POSITION OF SUN ON CELESTIAL SPHERE AT INPUT UNIVERSAL TIME (UT)

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(This is Sec. 3, pp 57 - 67, of Orbital Mechanics - Model & Simulation Software (OM-MSS), Sec 1 to 10, pp 1 - 402.)

POSITION OF SUN ON CELESTIAL SPHERE AT INPUT UNIVERSAL TIME (UT) .

Sun is a star at the center of our Solar System. Although stars are fixed relative to each other, but Sun moves relative to stars.

Sun follows a circular path on the celestial sphere, once a year. This path is known as the 'Ecliptic', representing the plane of the Earth's orbit.

Inclination of the Earth's equator to the Ecliptic (or earth's rotation axis to a perpendicular on ecliptic) is called Obliquity of the ecliptic.

The Obliquity of the ecliptic is currently 23.4392794383 deg with respect to the celestial equator, at standard epoch J2000 .

The position of any point on the Celestial Sphere is given with reference to the equator or the ecliptic.

- reference to Equator, the position is specified by Right ascension and Declination.
- reference to Ecliptic, the position is specified by celestial Longitude and Latitude.

The Earth moves in an elliptical orbit around the Sun. Therefore the distance from Earth to Sun is not same at all points on the orbit.

- distance Earth to Sun (d_sun) calculated as r = a(1-e*e)/(1+e cos(theta)) where a = semi-major axis, e = eccentricity and theta = mean anomaly of sun.
- radial distance from Earth to Sun (Rs) calculated as R = 1.00014 - (0.01671 * cos g) - (0.00014 * cos 2g) where g = mean anomaly of sun
- mean distance from Earth to Sun = 149,597,870.700 km, called 1 Astronomical Unit, **(Ref. http://en.wikipedia.org/wiki/Astronomical_unit)**
- minimum distance from Earth to Sun = 147,098,074 km or 0.98 AU, and this point is called Perihelion;
- maximum distance from Earth to Sun = 152,097,701 km or 1.02 AU, and this point is called Aphelion;
- average distance from Earth to Sun (As) = 149,597,887.5 km is the distance (max + min)/2.

  (Ref http://wiki.answers.com/Q/What_is_the_distance_between_Earth_and_the_Sun).

At any input Universal Time, to compute the position of Sun and its related traits, the algorithm goes through following steps :

(a) **Find Julian day of interest corresponding to the input Universal Time;**

(b) **Find Corresponding Ecliptic coordinates**

- Mean anomaly of the Sun (actually, Earth orbits around Sun, but here pretends Sun orbits Earth)
- Mean longitude of the Sun;
- Ecliptic longitude of the Sun;
- Ecliptic latitude of the Sun is always nearly zero (the value never exceeds 0.00033 deg)

- Distance of the Sun from the Earth, in astronomical units
- Obliquity of the ecliptic

(c) **Find Corresponding Equatorial coordinates**

- Right ascension
- Declination

In addition to these Ecliptic and Equatorial coordinates, computed many other parameters related to Sun's Position on Celestial Sphere.

The Position of Sun on Celestial Sphere is represented by computing following parameters :

Semi-major axis (SMA), Mean movement per day (n sun), Mean distance (As), Mean anomaly (m sun), True anomaly (T sun), Eccentric anomaly (E sun), Right ascension (Alpha), Declination (Delta), Mean longitude (Lmean), Ecliptic longitude (Lsun), Nodal elongation (U sun), Argument of perigee (W sun), Obliquity of ecliptic (Epcylone), Mean dist (d_sun), Radial distance (Rs).

Total 22 parameters computed at Standard Epoch JD2000 (ie YY 2000, MM 1, DD 1, hr 12.00) and at six orbit time event points for YY 2013.

The six orbit events points are when Earth reaches Perihelion & Aphelion, Vernal & Autumnal Equinox, Summer & Winter Solstice.

For any desired year, first computed the Universal time (UT) for earth to reach the respective orbit events point, then apply the same UT as input time for finding the corresponding orbit parameters at that time instnt.

