Celestial Techniques
by
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Topics

- Time
- Latitude at LAN
- Latitude by Polaris

Time

- Apparent Solar Time - Time reckoned according to the passage of the sun in the sky. Used in this context, the sun is referred to as the apparent sun*.*   Two disadvantages are associated with the use of apparent sun:
  - A traveler's watch would have to be adjusted one minute for every 15 degrees of longitude traversed.
  - The speed at which the earth revolves around the sun continually changes as does the inclination of the earth's axis with respect to the sun.

- Mean Solar Time - Mean solar time overcomes the disadvantages of the apparent sun. It employs as its reference a hypothesized mean sun*,* the hour circle of which is considered to move at a constant rate along the celestial equator.
  - The rate at which the mean sun moves is the average rate of motion of the apparent sun during each mean solar day over a solar year.
  - There are 24 hours in a mean solar day, and 360 degrees in the circumference of the earth, so the mean sun moves at a constant rate of 360/24=15 degrees per hour. This fact is important because the degrees of arc measured along a parallel of latitude are directly convertible into time units.

Time

- <u>Equation of time</u> - At certain times of the year, the apparent sun moves across the heavens at a slower rate than the mean sun, while at other times, it travels faster. The apparent sun may be as much as 15 minutes ahead or behind the mean sun. The difference between mean and apparent time at any instant is called the equation of time. The equation of time is tabulated for each day in the *Nautical Almanac.*
  - An example of the time tables found in the *Nautical Almanac* is shown below:

Day	SUN					
	Eqn. of Time				Mer. Pass.	
	00^h		12^h			
d	m	s	m	s	h	m
14	05	49	05	53	12	06
15	05	56	05	59	12	06
16	06	02	06	05	12	06

Time

- The first column gives the number of minutes and seconds by which the apparent sun either lags or leads the mean sun as these bodies pass over the 180th Meridian(00^h)
- The second column contains the time differences applying to the Prime Meridian (12^h).
- The third column provides the local mean times rounded to the nearest whole minute at which the apparent (actual) sun will pass over the Greenwich meridian.
- In this example, the apparent sun is ahead of the mean sun on these dates by the amount indicated because it passes over the Greenwich meridian at 1157. If it were behind the mean sun, the values in the third column would be after 1200. Because the equation of time will vary by only a few seconds as the sun continues around the earth in the course of each day, the local mean time of the sun's meridian passage at Greenwich tabulated in the *Nautical Almanac* for each day can also be used for all other meridians.

Time

- <u>Time and longitude:</u> Navigators use mean time reckoned according to the travel of the mean sun with respect to one of three reference meridians: the Greenwich meridian <u>(Greenwich mean time - GMT)</u> , the central meridian of the time zone in which they are located <u>(zone time - ZT)</u>*,* and the meridian passing through a their position <u>(local mean time - LMT)</u>*.*
  - Local mean time is based on the relationship between the mean sun and the observer's meridian.
    - When the mean sun is at <u>lower transit</u> of the observer's meridian (passing over the lower branch of the observer's meridian), LMT is midnight. Conversely, if the mean sun is at <u>upper transit</u> (passing over the upper branch of the observer's meridian), it is noon in LMT.
    - The relationship between local mean time and local zone time and Greenwich mean time is of great importance in determining times of sunrise and sunset, moonrise and moonset, and local apparent noon.
    - LMT differs from zone time by the amount of time required for the mean sun to traverse the difference in longitude between the observer's meridian and the central meridian of their time zone.

Time

» The differences in degrees of longitude, written d, can be converted into differences in time by multiplying by 4. (The sun moves at a rate of 15 deg/hr, so 1 degree of longitude equals 4 minutes (60 min/15 deg = 4 min).

– Example: An observer is located at a longitude of $064^0 13.3'$ W and desires to compute the time required for the mean sun to travel from the central meridian of their time zone , 60W, to their meridian. The difference in longitude $64^0 13.3'$ - $60^0 = 4^0 13.3'$.

» Step One: Divide 13.3' by 60 in order to convert these minutes to a fraction of a degree (13.3/60=.2217).

» Step Two: Multiply 4.2217 by 4 (4.2217 x 4 = 16.8868).

