THE SOLAR SYSTEM & TIME

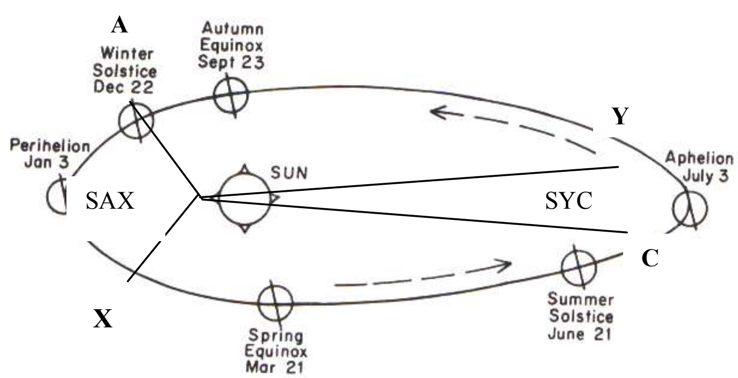
The measurement of the passage of time is based upon observations of events occurring at regular intervals. The two repetitive events which most influence life on Earth are the rotation of the Earth on its axis. Causing day and night, and the movement of the Earth in its orbit around the Sun, causing the seasons.

THE EARTH'S ORBIT

The orbit of a planet around the Sun conforms with Kepler's Laws of Planetary Motion which state :-

1. The orbit of a planet is an ellipse, with the Sun at one of the foci.

2. The line joining the planet to the Sun, known as the radius vector, sweeps out equal areas in equal in equal intervals of time.



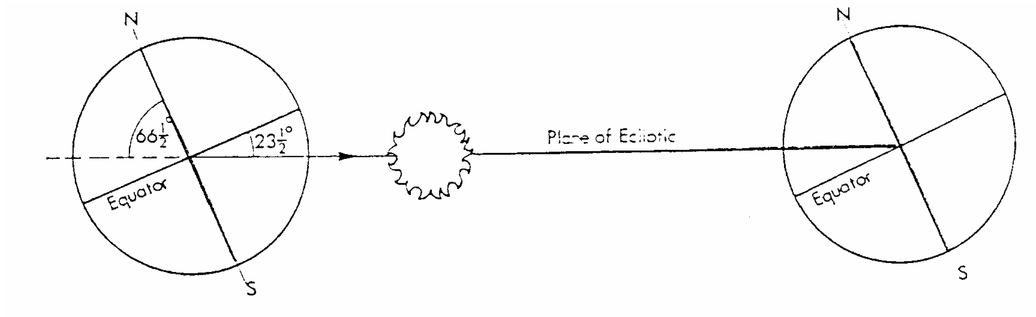
In the above sketch the planet (P) moves anticlockwise in its orbit and is at its closest position to the Sun at position A which is called **PERIHELION**. At Perihelion the Earth is about 91½ million miles from the Sun and occurs on January ±3.

At position C the planet is furthest from the Sun and is known as **APHELION**. At Aphelion the Earth is about 94½ million miles from the Sun and occurs on ±July 3.

The mean distance of the Earth from the Sun is about 93 million miles.

According to Kepler's Law the radius vector sweeps out equal areas in equal intervals of time. If the area SAX equals the area SYC then as the distance AX is greater than the distance CY and the orbital speed of the planet is faster at Perihelion than at Aphelion. The orbital speed of the Earth is variable.

The Earth completes one orbit around the Sun in about 365.25 days. The plane of the orbit is called the plane of the Ecliptic, and the N/S axis of the Earth is inclined to this plane at an angle of 66½°. The plane of The Ecliptic is at an angle of 23½ ° to the Earth's Equator and this angle is known as the obliquity of the ecliptic.



THE SEASONS

One effect of the tilt of the Earth's axis is the annual cycle of seasons. As the Earth moves around the Sun, on or near 23rd of December the North Pole is inclined away from the Sun, which is vertically above Latitude 23½°N. This is known as winter solstice and is midwinter in the Northern Hemisphere and midsummer in the Southern Hemisphere.