(Note : The orbit events being specific, the values computed can be verified easily with those reported from other sources.)

Move on to Find Position of Sun on Celestial Sphere, the Utilities of OM-MSS Software (Sections - 3.1 to 3.8).

Computing Sun Position on Celestial Sphere at Seven different Time events, respectively :

(a) Time Event - Standard Epoch JD2000 ;

(b) Time Event - when Earth at Perihelion ;

(c) Time Event - when Earth at Vernal equinox ;

(d) Time Event - when Earth at Summer solstice ;

(e) Time Event - when Earth at Aphelion ;

(f) Time Event - when Earth at Autumnal equinox ;

(g) Time Event - when Earth at Winter solstices ;

Next Section - 3.1 Position of sun at standard epoch time JD2000

OM-MSS Section - 3.1 ----------26

SUN Positional Parameters on Celestial Sphere : Input Time (UT) Standard Epoch JD2000

1. Finding Position of Sun on Celestial Sphere at Input UT Standard Epoch time JD2000 .

Input Universal Time Corresponds to Julian Day JD2000 : year = 2000, month = 1, day = 1, hour = 12, minute = 0, seconds = 0.00000

Output : Sun Position on Celestial Sphere Corresponding to input time, JD2000

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= -2.5081161195
07. Mean anomaly in deg per day from n_sun (m sun)	= -2.4719999999	08. Sun Mean longitude in deg (Lmean)	= 280.4600000000
09. Earth Mean anomaly in deg (ME)	= 357.5280000000	10. Sun Ecliptic longitude in deg (Lsun)	= 280.3756801972
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4392794444	12. Sun Right ascension in deg (Alpha)	= 281.2858630915
13. Sun Declination in deg (Delta)	= -23.0337026521	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 147101227.61694	16. Sun Nodal elongation in deg (U sun)	= -79.6243198028
17. Sun Mean anomaly in deg (M sun)	= 357.5280000002	18. Sun Eccentric anomaly in deg (E sun)	= 357.4860040557
19. Sun True anomaly in deg (T sun)	= 357.4436516380	20. Sun Argument of perigee in deg (W sun)	= 282.9320285593
21. Sun True anomaly in deg from U & W (V sun)	= 357.4436516380	22. Sun Distance in km (d sun)	= 147101040.52850

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Next Section - 3.2 Position of sun at time when earth is at perihelion

OM-MSS Section - 3.2 ----------27

SUN Positional Parameters on Celestial Sphere : Input Year Time when Earth is at Perihelion.

2. Finding Position of Sun on Celestial Sphere at Input Universal Time, when Earth is at Perihelion .

Input Universal Time Corresponds to Earth at Perihelion : year = 2013, month = 1, day = 3, hour = 9, minute = 11, seconds = 56.61639

Output : Sun Position on Celestial Sphere Corresponding to input time, Earth reaching Perihelion

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= 0.0000000000
07. Mean anomaly in deg per day from n_sun (m sun)	= 0.0000000000	08. Sun Mean longitude in deg (Lmean)	= 283.1557666033
09. Earth Mean anomaly in deg (ME)	= 0.0000000001	10. Sun Ecliptic longitude in deg (Lsun)	= 283.1557666033
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4375874462	12. Sun Right ascension in deg (Alpha)	= 284.2922173002
13. Sun Declination in deg (Delta)	= -22.7872783368	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 147098823.43315	16. Sun Nodal elongation in deg (U sun)	= -76.8442333967
17. Sun Mean anomaly in deg (M sun)	= 0.0000000000	18. Sun Eccentric anomaly in deg (E sun)	= 0.0000000000
19. Sun True anomaly in deg (T sun)	= 0.0000000000	20. Sun Argument of perigee in deg (W sun)	= 283.1557666033
21. Sun True anomaly in deg from U & W (V sun)	= 0.0000000000	22. Sun Distance in km (d sun)	= 147098790.67105

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Next Section - 3.3 Position of sun at time when earth is at vernal equinox

OM-MSS Section - 3.3 ----------28

SUN Positional Parameters on Celestial Sphere : Input Year Time when Earth is at Vernal equinox .