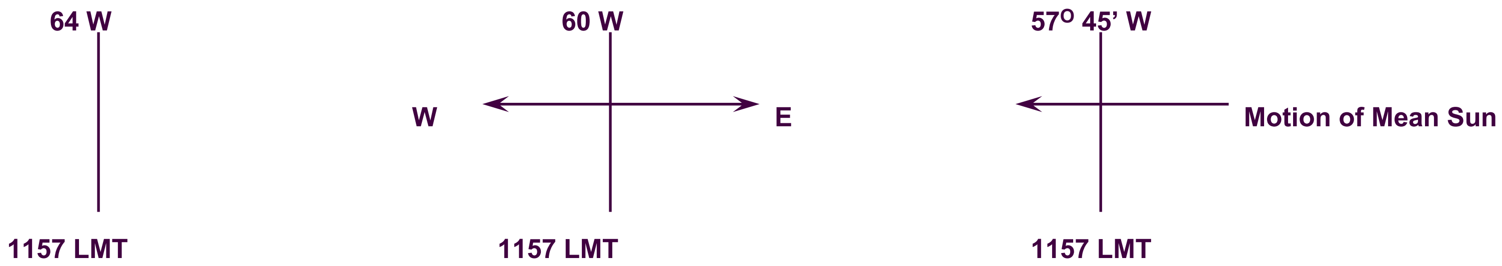
» Step Three: Convert the .8868 into seconds by multiplying by 60. The total time increment is 0 hours 16 minutes and 53 seconds.

» Tables in the *Nautical Almanac* can also be used to facilitate conversions of arc to time. (page i)

– It is the constant rate of travel of the mean sun that makes conversions of arc to time possible. The difference between any two solar mean times based on the travel of the mean is equal to the difference of longitude between their reference meridians, converted to units of time.

Time

<u>Example :</u> Observer's at three different longitudes wish to convert the LMT of LAN (local apparent noon) to the ZT of LAN.



» <u>Step One:</u> From the Equation of Time Table, the LMT of LAN is found to be 1157. The standard meridian of the time zone is 60 W. Meridians to the east of 60W will experience LAN at an earlier zone time and those to the west will experience LAN at a later zone time.

» <u>Step Two:</u> Convert the $2^{0}15'$ difference in arc between $57^{0}45'$W and 60^{0}W to time (2.25 x 4 = 9 minutes).

» <u>Step Three:</u> LAN will occur at 1148 zone time (1157 - 9). The same calculation can be performed to yield a ZT of 1213 for LAN AT 64W.

» The format of writing complete zone time in celestial navigation is as follows:

HH-MM-SS   example: 12-13-53 zone time.

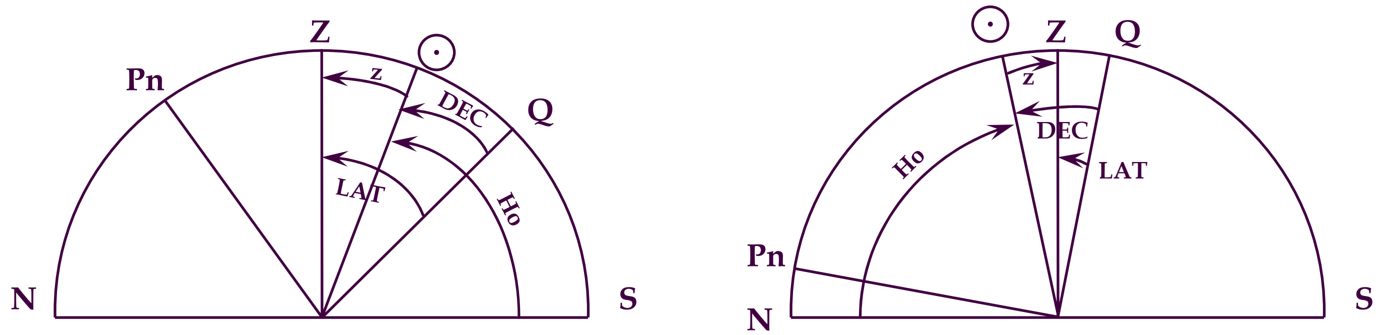
Time

- Timing of celestial observations - It is necessary that the GMT of each celestial observation be recorded to the nearest second in order to be able to extract the required data from the almanacs with sufficient precision to make an accurate determination of position possible. There are three methods of determining the correct time to the degree of precision necessary to make an accurate determination of position - a chronometer (synchronized watch), radio time signals, GPS time from satellites.