As the Earth travels around its orbit, being a gyro. its axis will always point in the same direction relative to space and will reach a point at the summer solstice, on or about 22nd June, when the Sun is vertically overhead Latitude 23½°N. It is then midsummer in the Northern Hemisphere and midwinter in the Southern Hemisphere.

Between these dates the Sun. will be overhead the Equator. These events occur on ±21st March which is the spring or vernal equinox, and ±23rd September which is the autumn equinox.

Approximate dates

Jan 4	Perihelion	Sun 91½ million miles
Mar 21	Vernal or Spring Equinox	Sun overhead Equator Declination 00:N/S
Jun 22	Summer Solstice	Sun overhead Tropic of Cancer Declination 23½°N
July 4	Aphelion	Sun 94½ million miles
Sep 23	Autumn Equinox	Sun overhead Equator Declination 00:N/S
Dec 23	Winter Solstice	Sun overhead Topic of Capricorn 23½°S

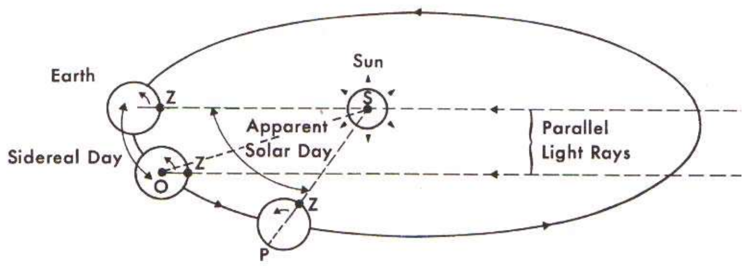
The seasons apply to the Northern Hemisphere and reversed in the Southern Hemisphere.

MEASUREMENT OF TIME - THE DAY

The rotation of the Earth on its axis is used as a basis for the measurement of the length of a day. The length of time taken for the Earth to complete one revolution on its axis can be found by taking the time between two successive transits of a fixed point in space over a particular meridian.

SIDEREAL DAY (23 hours 56 minutes 4 seconds)

As stars are at immense distances from the Earth, they can be considered to be at infinity and rays of light from stars can be considered parallel regardless of the position of the Earth in its orbit round the Sun. The time interval between two successive transits of a star or a fixed point in space over a meridian is called a SIDEREAL DAY and is constant at 23 hours 56 minutes and 4 seconds.



APPARENT SOLAR DAY

The time interval between two successive transits of the True Sun over a meridian is an Apparent Solar Day.

The Sun and a star are in transit overhead a meridian. After 23 hours 56 minutes and 4 seconds the star is in transit for a second time (a Sidereal Day), rays of light from a star being parallel. Due to the Earth's orbital speed (approximately 58 000 Kts) it has moved some 1 400 000 nm along its orbit and the Sun has to rotate 'X' degrees before the Sun is in transit for a second time. This of course takes time thus an Apparent Solar Day is always longer than a Sidereal Day.

An average of 365 Apparent Solar Days is taken and termed a **Mean Solar Day** which is 24 hours.

MEAN SOLAR DAY

The 24 hour day is based on the Mean Sun. When the Mean Sun is overhead a meridian it is 12:00 Local Mean Time (LMT). Each and every meridian has its own LMT.

THE EQUATION OF TIME

The equation of time is the time difference between the apparent solar day and the mean solar day and is of varying duration.

THE SIDERIAL DAY

Because of the relative proximity of the earth to the sun, attempts to measure the length of the day (one revolution of the earth) are contaminated by the movement of the earth in its orbit relative to the sun.

To solve this problem, a fixed point in space is chosen which is so enormously distant that the movement of the earth in its orbit relative to this point is basically zero. This point in space is called the siderial point or the first point of Aries.

The Siderial day then, is defined as two successive transits of the Siderial point at the same meridian. The Siderial day is of constant duration : 23 hours 56 mins 4 seconds

The Earth rotates on its axis from West to East. It is more convenient to imagine the Earth. stationary with the Sun rising in the East and setting in the West.

At the Greenwich Meridian the sun is rising at 06:00 LMT.
At 90E the sun is overhead at 12:00 LMT.
At 180°E/W the sun is setting at 18:00 LMT.
At 90°W it is midnight 24:00 LMT on the 5th LD Local Date or 00:00 LMT on the 6 th LD.