3. Finding Position of Sun on Celestial Sphere at Input Universal Time, when Earth is at Vernal equinox .

Input Universal Time Corresponds to Earth at Vernal equinox : year = 2013, month = 3, day = 20, hour = 11, minute = 2, seconds = 9.15719

Output : Sun Position on Celestial Sphere Corresponding to input time, Earth reaching Vernal equinox

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= 76.0765340370
07. Mean anomaly in deg per day from n_sun (m sun)	= 74.9810547699	08. Sun Mean longitude in deg (Lmean)	= 358.1404045779
09. Earth Mean anomaly in deg (ME)	= 74.9810547700	10. Sun Ecliptic longitude in deg (Lsun)	= 0.0000000000
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4375603478	12. Sun Right ascension in deg (Alpha)	= 0.0000000000
13. Sun Declination in deg (Delta)	= 0.0000000000	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 148989898.67840	16. Sun Nodal elongation in deg (U sun)	= 0.0000000000
17. Sun Mean anomaly in deg (M sun)	= 74.9810547697	18. Sun Eccentric anomaly in deg (E sun)	= 75.9096738744
19. Sun True anomaly in deg (T sun)	= 76.8402303407	20. Sun Argument of perigee in deg (W sun)	= 283.1597696594
21. Sun True anomaly in deg from U & W (V sun)	= 76.8402303407	22. Sun Distance in km (d sun)	= 148912015.96700

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Next Section - 3.4 Position of sun at time when earth is at summer solsticex

OM-MSS Section - 3.4 ----------29

SUN Positional Parameters on Celestial Sphere : Input Year Time when Earth is at Summer solstice .

4. Finding Position of Sun on Celestial Sphere at Input Universal Time, when Earth is at Summer solstice .

Input Universal Time Corresponds to Earth at Summer solstice : year = 2013, month = 6, day = 21, hour = 5, minute = 1, seconds = 19.19999

Output : Sun Position on Celestial Sphere Corresponding to input time, Earth reaching Summer solstice

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= 168.8259558287
07. Mean anomaly in deg per day from n_sun (m sun)	= 166.3949127126	08. Sun Mean longitude in deg (Lmean)	= 89.5586310183
09. Earth Mean anomaly in deg (ME)	= 166.3949127126	10. Sun Ecliptic longitude in deg (Lsun)	= 89.9999483110
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4375273104	12. Sun Right ascension in deg (Alpha)	= 89.9999436629
13. Sun Declination in deg (Delta)	= 23.4375273104	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 152030583.04072	16. Sun Nodal elongation in deg (U sun)	= 90.0000000000
17. Sun Mean anomaly in deg (M sun)	= 166.3949127122	18. Sun Eccentric anomaly in deg (E sun)	= 166.6165253213
19. Sun True anomaly in deg (T sun)	= 166.8363660940	20. Sun Argument of perigee in deg (W sun)	= 283.1636339060
21. Sun True anomaly in deg from U & W (V sun)	= 166.8363660940	22. Sun Distance in km (d sun)	= 152025947.60113

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Next Section - 3.5 Position of sun at time when earth is at aphelion

OM-MSS Section - 3.5 ----------30

SUN Positional Parameters on Celestial Sphere : Input Year Time when Earth is at Aphelion .

5. Finding Position of Sun on Celestial Sphere at Input Universal Time, when Earth is at Aphelion .

Input Universal Time Corresponds to Earth at Aphelion : year = 2013, month = 7, day = 5, hour = 0, minute = 18, seconds = 52.59269

Output : Sun Position on Celestial Sphere Corresponding to input time, Earth reaching Aphelion