Latitude at LAN

- Obtaining a Latitude Line by the sun: Because the sun completes upper transit above the observer's celestial horizon in the mid-latitudes of the world, observation of the sun at this meridian transit is a very convenient method of determining a latitude line. The sun latitude line thus obtained is considered to be one of the most accurate LOPs available.
  - The moment at which the apparent sun transits the observer's meridian is known as *local apparent noon*, abbreviated LAN. The observed altitude of the sun and its declination at the moment of LAN are the two basic data required to determine a latitude line.
  - Since the declination of the sun changes from north 23 1/2 degrees to south 23 1/2 degrees in the course of each year, there are a number of different relationships possible among the elevated celestial pole, the position of the sun, and the zenith of the observer at LAN. The observer's zenith and the position of the sun can both lie in the same celestial hemisphere, or in different hemispheres. If they are in the same hemisphere, the observer's zenith can be either north or south of the position of the sun.

Latitude at LAN



– In general, the latitude of the observer can be obtained by an observation of the sun at LAN by applying the following two rules when in the northern hemisphere:
  - » If the assumed latitude is north of the sun, add the zenith distance z and declination for the latitude of the observer.
  - » If the assumed latitude is south of the sun, subtract zenith distance z from the declination.
  - » Example: If the declination of the sun shown in the the figure on the left were N20° and the observed altitude Ho at LAN were 70°, the zenith distance z would be 90°-70° or 20°N, and the observer's latitude would be 20°N + N20° , or 40°N. If the declination of the sun were N20° and the Ho were 80° as in the figure on the right, the zenith distance would be 90°-80°, or 10° S, since the observer's zenith is located south of the sun. Hence, the observer's latitude would be N20°-10°S, or 10°N.

Latitude at LAN

- **<u>Determination of the time of LAN:</u> The following is a summary of the steps necessary to determine the zone time of LAN:**

1. Obtain the LMT of meridian passage from the *Nautical Almanac*. An example of the tables giving the times of meridian passage of the sun located in the daily pages of the *Nautical Almanac* is shown below.

Day	SUN					
	Eqn. of Time				Mer. Pass.	
	00h		12h			
d	m	s	m	s	h	m
14	05	49	05	53	12	06
15	05	56	05	59	12	06
16	06	02	06	05	12	06

2. Plot a DR position for this time.

3. Determine the difference in longitude between this position and the central meridian of the time zone being used; convert this arc difference to time difference.

Latitude at LAN

4. Apply this time difference to the LMT of meridian passage, adding if west of the time zone central meridian, subtracting if east. The resulting time is the first estimate of the zone time of LAN.
5. If the ship is stationary, the first estimate should be the actual zone time of LAN. If the ship is moving:
6. Plot another DR position for the first estimate zone time of LAN.
7. Compute and apply the time difference for this position to the tabulated LMT of meridian passage. The resulting time is the second and final estimate of LAN.

Latitude at LAN

- **<u>Determining the Latitude at LAN:</u> The sun LAN form shown below shows a complete solution for the following example:**
  - **Zone time - At <u>1100</u> on 16 July, your DR position is 35º45.0' N / 069º 28.0' W. Course – 090T, speed 6 kts.**
  - **1) Record the given information on the form.**
  - **2) The central meridian is obtained by dividing the longitude by 15. In this example the central meridian of 75W.**
  - **3) Determine the arc difference between the central meridian and the DR longitude (5-38.0).**
  - **4) Convert the arc difference to a time difference by multiplying this quantity by 4. This time difference is applied to the meridian passage time. The result, 1143, is the first estimate of the zone time of LAN.**

Day	SUN		
	Eqn. of Time		Mer. Pass.
	00^h	12^h	
d	m s	m s	h m
14	05 49	05 53	12 06
15	05 56	05 59	12 06
16	06 02	06 05	12 06

FIRST ESTIMATE	
Date	16-Jul
DR Latitude	35-45.0
DR λ	069-22.0
Central Meridian	75
dλ (arc)	5-38.0
dλ*= dλ (deg + min/60)	5.633
dλ (time)= 4xdλ*	23 min
Mer. Pass. (LMT)	1206
ZT (est) 1st	1143