The Local Date changes at midnight and also at the International Date Line.

UTC UNIVERSAL CO-ORDINATED TIME

UTC is the LMT at the Greenwich Meridian and is used as the standard reference from time keeping for aviation. UTC is the same as GMT (Greenwich Mean Time).

ARC TO TIME

As the Earth rotates through 360 in 24 hours. 90 in 6 hours, or 15° per hour there is a direct relationship between Longitude and LMT. The Conversion of Arc to Time table on the next page is also available in the Navigation Tables booklet provided in the examination.

The first six columns are degrees of Longitude on the left with the corresponding time in hours and minutes on the right.

10° 0:40 15° 1:00 79° 5:16 161° 10:44

The right hand column gives the time equivalent for minutes of Longitude.

28' Long 1 minutes 52 seconds 42' Long 2 minutes 48 seconds

127° 37'E Arc to Time 127° = 8:28 37' = 2:28 127° 37' = 8:30:28

CONVERSION OF LMT TO UTC		
	LONGITUDE EAST	UTC LEAST
	LONGITUDE WEST	UTC BEST

Q1. At position A (N 45:05 E 065:30) it is 13:15 LMT on 23rd March.
The LJTC at this position is :-

A	13:15 LMT 23rd March
E 065:30 Arc to Time	4:22
A	08:53 UTC 23rd March

Longitude East - UTC Least UTC must be an earlier time than LMT

Q2. The time is 06:45 UTC on 21st May GD (Greenwich Date).
At position B (S 28:37 W 092:20) the LMT is :-

B	06:45:00 UTC 21°May GD°
W 092:20 Arc to Time	6:09:20
B	00:35:40 LMT 21" May LD

Longitude West - UTC Best UTC must be a later time than LMT

Q3. If the UTC is 15:30 on the 22nd June GD and the LMT at position X is 09:45 on 22nd June LD the Longitude of X is :-

15:30 UTC 22nd June
09:45 LMT 22nd June

Time difference 5:45 Time to Arc = W 086° 15' Longitude

Q4. An aircraft departs C (N 45:35 E 010:15) at 15:30 LMT on 15th May LD.
Flight time to D (42:37 E 135:45) is 11 hours 18 minutes. The ETA in LMT is :-

C	ETD	15:30 LMT 15th May LD
E 010:15 Arc to Time		0:41
C	ETD	14:49 UTC 15th May GD
Flight Time		11:18
D	ETA	26:07 UTC 15 th May GD
	ETA	02:07 UTC 16 th May GD
E 135:45 Arc to Time		9:03
D	ETA	11:10 LMT 16 th May LD

NOTE: In flight the time standard is UTC. always work in UTC.

ZONE TIME (ZT)

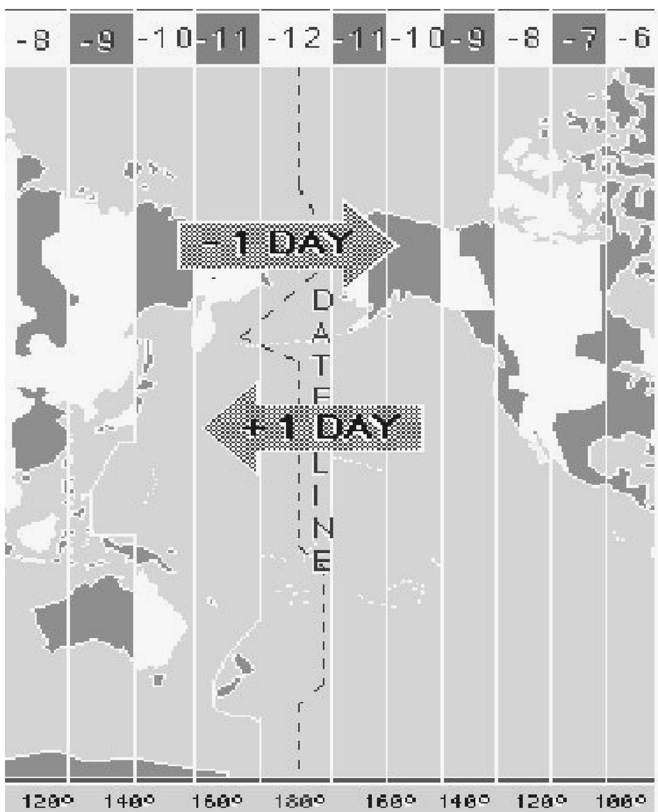
UTC is a method of co-ordination, not time keeping. LMT could be a method of time keeping, but is not practical because each and every meridian would have its own time. To solve this problem, the earth is divided into zones, 15º wide. The time in each zone is the same and is referenced to the mid-meridian for that zone.