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= 182.6298145405
07. Mean anomaly in deg per day from n_sun (m sun)	= 180.0000000001	08. Sun Mean longitude in deg (Lmean)	= 103.1643684676
09. Earth Mean anomaly in deg (ME)	= 180.0000000002	10. Sun Ecliptic longitude in deg (Lsun)	= 103.1643684676
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4375223935	12. Sun Right ascension in deg (Alpha)	= 104.3014954901
13. Sun Declination in deg (Delta)	= 22.7863704018	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 152098409.19029	16. Sun Nodal elongation in deg (U sun)	= 76.8356315324
17. Sun Mean anomaly in deg (M sun)	= 179.9999999997	18. Sun Eccentric anomaly in deg (E sun)	= 179.9999999997
19. Sun True anomaly in deg (T sun)	= 179.9999999997	20. Sun Argument of perigee in deg (W sun)	= 256.8356315327
21. Sun True anomaly in deg from U & W (V sun)	= 179.9999999997	22. Sun Distance in km (d sun)	= 152098441.95238

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Next Section - 3.6 Position of sun at time when earth is at autumnal equinox

OM-MSS Section - 3.6 ----------31

SUN Positional Parameters on Celestial Sphere : Input Year Time when Earth is at Autumnal equinox .

6. Finding Position of Sun on Celestial Sphere at Input Universal Time, when Earth is at Autumnal equinox .

Input Universal Time Corresponds to Earth at Autumnal equinox : year = 2013, month = 9, day = 22, hour = 20, minute = 45, seconds = 38.50711

Output : Sun Position on Celestial Sphere Corresponding to input time, Earth reaching Autumnal equinox

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= 262.4817348463
07. Mean anomaly in deg per day from n_sun (m sun)	= 258.7020766091	08. Sun Mean longitude in deg (Lmean)	= 181.8702061020
09. Earth Mean anomaly in deg (ME)	= 258.7020766091	10. Sun Ecliptic longitude in deg (Lsun)	= 180.0000000001
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4374939503	12. Sun Right ascension in deg (Alpha)	= 180.0000000001
13. Sun Declination in deg (Delta)	= -0.0000000001	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 150128632.16764	16. Sun Nodal elongation in deg (U sun)	= -0.0000000001
17. Sun Mean anomaly in deg (M sun)	= 258.7020766085	18. Sun Eccentric anomaly in deg (E sun)	= 257.7663930098
19. Sun True anomaly in deg (T sun)	= 256.8323186392	20. Sun Argument of perigee in deg (W sun)	= 103.1676813607
21. Sun True anomaly in deg from U & W (V sun)	= 256.8323186392	22. Sun Distance in km (d sun)	= 150048057.36583

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Next Section - 3.7 Position of sun at time when earth is at winter solstice

OM-MSS Section - 3.7 ----------32

SUN Positional Parameters on Celestial Sphere : Input Year Time when Earth is at Winter solstice .

7. Finding Position of Sun on Celestial Sphere at Input Universal Time, when Earth is at Winter solstice.

Input Universal Time Corresponds to Earth at Winter solstice : year = 2013, month = 12, day = 21, hour = 17, minute = 10, seconds = 3.73442

Output : Sun Position on Celestial Sphere Corresponding to input time, Earth reaching Winter solstice

01. Earth around Sun Mean motion rev per day (mm)	= 0.0027377786	02. Semi-major axis in km considering oblateness (SMA)	= 149598616.31172
03. Earth mean motion deg per day using SMA (mm)	= 0.9856003000	04. Sun mean movement deg per day (n sun)	= 0.9856003000
05. Eccentricity of earth orbit (e sun)	= 0.0167102190	06. Perihelion to input time diff in Julian days	= 352.3320268290
07. Mean anomaly in deg per day from n_sun (m sun)	= 347.2585513424	08. Sun Mean longitude in deg (Lmean)	= 270.4309127840
09. Earth Mean anomaly in deg (ME)	= 347.2585513424	10. Sun Ecliptic longitude in deg (Lsun)	= 269.9999511320
11. Obliquity of ecliptic in deg (Epcylone)	= 23.4374619456	12. Sun Right ascension in deg (Alpha)	= 269.9999467376
13. Sun Declination in deg (Delta)	= -23.4374619456	14. Sun Mean distance in km (As)	= 149598616.31172
15. Sun Radial distance from earth in km (Rs)	= 147162417.75585	16. Sun Nodal elongation in deg (U sun)	= -90.0000000000
17. Sun Mean anomaly in deg (M sun)	= 347.2585513416	18. Sun Eccentric anomaly in deg (E sun)	= 347.0438922873
19. Sun True anomaly in deg (T sun)	= 346.8274560675	20. Sun Argument of perigee in deg (W sun)	= 283.1725439325
21. Sun True anomaly in deg from U & W (V sun)	= 346.8274560675	22. Sun Distance in km (d sun)	= 147158348.89183