Latitude at LAN

- 5) Plot A DR position for 1143 in order to compensate.
- 6) Follow the same procedures used in the first estimate section of the form to obtain a second estimate of LAN. The second an final estimate of zone time of LAN is therefore 1144.
- 7) Record the actual zone time of the observation of the sun when the it appeared at its greatest altitude. The zone descriptor is then applied to yield the GMT of the observation.
- 8) Use the GMT time to obtain the declination of the sun and the appropriate d correction. True declination in this example is N21.033

ZT (est) 1st	1143
SECOND ESTIMATE	
DR λ	069-24.0
Central Meridian	75 W
$d\lambda$ (arc)	5-36.0
$d\lambda^* = d\lambda$ (deg + min/60)	5.6000
$d\lambda$ (time)= $4 x d\lambda^*$	22 min
Mer. Pass. (LMT)	1206
ZT (est) 2nd	1144
ZT (actual)	11:45:05
ZD (+W,-E)	+5
GMT	16:45:05
Date (GMT)	16-Jul
GMT_{hr}	1600
$GMT_{fract} = GMT_{min} + GMT_{sec/60}$	45.083
Dec_{hr} | $d^* = d/60$ (+/-)	21-14.0 | -.0067
$Dec_{hr}^* = Dec_{deg} + Dec_{min/60}$	21.23
$Dec_{total} = Dec_{hr}^* + GMT_{fract} \times d^*$	21.033

Latitude at LAN

- **9) Apply the I.C. and dip corrections to Hs to yield Ha. Ha is then used as an entering argument for the altitude correction tables.**
- **10) Apply the altitude correction to Ha to yield Ho.**

DIP				
Ht. of Eye	Corr^n	Ht. of Eye	Ht. of Eye	Corr^n
m	′	ft.	m	′
2·4		8·0	1·0	− 1·8
	−2·8			
2·6		8·6	1·5	− 2·2
	−2·9			
2·8		9·2	2·0	− 2·5
	−3·0			
3·0		9·8	2·5	− 2·8
	−3·1			
3·2		10·5	3·0	− 3·0
	−3·2			
3·4		11·2	See table	
	−3·3			

$Dec_{total} = Dec_{hr}{}^{*} + GMT_{fract} \times d^{*}$	21.033
IC	-0.5
Dip (ht **9'**)	-2.9
Sum	-3.4
Hs (at LAN)	74-54.8
Ha	74-51.4
Alt Corr	+15.7
Ho	75-07.1

