ALMUSTAQBAL UNIVERSITY COLLEGE
Iraq - Babylon

RENEWABLE ENERGY TECHNOLOGY

Sustainable Path For a Carbon Free Future

Refrigeration and Air conditioning Techniques Engineering Department

Subject : Renewable Energy

Grade: 4th Class

Lecture :3

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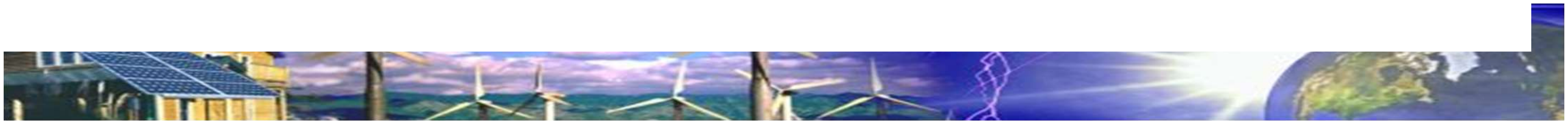
– October 2019



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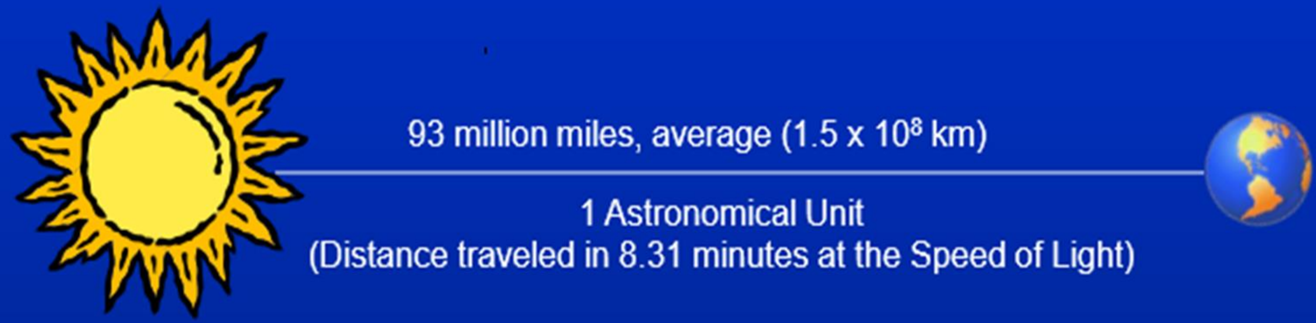
Sun – Earth Relationships



Sun:

Diameter: 865,000 miles (1,392,000 km, 109 times earth)
Mass: 2 x 10^{30} kg (330,000 times earth)
Density: 1.41 g/cm^3
Gravity: 274 m/s^2 (28 g)

Surface Temperature: 10,000 F (5800 K)

Earth:

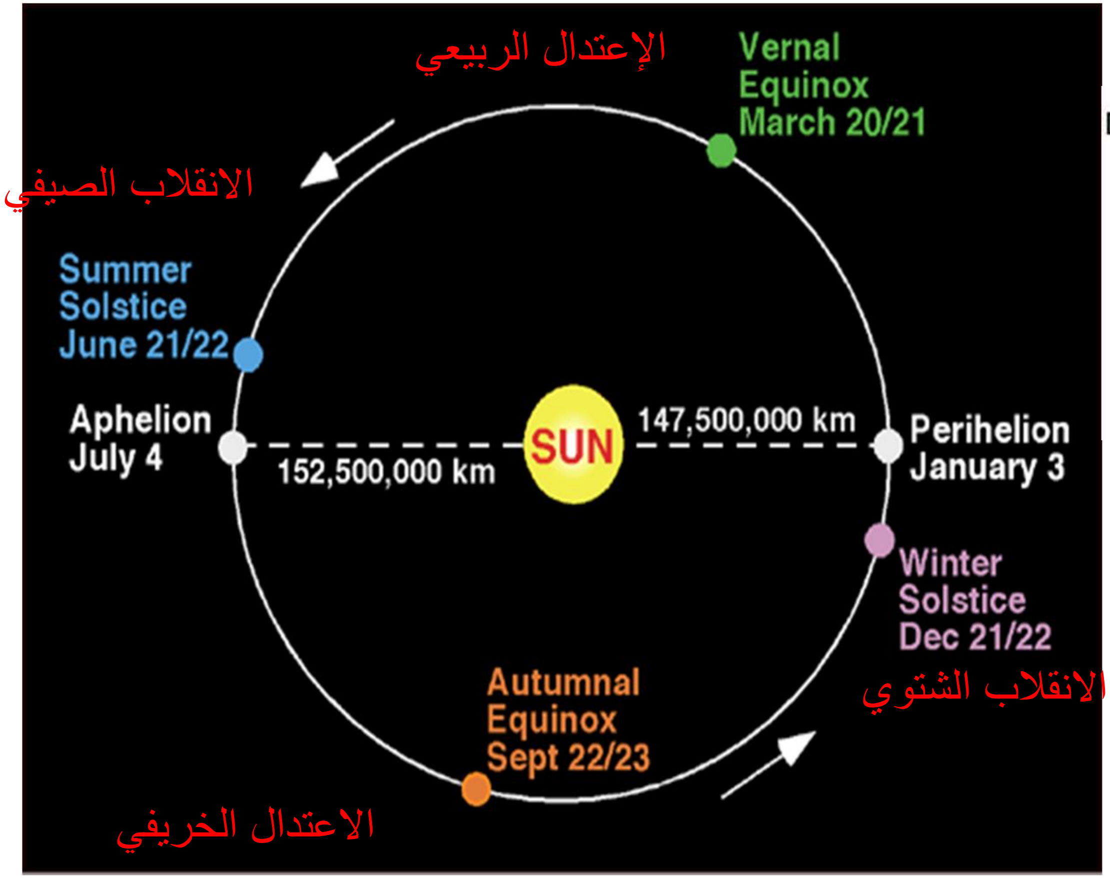
Diameter: 7,930 miles (12,756 km)
Mass: 5.97 x 10^{24} kg
Density: 5.52 kg/cm^3
Gravity: 9.81 m/s^2 (1 g)