Sun Ecliptic latitude is always nearly zero (the value never exceeds 0.00033 deg)

Thus Computed values for Position of Sun on Celestial Sphere corresponding to Standard Epoch time JD2000, and six astronomical events while earth reaches Perihelion, Vernal equinox, Summer solstice, Aphelion, Autumnal equinox, Winter solstices.

Move on to Summary of these Computed values are presented next.

Next Section - 3.8 Concluding Position of Sun at six astronomical events.

OM-MSS Section - 3.8 ----------33

Concluding Position of Sun on Celestial Sphere (Sections 3.0 to 3.7)

Concluding Sun Position on Celestial Sphere with respect to Earth orbit, in the Year = 2013, at six astronomical events.

In previous Sections (3.1 to 3.7), the position of Sun on Celestial Sphere were represented by computing following parameters :

Orbit Semi-major axis (SMA), Mean movement per day (n sun), Mean distance (As), Mean anomaly (m sun), True anomaly (T sun),

Eccentric anomaly (E sun), Right ascension (Alpha), Declination (Delta), Mean longitude (Lmean), Ecliptic longitude (Lsun),

Nodal elongation (U sun), Argument of perigee (W sun), Obliquity of ecliptic (Epcylone), Mean dist (d_sun), Radial distance (Rs).

All these parameters were computed while Earth moves around Sun and reaches six astronomical event points :

Perihelion, Vernal equinox, Summer solstice, Aphelion, Autumnal equinox, Winter solstice .

Summary of Sun Position on Celestial Sphere with respect to Earth while moved around Sun, passed through at six astronomical events.

Universal time while earth at	Mean anom M_sun	True anom T_sun	Ecce.anom E_sun	Right asc. Alpha	Declina Delta	Mean log. L_mean	Ecli.log. L_sun	Nodal elon. U_sun	Arg of peri w_sun	Obliquity Epcylone	Mean dist. d_sun	Radial dist. Rs
Perihelion	0.00	0.00	0.00	284.29	-22.79	283.16	283.16	-76.84	283.16	23.44	147098790.67	147098823.43
Vernal equinox	74.98	76.84	75.91	0.00	0.00	358.14	0.00	0.00	283.16	23.44	148912015.97	148989898.68
Summer solstice	166.39	166.84	166.62	90.00	23.44	89.56	90.00	90.00	283.16	23.44	152025947.60	152030583.04
Aphelion	180.00	180.00	180.00	104.30	22.79	103.16	103.16	76.84	256.84	23.44	152098441.95	152098409.19
Autumnal equinox	258.70	256.83	257.77	180.00	-0.00	181.87	180.00	-0.00	103.17	23.44	150048057.37	150128632.17
Winter solstice	347.26	346.83	347.04	270.00	-23.44	270.43	270.00	-90.00	283.17	23.44	147158348.89	147162417.76

Orbit Semi-major axis in km (SMA) = 149598616.31172, Eccentricity (e sun) = 0.0167102190

Mean movement deg per day (n sun) = 0.9856003000, Mean distance from earth in km (As) = 149598616.31172

Continue Section - 2.8

In the table above , all angles are in deg and distances in km. The values show consistency. About accuracy, for an input Universal Time,

Compared below the computed values against that reported **(Ref. http://www.stargazing.net/kepler/sun.html).**

For Input Universal Time year = 1997, month = 8, day = 7, hour = 11, minute = 0, seconds = 0.0000000000 (under reference)