ALTITUDE CORRECTIO

OCT.—MAR. SUN			APR.—SEPT.		
App. Alt.	Lower Limb	Upper Limb	App. Alt.	Lower Limb	Upper Limb
° ′	′	′	° ′	′	′
9 33	+10·8	−21·5	9 39	+10·6	−21·2
9 45	+10·9	−21·4	9 50	+10·7	−21·1
9 56	+11·0	−21·3	10 02	+10·8	−21·0
10 08	+11·1	−21·2	10 14	+10·9	−20·9
10 20	+11·2	−21·1	10 27	+11·0	−20·8
10 33	+11·3	−21·0	10 40	+11·1	−20·7
10 46	+11·4	−20·9	10 53	+11·2	−20·6
11 00	+11·5	−20·8	11 07	+11·3	−20·5
11 15	+11·6	−20·7	11 22	+11·4	−20·4
11 30	+11·7	−20·6	11 37	+11·5	−20·3
11 45	+11·8	−20·5	11 53	+11·6	−20·2
12 01	+11·9	−20·4	12 10	+11·7	−20·1
12 18	+12·0	−20·3	12 27	+11·8	−20·0
12 36	+12·1	−20·2	12 45	+11·9	−19·9
12 54	+12·2	−20·1	13 04	+12·0	−19·8
13 14	+12·3	−20·0	13 24	+12·1	−19·7
13 34	+12·4	−19·9	13 44	+12·2	−19·6
13 55	+12·5	−19·8	14 06	+12·3	−19·5
14 17	+12·6	−19·7	14 29	+12·4	−19·4
14 41	+12·7	−19·6	14 53	+12·5	−19·3
15 05	+12·8	−19·5	15 18	+12·6	−19·2
15 31	+12·9	−19·4	15 45	+12·7	−19·1
15 59	+13·0	−19·3	16 13	+12·8	−19·0
16 27	+13·1	−19·2	16 43	+12·9	−18·9
16 58	+13·2	−19·1	17 14	+13·0	−18·8
17 30	+13·3	−19·0	17 47	+13·1	−18·7
18 05	+13·4	−18·9	18 23	+13·2	−18·6
18 41	+13·5	−18·8	19 00	+13·3	−18·5
19 20	+13·6	−18·7	19 41	+13·4	−18·4
20 02	+13·7	−18·6	20 24	+13·5	−18·3
20 46	+13·8	−18·5	21 10	+13·6	−18·2
21 34	+13·9	−18·4	21 59	+13·7	−18·1
22 25	+14·0	−18·3	22 52	+13·8	−18·0
23 20	+14·1	−18·2	23 49	+13·9	−17·9
24 20	+14·2	−18·1	24 51	+14·0	−17·8
25 24	+14·3	−18·0	25 58	+14·1	−17·7
26 34	+14·4	−17·9	27 11	+14·2	−17·6
27 50	+14·5	−17·8	28 31	+14·3	−17·5
29 13	+14·6	−17·7	29 58	+14·4	−17·4
30 44	+14·7	−17·6	31 33	+14·5	−17·3
32 24	+14·8	−17·5	33 18	+14·6	−17·2
34 15	+14·9	−17·4	35 15	+14·7	−17·1
36 17	+15·0	−17·3	37 24	+14·8	−17·0
38 34	+15·1	−17·2	39 48	+14·9	−16·9
41 06	+15·2	−17·1	42 28	+15·0	−16·8
43 56	+15·3	−17·0	45 29	+15·1	−16·7
47 07	+15·4	−16·9	48 52	+15·2	−16·6
50 43	+15·5	−16·8	52 41	+15·3	−16·5
54 46	+15·6	−16·7	56 59	+15·4	−16·4
59 21	+15·7	−16·6	61 50	+15·5	−16·3
64 28	+15·8	−16·5	67 15	+15·6	−16·2
70 10	+15·9	−16·4	73 14	+15·7	−16·1
76 24	+16·0	−16·3	79 42	+15·8	−16·0
83 05	+16·1	−16·2	86 31	+15·9	−15·9
90 00			90 00		

App. Alt. = Apparent altitud

Latitude at LAN

- 11) Subtract Ho* from 90 degrees; the resulting value is the zenith distance.
- 12) Add the true declination and the zenith distance .
- The sun latitude line may be combined with other simultaneous or non-simultaneous LOPs to form a fix or running fix, or the line can be crossed with the longitude line of the DR position corresponding to the time of the observation to produce an estimated position of unusual reliability.

Ho	75-07.1
$Ho^* = Ho_{deg} + Ho_{min/60}$	75.118
ZD = 90 - Ho*	14.882
Dec_{total}	21.033
Lat*	35.915
$Lat = Lat^*_{deg} + Lat^*_{fract} x60$	35-54-54 N

Latitude by Polaris

- <u>The Celestial Triangle and Polaris:</u> The position of the star Polaris and the North celestial pole Pn are nearly coincident in the celestial triangle.
  - The observed altitude of Polaris is approximately equal to the latitude of the observer. This fact is of great usefulness to the navigator operating at sea in northern latitudes.
  - Polaris is about three-quarters of a degree off to one side of the Celestial north pole. Polaris has a small diurnal circle of variable radius about the pole, which must be taken into account in order to obtain a latitude line precise to more than 1 degree by Polaris.
  - Tables are provided in the *Nautical Almanac* for the purpose of correcting the apparent altitude ha of Polaris for this distance at any given moment.

Latitude by Polaris

- The Polaris correction is taken from the "Polaris Tables" in three parts, which are designated a_o,a_1,and $a_{2.}$
  - » The a_0, can be thought of as a compensation for the component of the distance between the position of Polaris in its diurnal circle and the north celestial pole, measured along the observer's meridian; the effect and hence the correction varies with the observer's longitude.
  - » The a_1 is compensation for the tilt of the diurnal circle of Polaris with respect to the vertical circle of the observer; this correction increases as the latitude of the observer increases.
  - » The a_2 part compensates for an aberration in the apparent position of Polaris because bending of the incoming light rays from the star, occurring as a result of the velocity of the earth in its orbit; the orbital velocity, and therefore the a_2 correction thus obtained varies with the time of the year.
  - » The composition of the "Polaris Tables" in the *Nautical Almanac* is such that these three parts are always positive; but after they have been added together, 1 degree (60') is always subtracted from their sum. The total Polaris correction therefore can be negative.