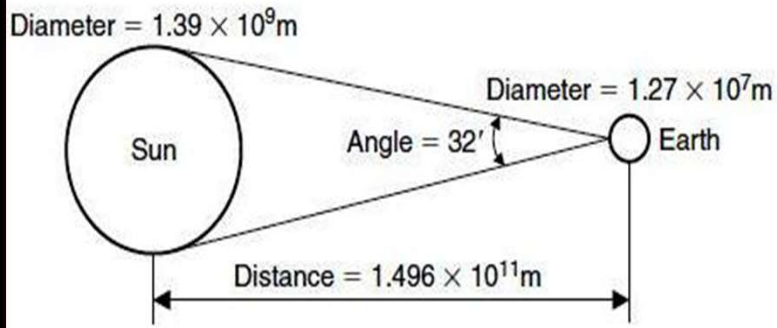
Typical Surface Temperature: 68 F (300K)

Earth's Orbit Around Sun: 1 year
Earth's Rotation about its Polar Axis: 1 day

2- Solar Radiation Analysis

2.1 The Main Parameters of the Sun





The **separation angle for mean distance between the earth and the sun :**

$$\theta = \frac{2r_\theta}{r}$$

The perihelion and aphelion are the nearest and farthest points (apsides) of a body's direct orbit around the Sun.

Distance between the sun and earth

2- Solar Radiation Analysis

The erath's orbit around the sun

$$r = \frac{a(1-\epsilon^2)}{1+\epsilon\cos\theta}$$

a : average orbit distance = 1.5 * 10^8 km ;

ϵ : Eccentricity= 0.01673

θ: is equal to the No. of the day at year and can by calculate accordant to table 1:

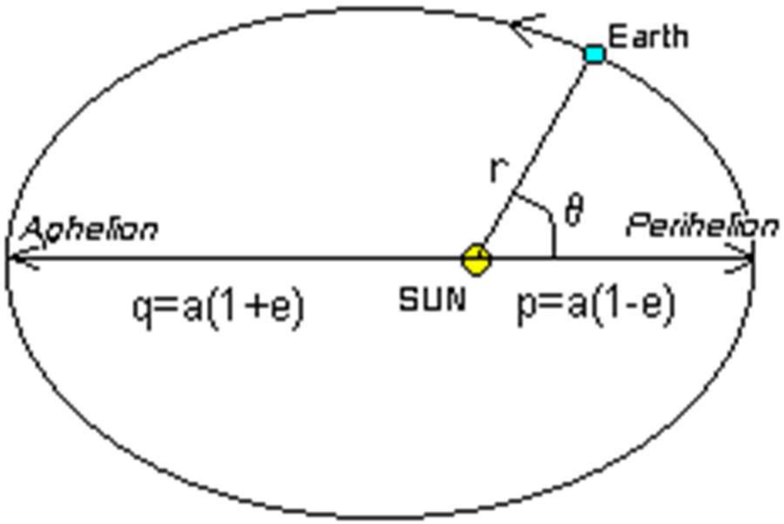


Fig. 2.1 Distance between the sun and the earth

Eccentricity: deviation of a curve or orbit from circularity

The apparent solar radiation values

$$I_0 = I_{SC}\left[1 + 0.033\cos\left(\frac{N}{365}\times 360°\right)\right]$$

solar constant, I_{SC} = 429.5 Btu/hr·ft^2 (1353 W/m^2).