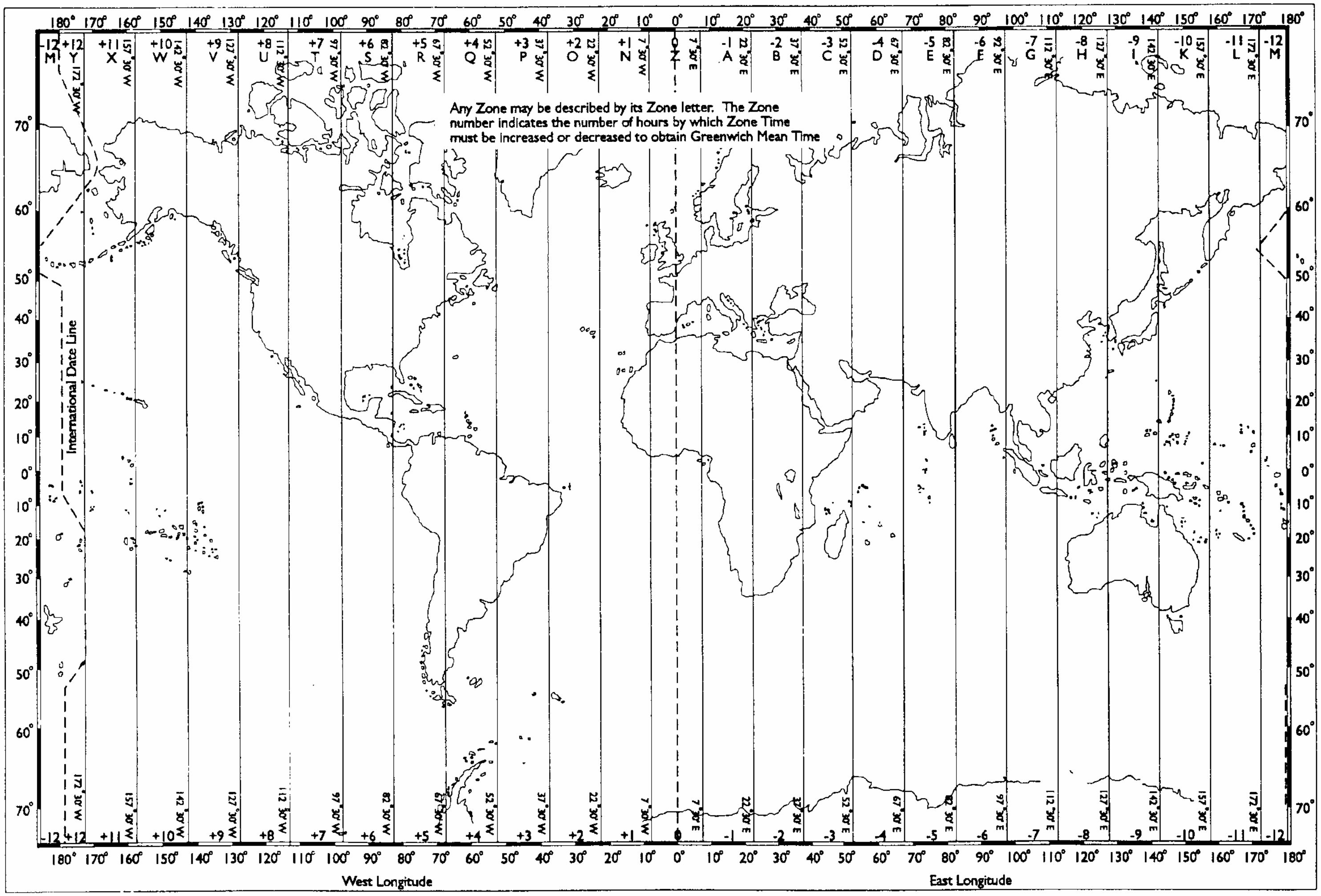
To convert UTC to zone time or vice versa, add or subtract the zone number (hours).