The Output Computed values : Sun Position on Celestial Sphere at Input UT time

07. Sun Mean anomaly in deg per day from n_sun (m sun) = 213.1154702210

08. Sun Mean longitude in deg (Lmean) = 136.0061615585

10. Sun Ecliptic longitude in deg (Lsun) = 134.9782467378

11. Obliquity of the ecliptic plane in deg (Epcylone) = 23.4395921140

12. Sun Right ascension in deg (Alpha) = 137.44256792552

13. Sun Declination in deg (Delta) = 16.3426505298

The Output Reported values : Sun Position on Celestial Sphere at same UT time, **(Ref. http://www.stargazing.net/kepler/sun.html).**

07. Sun Mean anomaly in deg per day from n_sun (m sun) = 213.11547

08. Sun Mean longitude in deg (Lmean) = 136.00716

10. Sun Ecliptic longitude in deg (Lsun) = 134.97925

11. Obliquity of the ecliptic plane in deg (Epcylone) = 23.439351

12. Sun Right ascension in deg (Alpha) = 137.44352

13. Sun Declination in deg (Delta) = 16.342193

End of Computing Position of Sun on Celestial Sphere at Standard Epoch JD2000 and at Six Astronomical Events.

Move on to Compute the Position of Earth on Celestial Sphere at Input Universal Time (UT).

Next Section - 4 Position of Earth on Celestial Sphere at UT

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ANNEXURE : A Collection of few OM-MSS related Diagrams / Help.