Solar Emission Spectrum

total power of solar emission by :

$$P_o = A_s * F_o$$

The **solar constant** *Isc* is the energy from the sun per unit time received on a unit area of surface perpendicular to the direction of propagation of the radiation at mean earth-sun distance outside the atmosphere.

$$I_{sc} = \frac{Po}{4\,\pi\,r^2} = \frac{As * Fo}{4\,\pi\,r^2} = \frac{\sigma^* T^4 * 4\,\pi r_{\theta}{}^2}{4\,\pi\,r^2}$$

2.2 Basic Earth Sun Angles

φ **Latitude** is the angle measured at the centre of the Earth, between the Equator plane and where you are. It is expressed either north or south, and varies .; $-90^\circ \le \varphi \le 90^\circ$.

δ **Declination**; is the angle made between the plane of the equator and the line joining the two centers of the earth and the sun: $-23.45^\circ \le \delta \le 23.45^\circ$.

The position of a point P on the earth's surface with respect on the sun's rays is known at any instant if the latitude (ϕ) and hour angle (ω) for the point, and the sun's declination (δ) are known.

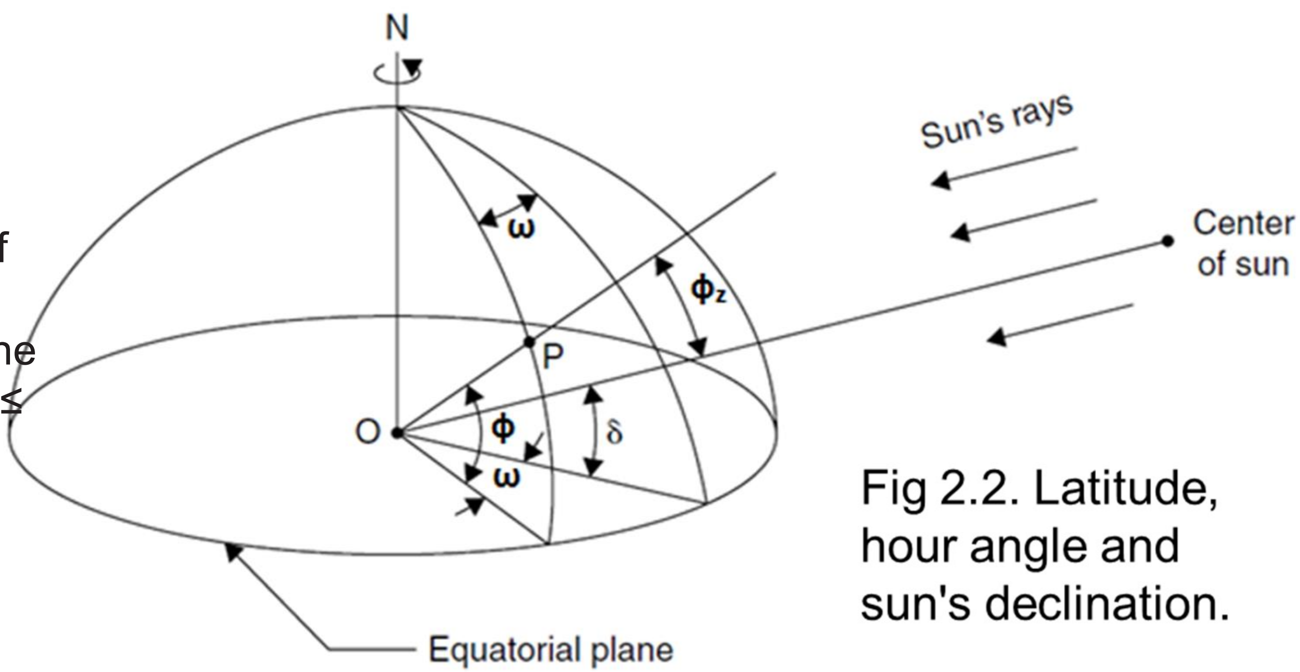
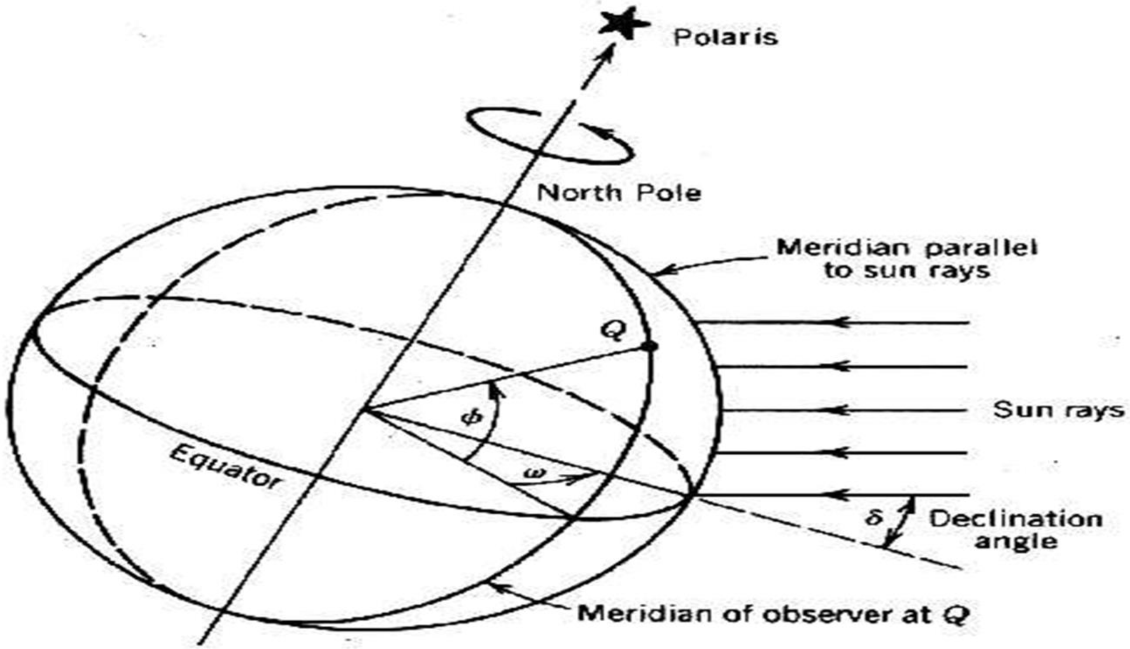
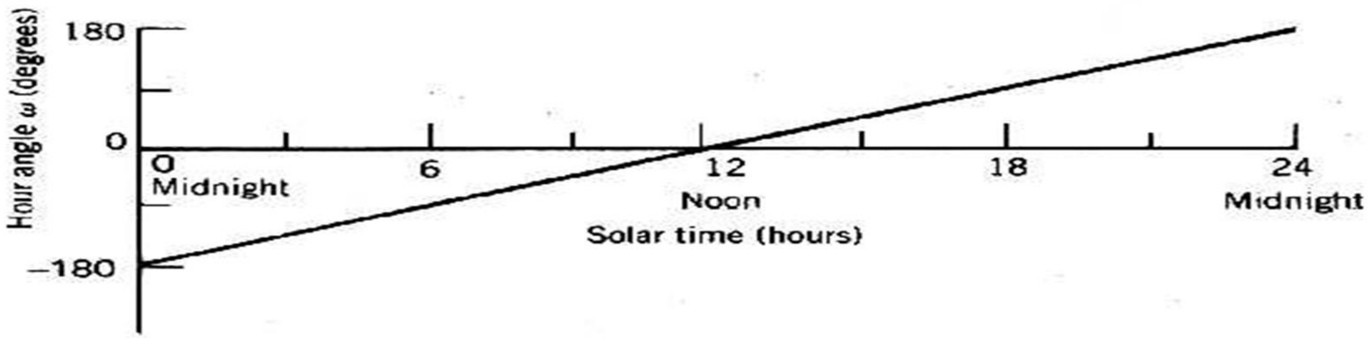


Fig 2.2. Latitude, hour angle and sun's declination.

2.2 Basic Earth Sun Angles





As shown in Figure, the hour angle is the angular distance between the meridian of the observer and the meridian whose plane contains the sun.