Latitude by Polaris

– **Polaris Tables**

POLARIS (POLE STAR) TABLES, 2004 275

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

LHA ARIES	120° – 129°	130° – 139°	140° – 149°	150° – 159°	160° – 169°	170° – 179°	180° – 189°	190° – 199°	200° – 209°	210° – 219°	220° – 229°	230° – 239°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 52·3	0 59·8	1 07·2	1 14·4	1 21·1	1 27·1	1 32·2	1 36·4	1 39·4	1 41·2	1 41·7	1 40·9
1	53·1	1 00·6	08·0	15·1	21·7	27·6	32·7	36·7	39·6	41·3	41·7	40·8
2	53·8	01·3	08·7	15·8	22·3	28·2	33·1	37·1	39·8	41·4	41·6	40·6
3	54·6	02·0	09·4	16·5	23·0	28·7	33·6	37·4	40·0	41·5	41·6	40·5
4	55·3	02·8	10·1	17·1	23·6	29·3	34·0	37·7	40·2	41·5	41·5	40·3
5	0 56·1	1 03·5	1 10·9	1 17·8	1 24·2	1 29·8	1 34·4	1 38·0	1 40·4	1 41·6	1 41·5	1 40·1
6	56·8	04·3	11·6	18·5	24·8	30·3	34·8	38·3	40·6	41·6	41·4	39·9
7	57·6	05·0	12·3	19·1	25·4	30·8	35·2	38·6	40·8	41·7	41·3	39·6
8	58·3	05·8	13·0	19·8	25·9	31·3	35·6	38·9	40·9	41·7	41·2	39·4
9	59·1	06·5	13·7	20·4	26·5	31·8	36·0	39·1	41·0	41·7	41·1	39·2
10	0 59·8	1 07·2	1 14·4	1 21·1	1 27·1	1 32·2	1 36·4	1 39·4	1 41·2	1 41·7	1 40·9	1 38·9
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·6	0·6
10	·3	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·6
20	·4	·4	·4	·4	·5	·5	·5	·6	·6	·6	·6	·6
30	·4	·4	·4	·5	·5	·5	·5	·6	·6	·6	·6	·6
40	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6
45	·5	·5	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6	·6	·6
60	·7	·7	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6
62	0·8	0·8	0·8	0·7	0·7	0·7	0·7	0·6	0·6	0·6	0·6	0·6
64	·8	·8	·8	·8	·8	·7	·7	·6	·6	·6	·6	·6
66	·9	·9	·9	·8	·8	·7	·7	·6	·6	·6	·6	·6
68	0·9	0·9	0·9	0·9	0·8	0·8	0·7	0·7	0·6	0·6	0·6	0·6
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5
Feb.	·8	·8	·7	·7	·7	·6	·6	·5	·5	·5	·4	·4
Mar.	0·9	0·9	0·9	0·8	·8	·8	·7	·7	·6	·6	·5	·5
Apr.	1·0	1·0	1·0	1·0	0·9	0·9	0·9	0·8	0·8	0·7	0·6	0·6
May	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8	·8	·7
June	·8	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	·9	·8
July	0·7	0·7	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0	0·9	0·9
Aug.	·5	·5	·6	·7	·7	·8	·8	0·9	0·9	0·9	·9	·9
Sept.	·4	·4	·4	·5	·5	·6	·6	·7	·7	·8	·8	·9
Oct.	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·7
Nov.	·2	·2	·2	·2	·2	·2	·3	·3	·4	·4	·5	·6
Dec.	0·3	0·2	0·2	0·2	0·2	0·1	0·2	0·2	0·2	0·3	0·3	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	359·3	359·3	359·3	359·4	359·4	359·5	359·6	359·7	359·8	359·9	0·1	0·2
20	359·2	359·2	359·3	359·3	359·4	359·5	359·6	359·7	359·8	359·9	0·1	0·2
40	359·1	359·1	359·1	359·2	359·2	359·4	359·5	359·6	359·8	359·9	0·1	0·3
50	358·9	358·9	358·9	359·0	359·1	359·2	359·4	359·6	359·7	359·9	0·1	0·3
55	358·8	358·8	358·8	358·9	359·0	359·1	359·3	359·5	359·7	359·9	0·1	0·3
60	358·6	358·6	358·6	358·7	358·9	359·0	359·2	359·4	359·7	359·9	0·1	0·4
65	358·3	358·3	358·4	358·5	358·7	358·8	359·1	359·3	359·6	359·9	0·2	0·5