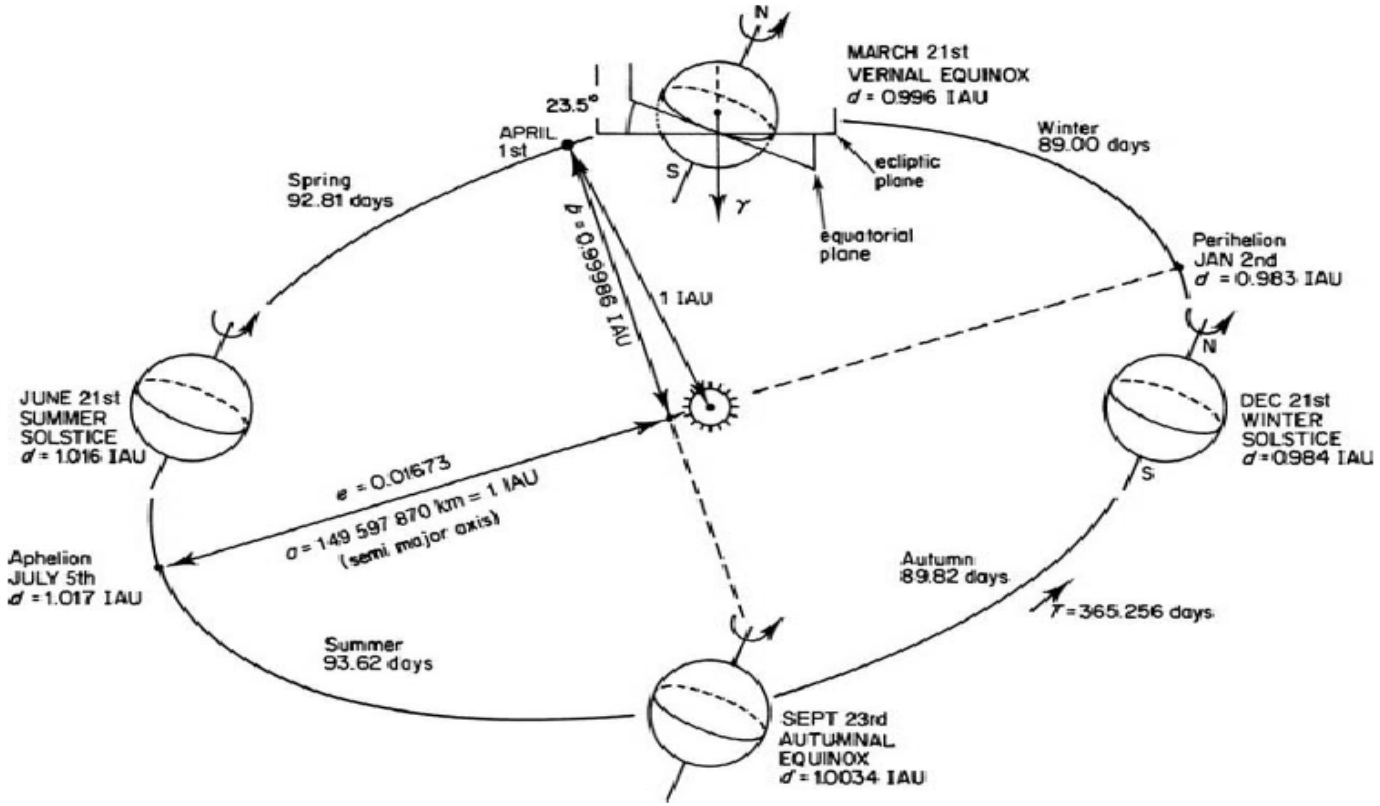
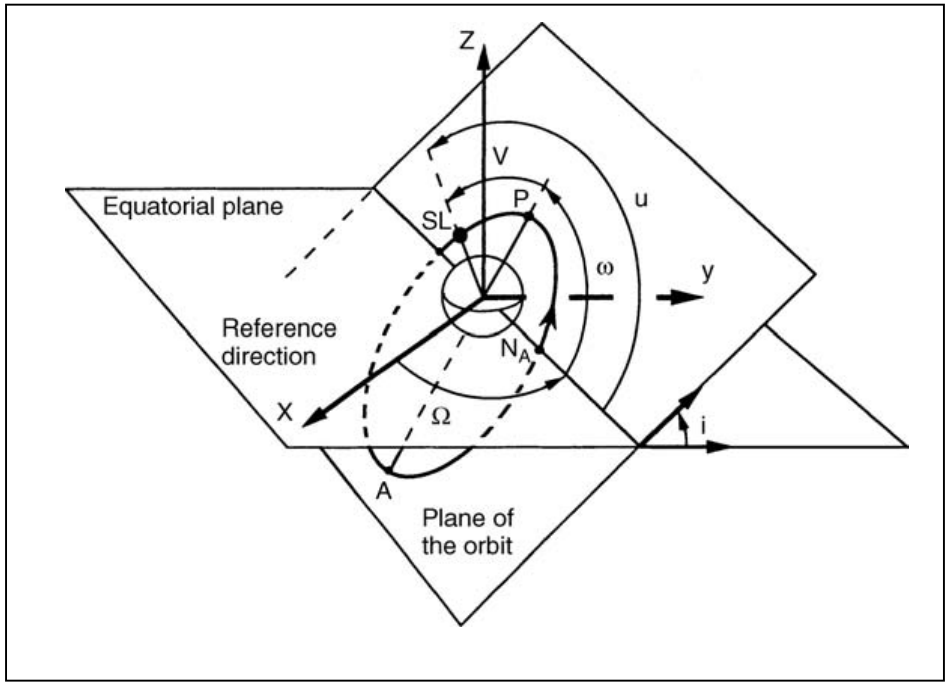


Fig-3. Orbit of Earth Around Sun

Earth rotates around sun with a period of approximately 365.25 days following an Ellipse of Eccentricity 0.01673 and Semi-major axis 149597870 km, which defines the Astronomical unit of distance (AU). Around 2 January, Earth is nearest from sun called Perihelion while around 5 July it is farthest from Sun called Aphelion (around 152100000 km). The other events point are Vernal equinox around 21 March, Autumnal equinox around 23 September, Summer solstice around 21 June and Winter solstic around 21 December. The plane of the orbit is called the plane of the Ecliptic that makes an angle 23.44 deg (the Obliquity of the Ecliptic) with the mean Equatorial plane.