2.2 Basic Earth Sun Angles

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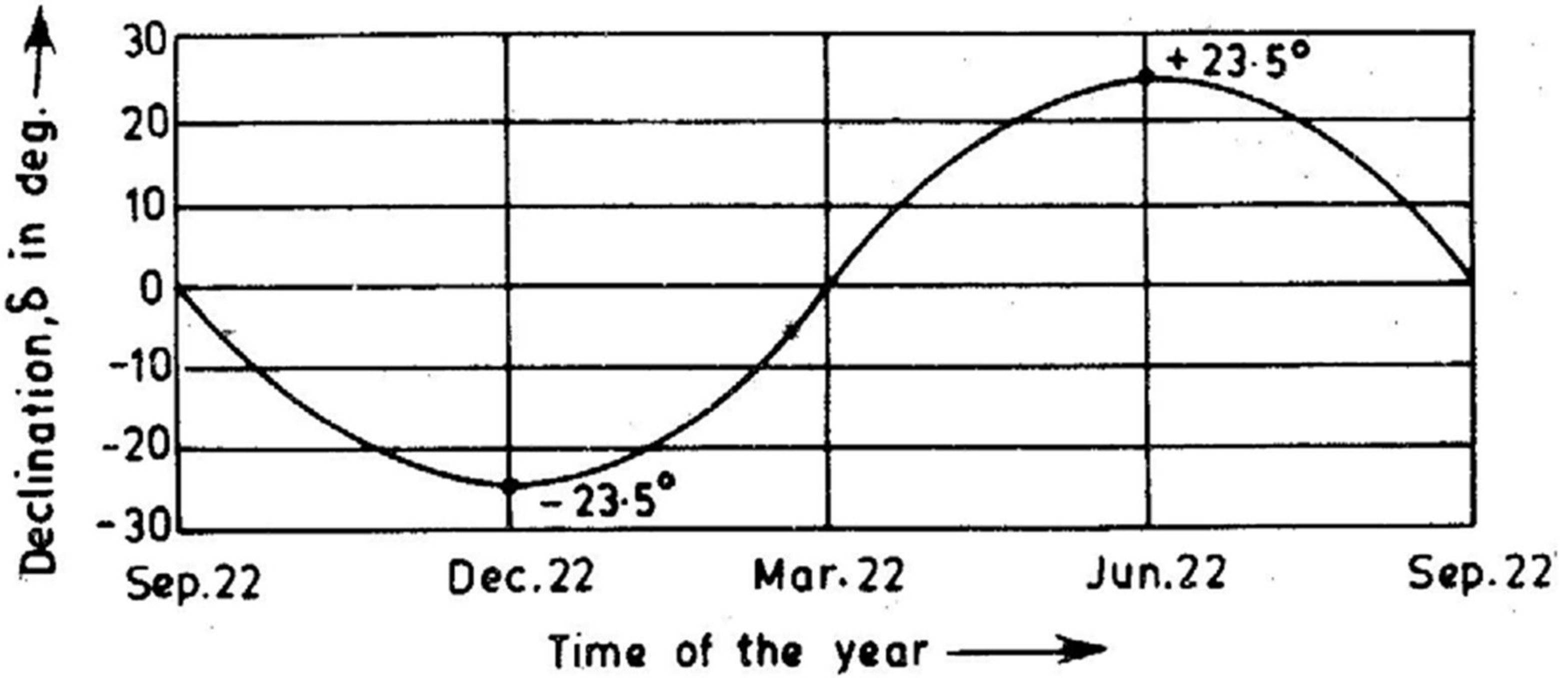


2.2 Basic Earth Sun Angles

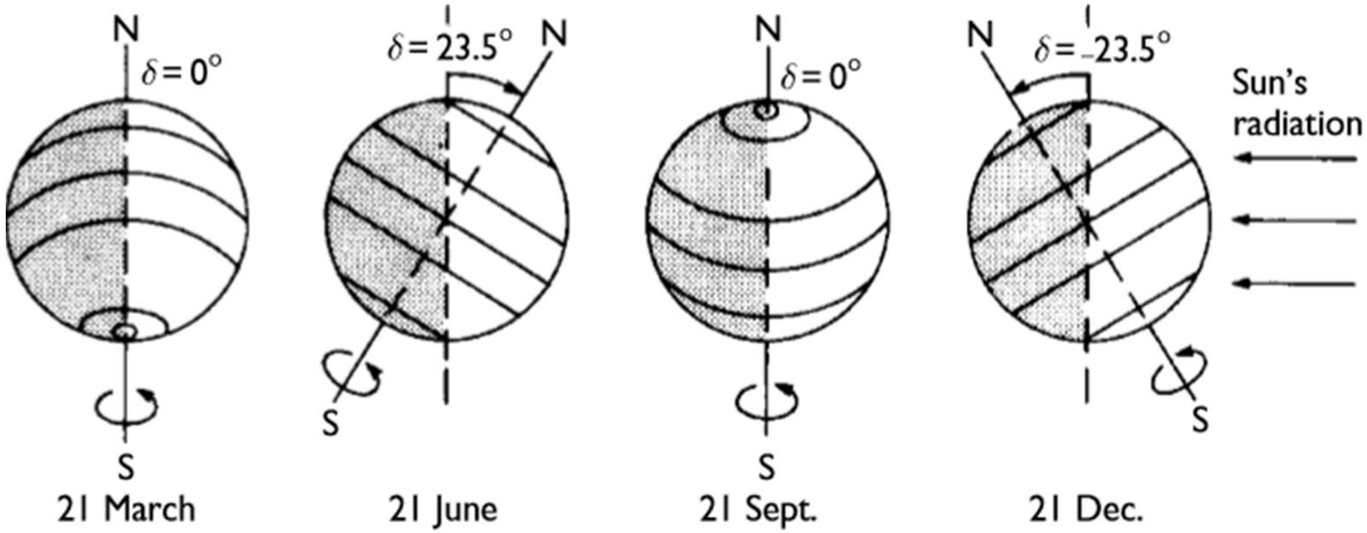
Since the Earth rotates at 360 ◦ /24h=15 ◦ h−1, the hour angle is given by

