
June	$151 + i$	11	162	23.1
July	$181 + i$	17	198	21.2
August	$212 + i$	16	228	13.5
September	$243 + i$	15	258	2.2
October	$273 + i$	15	288	−9.6
November	$304 + i$	14	318	−18.9
December	$334 + i$	10	344	−23.0

Q.5.1: Determine the angle of incidence of direct irradiance/solar radiation on an inclined surface at 45^{o} from the horizontal with orientation of 30^{o} west of south and located at Mumbai (latitude: $72^{o}49'$ E and $18^{o}54'$N) at 1.30 (solar Time) on December 15, 2019. The standard longitude for India is $81^{o}44'$E

Q.5.2: Calculate the number of daylight hours (sunshine hours) in Guwahati on January 2nd and July Second. The latitude of Guwahati is 26.15^{o} N)

Summary

- Different Angles
- Solar Radiation Geometry
- Local Apparent Time (Solar Time)

Thank you