Source Book by Gerard Maral, Michel Bousquet, 'Satellite Communications Systems', Fifth Edition, John Wiley & Sons, chap. 2, Pg 29, 2002.



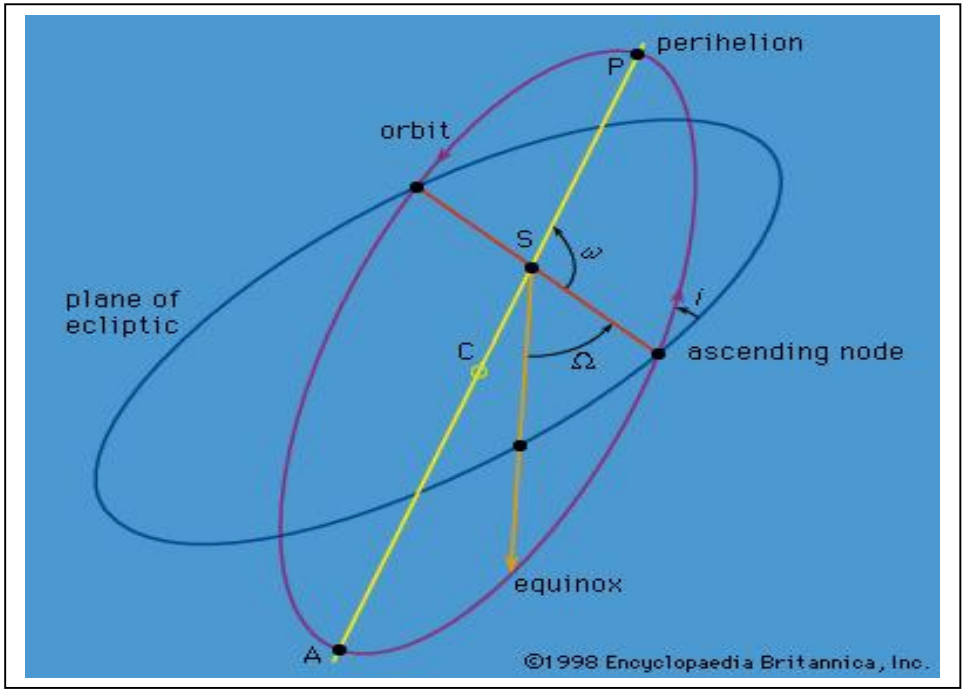


Fig- 4 & 5 Positioning of Orbit in Space

Orbit Position in Space at Epoch is defined by the Values of Kepler Orbit elements : (definations apply to both planets & Satellits)

1. Inclination 'i' of the orbit of a planet, is angle between the plane of planet's orbit and the plane containing Earth's orbital path (ecliptic).
2. Right ascension 'Ω' of the ascending node is the angle taken positively from 0 to 360 deg in the forward direction, between the reference direction and the ascending node of the orbit (the intersection of the orbit with the plane of the equator crossing this plane from south to north).
3. Argument of Perigee 'ω', specify angle between orbit's perigee and orbit's ascending node, measured in orbital plane and direction of motion.
4. Eccentricity '*e*' of an orbit shows how much the shape of an object's orbit is different from a circle;
5. Mean Anomaly '*v*' relates the position and time for a body moving in a Kepler orbit. The mean anomaly of an orbiting body is the angle through which the body would have traveled about the center of the orbit's auxiliary circle. 'M' grows linearly with time.

A knowledge of above five parameters completely defines the trajectory of an object or satellite in space. However, the Nodal angular elongation '*u*' can also be used to define the position of the satellite in its orbit. This is the angle taken positively in the direction of motion from 0 to 360 deg between the direction of the ascending node and the direction of the satellite ***(u = ω + v).***

Source Book by Gerard Maral, Michel Bousquet, 'Satellite Communications Systems', Fifth Edition, John Wiley & Sons, chap. 2, Pg 29, 2002. & http://www.britannica.com/EBchecked/topic/101285/celestial-mechanics/images-videos/2285/orbital-element-keplers-laws-of-planetary-motion