$$\omega = (15^\circ\,\mathrm{h}^{-1})(t_{\mathrm{solar}} - 12\,\mathrm{h}) \qquad (3.3)$$

$$= (15^\circ\,\mathrm{h}^{-1})(t_{\mathrm{zone}} - 12\,\mathrm{h}) + \omega_{\mathrm{eq}} -$$

where t_{solar} and t_{zone} are respectively the local solar and civil times (measured in hours), zone is the longitude where the Sun is overhead when t_{zone} is noon (i.e. where solar time and civil time coincide). ω is positive in the evening and negative in the morning. The small correction term ω_{eq} is called the equation of time; it never exceeds 15 min and can be neglected for most purposes

2.2 Basic Earth Sun Angles



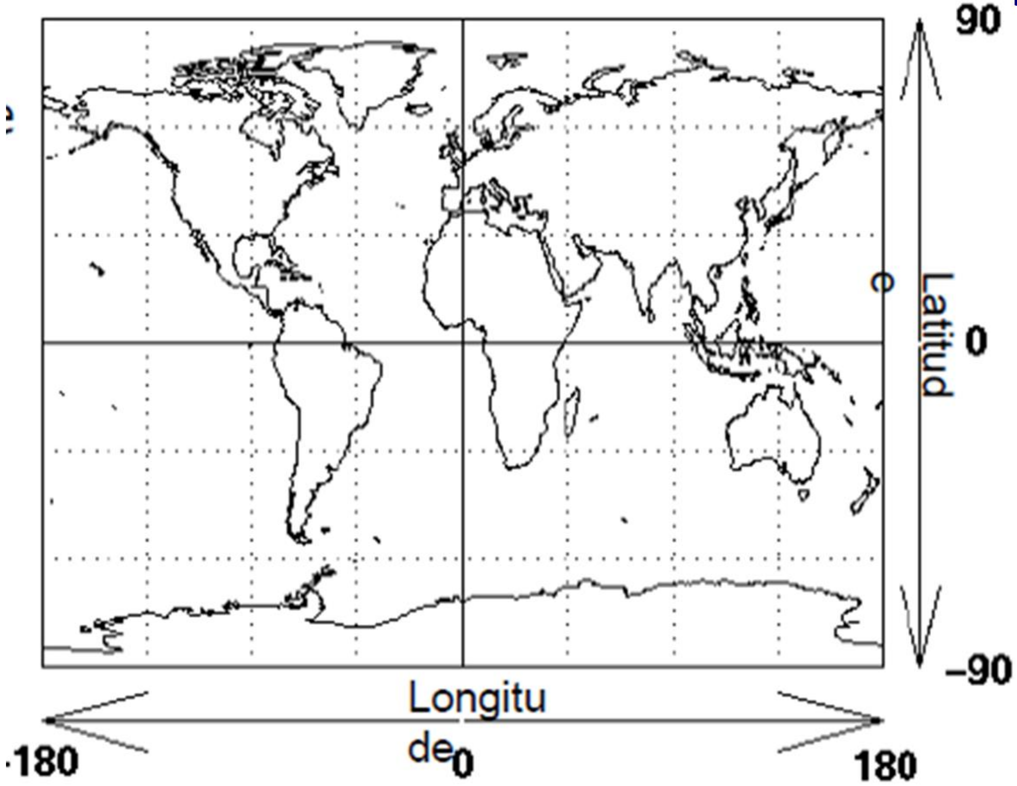
The Tropic of Cancer and Tropic of Capricorn are located at +23.45° and –23.45°, respectively