Latitude by Polaris

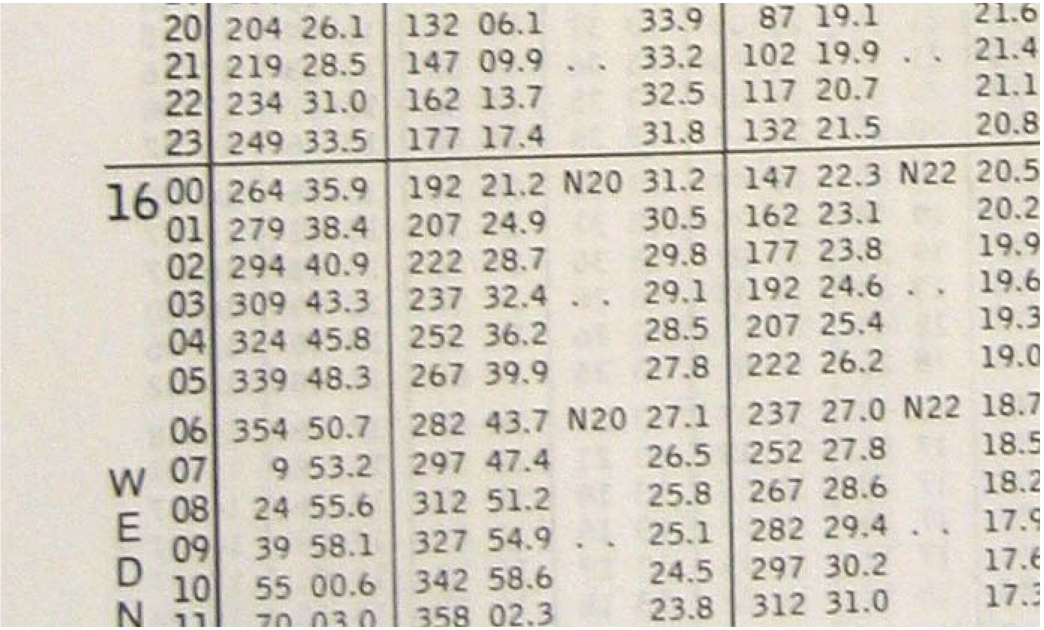
– <u>Example Problem</u> Given: Zone time of observation: 20-12-09, DR position: 30°30.5'N/067°37.2W, I.C. = -0.5'; height of eye = 9'.

- » NOTE: Procedures for calculating LHA of Aries and ha are covered briefly as they were covered in depth in previous sections.
- » 1) Record the information on the sight form and determine the GMT hour of observation and the GMT fraction. DST??
- » 2) Record the GHA for the hour of observation. Use the GMT fraction to compute the GHA fraction. Convert this decimal number to the degree-minute format by multiplying the decimal portion of the number by 60'. Combine the GHA_{hr} and GHA_{fract} to get the total GHA.