Remember, east is later and west is earlier.

Rule for the international date line:

When heading east, subtract 24 hours.
When heading west, add 24 hours.





Any Zone may be described by its Zone letter. The Zone number indicates the number of hours by which Zone Time must be increased or decreased to obtain Greenwich Mean Time
International Date Line
-12 M
+12 Y
+11 X
+10 W
+9 V
+8 U
+7 T
+6 S
+5 R
+4 Q
+3 P
+2 O
+1 N
0 Z
-1 A
-2 B
-3 C
-4 D
-5 E
-6 F
-7 G
-8 H
-9 I
-10 K
-11 L
-12 M
West Longitude
East Longitude

LOCAL STANDARD TIME

As every Meridian has a different LMT, LMT is not suitable for civil time keeping. Durban has a different LMT to Johannesburg. Each country has its own standard time factor which is applied to UTC to give local standard time. Standard times appear on the next four pages. For GMT (Greenwich Mean Time) read UTC.

List 1 Mainly countries with Easterly Longitude (including Spain & Portugal which are Westerly Long.)

List 2 Countries normally keeping GMT or UTC.

List 3 Countries with Westerly Longitude

Apply Standard Times in the same manner as LMT (Long East - UTC Least & Long West - UTC Best) or apply as given at the top of each list. Ignore summer time.

OOPS

SUNRISE, SUNSET AND TWILIGHT

SUNRISE

The time at which the upper rim of the sun just becomes visible above the horizon. This time can be extracted from one of the following sources:

a) The Air Almanac (LMT)
b) The Jeppesen (LMT)
c) The Aerad (UTC)
d) The SA AIP for the major airports

The times extracted have been corrected for atmospheric refraction.

SUNSET

The time at which the upper rim of the sun just disappears below the horizon. This time can be extracted from one of the following sources:

a) The Air Almanac (LMT)
b) The Jeppesen (LMT)
c) The Aerad (UTC)
d) The SA AIP for the major airports

The time extracted have been corrected for atmospheric refraction.

TWILIGHT

The beginning of morning civil twilight.

The time at which the sun is 6° below the horizon on its way up. This time can be extracted from the Air Almanac (LMT).

The end of evening civil twilight

The time at which the sun is 6° below the horizon on its way down. This time can be extracted from the Air Almanac (LMT).

IMPORTANT NOTES

a) Sunrise, sunset and twilight do not occur at the same LMT for places on the same meridian. Due to the inclination of the earth's axis, the time for sunrise, sunset and twilight varies with latitude and date. Sunrise, sunset and twilight do however occur at the same LMT for all places on the same latitude for a particular date.

b) The duration of morning civil twilight is determined by subtracting the time for sunrise (end of morning civil twilight) and the time for (beginning of) morning civil twilight.

c) The duration of evening civil twilight is determined by subtracting the time by sunset (beginning of evening civil twilight) and the time for (the end of) evening civil twilight.

MOONRISE AND MOONSET

The moon rotates anti-clockwise around the earth in a nearly circular orbit at an average distance of 250 000 miles. The point where the moon is closest to the earth in its orbit is called PERIGEE. The point where the moon is furthest from the earth in its orbit is called APOGEE.