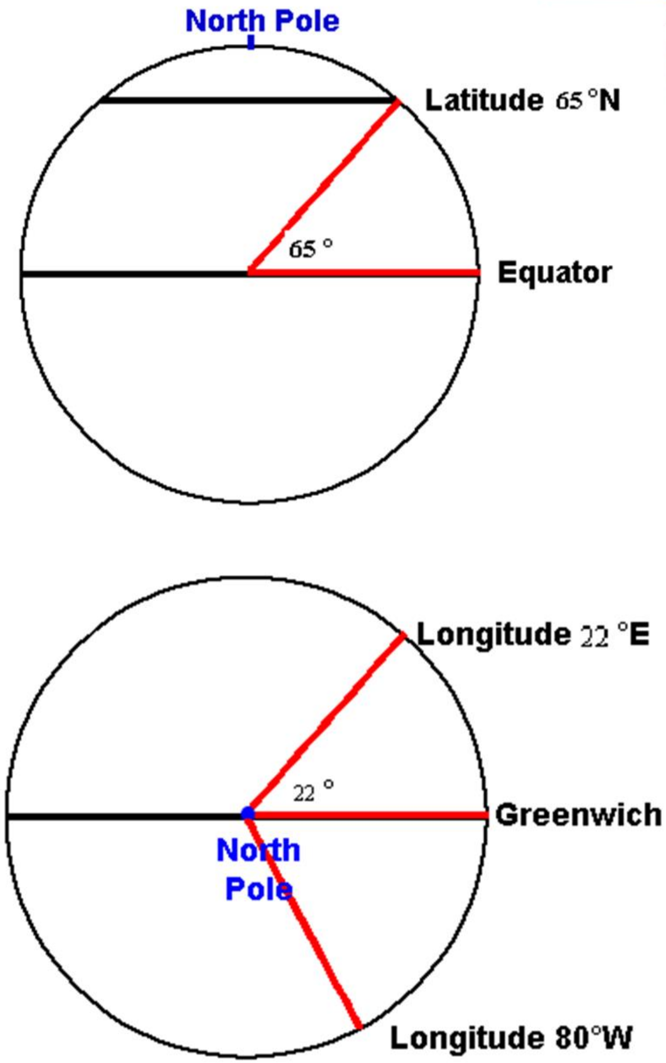
δ varies smoothly from + δ_0 =+23.45º at midsummer in the northern hemisphere, to − δ_0 =−23.45º at northern midwinter. Analytically,

$$\delta = 23.45^o \sin\left[\frac{360}{365}(284+n)\right] \qquad (3.4)$$

n: is the day of the year; $1 \leq n \leq 365$

2.2 Basic Earth Sun Angles





The longitudes are described in terms of how many degrees they lie to the east or west of the prime meridian

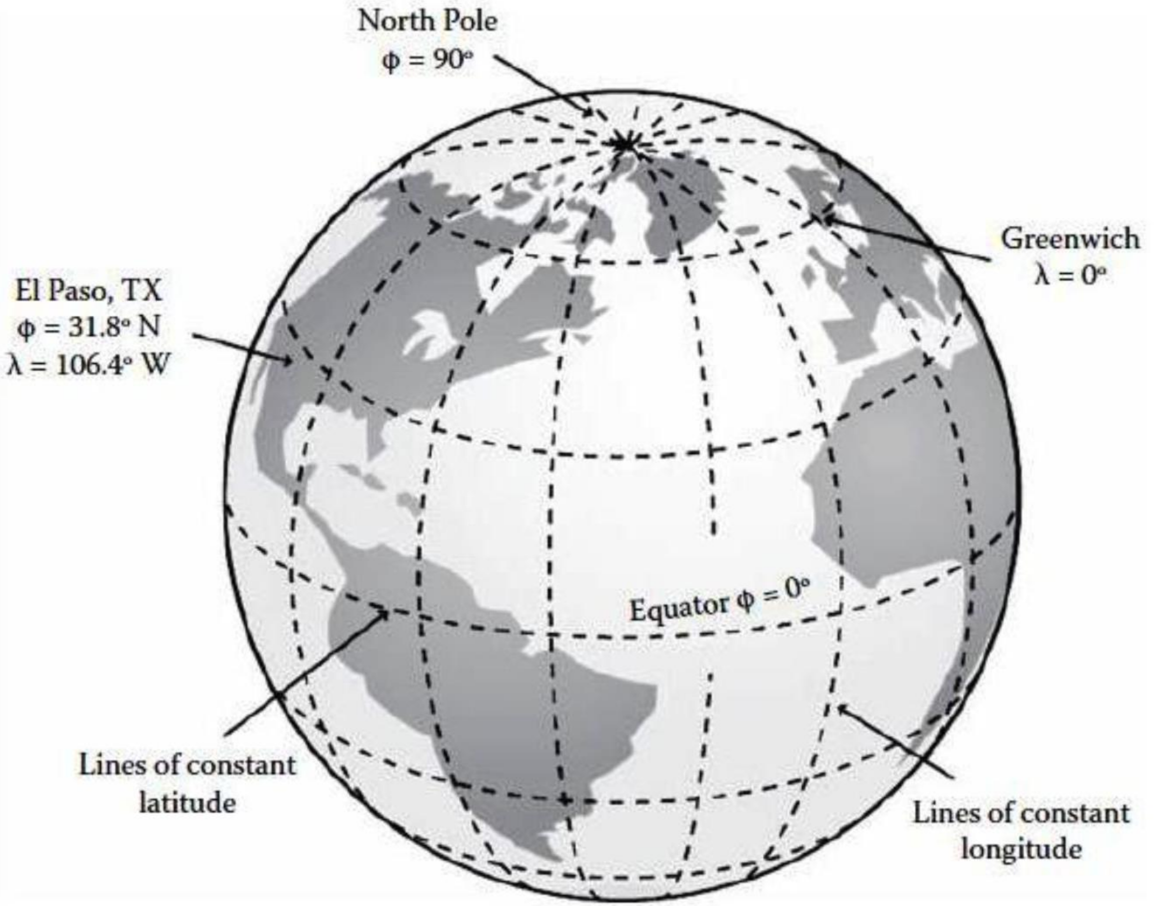
2.2 Basic Earth Sun Angles

Table (1) : Day number and recommended average day for each month

Month	Day number	Average day of the month	
		Date	N
January	i	17	17
February	$31 + i$	16	47
March	$59 + i$	16	75
April	$90 + i$	15	105
May	$120 + i$	15	135
June	$151 + i$	11	162
July	$181 + i$	17	198
August	$212 + i$	16	228
September	$243 + i$	15	258
October	$273 + i$	15	288
November	$304 + i$	14	318
December	$334 + i$	10	344

2.3 Determination of Solar Time

Greenwich meridian (zero longitude) is taken as reference for the time and time reckoned from mid night is known as universal time or Greenwich civil time (GCT or GMT). Such time is expressed on an hour scale from 0_h to 24_h.



The solar time

Solar Time : Time based on the apparent angular motion of the sun across the sky with solar noon the time the sun crosses the meridian of the observer

الوقت الذي
يقاس من قبل
الحركة اليومية
الظاهرة من
الشمس

$$\text{Solar time} - \text{standard time} = 4(L_{st} - L_{loc}) + E \qquad (3.2)$$

where L_{st} is the standard meridian for the local time zone, L_{loc} is the longitude of the location in question, and longitudes are in degrees west, that is, $0^\circ < L < 360^\circ$

where E is the equation of the time and can express by :

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

where B is

$$\underline{\mathbf{B}} = \frac{360}{364}(n - 81) \qquad \mathbf{n}\text{: is the day of the year}$$

The solar time

Example 1

At Madison, Wisconsin, what is the solar time corresponding to 10:30 AM central time

on February 3?

Solution

In Madison, where the longitude is 89.4° and the standard meridian is 90°,

$$\text{Solar time} = \text{standard time} + 4(90 - 89.4) + E$$
$$= \text{standard time} + 2.4 + E$$

On February 3, $n = 34$, and from Equation 3.2, $E = -13.5$ min, so the correction to standard time is −11 min. Thus 10:30 AM Central Standard Time is 10:19 AM solar time.

The solar time

Example 2

Find Eastern daylight Time for solar noon in Boston (Longitude 71.1º w) on July 1st?

Solution

July 1st , is day number n= 182 to adjust for local time , we obtain :

B= 360/364(182-81) 99.89º

E = 229.2 (0.000075 + 0.001868 cos(*99.89)* − 0.032077 sin(*99.89)* − 0.014615 cos (2* *99.89)* − 0.04089 sin) = -3.5

For Boston at longitude 71.7º w in the Eastern Time Zone with time maridian 75º.

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

To adjust for daylight savings time add 1 h , so solar noon will be about 12.48 p.m

12− standard time = 4*(75- 71.1 º)* + *(-3.5) = 12:00 – 12.1 min = 11:47.9 A.M East*

References

1- J. Twidell. and T. Weir " Renewable Energy Resources " Taylor and Francis Group, 2006.

2- J. A. Duffie and W. A. Beckman" Solar Engineering of Thermal Processes" John Wiley & Sons, Inc., Hoboken, New Jersey , 2013.

Do You Have Any Questions?