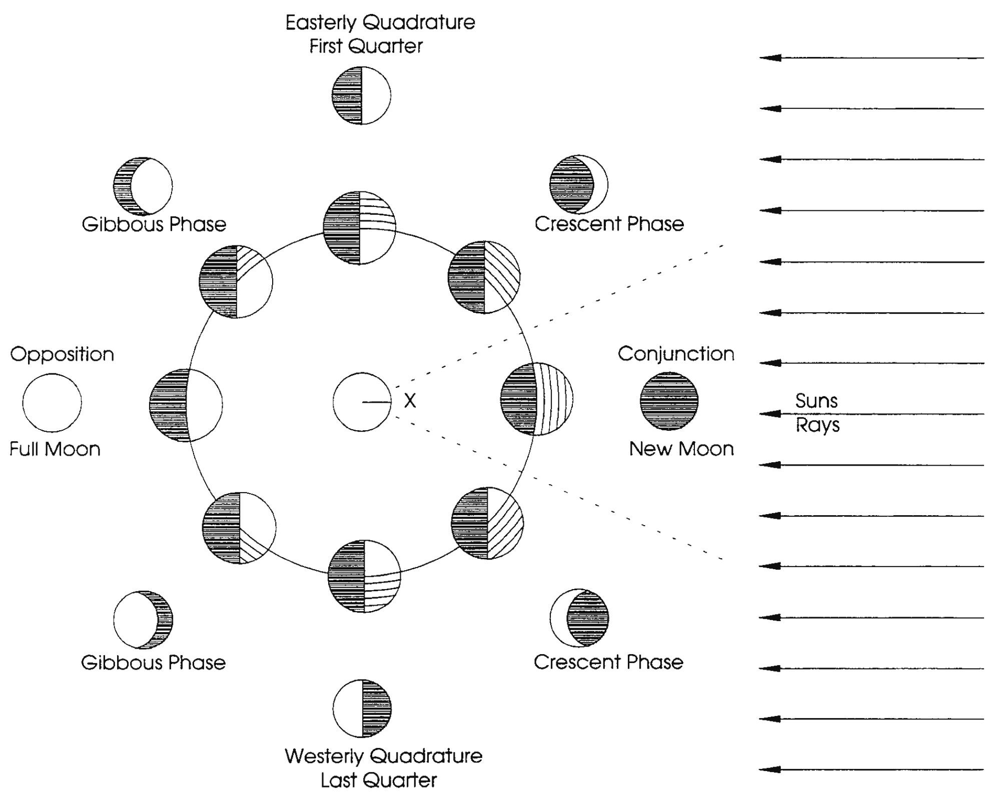
THE SYNODIC PERIOD

This is the time it takes for the moon to make one complete orbit around the earth relative to the sun i.e. the time interval between two new moons. The synodic period is ± 29½ days and forms the origin of the month.

THE SIDERIAL PERIOD

This is the time it takes for the moon to make one complete orbit around the earth relative to a fixed point in space. The Siderial period is 27 days 7 hours 43 minutes ± 3 minutes.

THE PHASES OF THE MOON



QUESTIONS

Part 1

1. An aircraft leaves position A (25° N 067° 19' E) at 1407 LMT on the 3rd on a flight to B (23° N 014° 27' W). The flight time is 9 H 12.

   What is the arrival time at B in LMT?

2. The aircraft arrives at position B (63° N 168° W) at 2208 ST on the 2nd. The standard factor at B is 11 hours. The aircraft departed from A (71° N 174° E) and the flight time was 7 H 06.

   What was the departure time in LMT?

3. An aircraft arrives at position B (12° N 008° E) at 1823 ST on the 4th. The standard factor at B is 1 hour. The aircraft departed position A (08° N x° W) at 0838 LMT on the 4th and the flying time was 6H33.

   What is the longitude of position A?

4. An aircraft flies a rhumb line track of 270° for 3 hours and covers 1580 nm.

   If the LMT of departure is the same as the LMT of arrival, what was the parallel of l altitude which the aircraft followed?

Part 2

1. An aircraft is to fly from A (12° S 22° 08' W) to B (10° S 63° 47' W). The aircraft must arrive at B no later than the end of evening civil twilight on 11 JAN.

   What is the latest standard LMT that the aircraft can depart from A if the flying time is 4H20?

2. An aircraft departs from position A (60° N 015° E) at 0715 LMT on JAN 2nd. the aircraft flies a rhumb line track of 090° at a ground speed of 300 Kts. The aircraft arrives at destination on sunset of the same day.

   What is the destination position?

3. An aircraft departs from position A (60°N 098°30’E) at 0800Z on Jan 15 flying due west at a mean groundspeed of 300 Kts and lands at sunset the same day, at destination longitude?