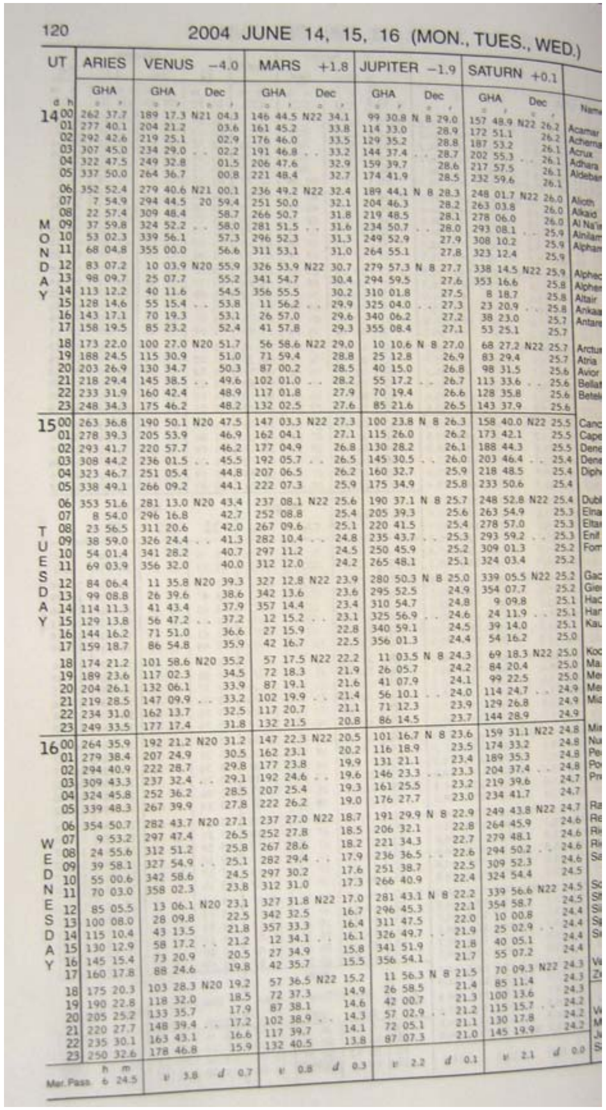
LATITUDE BY POLARIS	
DR Lat.	30-30.5 N
DR Long	67-37.2 W
Date	15-Jun
Obs Time	21-12-09
ZD (W+,E-)	+4
GMT	01-12-09
GMT date	16-Jun
GMT_{hr}	0100
GMT_{fract}	0.2025
GHA_{hr}	279-38.4
GHA_{fract} = GMTfract x 15.04	3.0456
GHA_{fract} (in degrees + minutes)	3-02.7
GHA_{tot} = GHAhr + GHAmin	282-41.1

Latitude by Polaris

– **GHA**



	20	204 26.1	132 06.1	33.9	87 19.1		21.6
	21	219 28.5	147 09.9 . .	33.2	102 19.9 . .		21.4
	22	234 31.0	162 13.7	32.5	117 20.7		21.1
	23	249 33.5	177 17.4	31.8	132 21.5		20.8
16	00	264 35.9	192 21.2	N20 31.2	147 22.3	N22	20.5
	01	279 38.4	207 24.9	30.5	162 23.1		20.2
	02	294 40.9	222 28.7	29.8	177 23.8		19.9
	03	309 43.3	237 32.4 . .	29.1	192 24.6 . .		19.6
	04	324 45.8	252 36.2	28.5	207 25.4		19.3
	05	339 48.3	267 39.9	27.8	222 26.2		19.0
	06	354 50.7	282 43.7	N20 27.1	237 27.0	N22	18.7
W	07	9 53.2	297 47.4	26.5	252 27.8		18.5
E	08	24 55.6	312 51.2	25.8	267 28.6		18.2
	09	39 58.1	327 54.9 . .	25.1	282 29.4 . .		17.9
D	10	55 00.6	342 58.6	24.5	297 30.2		17.6
N	11	70 03.0	358 02.3	23.8	312 31.0		17.3



Latitude by Polaris

– **Example Problem Given: Zone time of observation: 20-12-09, DR position: 30°30.5'N/067°37.2W, I.C. = -0.5'; height of eye = 9'.**

» **NOTE: Procedures for calculating LHA of Aries and ha are covered briefly as they were covered in depth in previous sections.**

» **1) Record the information on the sight form and determine the GMT hour of observation and the GMT fraction. DST??**

» **2) Record the GHA for the hour of observation. Use the GMT fraction to compute the GHA fraction. Convert this decimal number to the degree-minute format by multiplying the decimal portion of the number by 60'. Combine the GHA_{hr} and GHA_{fract} to get the total GHA.**

» **3) Apply our DR longitude to the total GHA and obtain an LHA of Aries.**

LATITUDE BY POLARIS	
DR Lat.	30-30.5 N
DR Long	67-37.2 W
Date	15-Jun
Obs Time	21-12-09
ZD (W+,E-)	+4
GMT	01-12-09
GMT date	16-Jun
GMT_{hr}	0100
GMT_{fract}	0.2025
GHA_{hr}	279-38.4
$GHA_{fract} = GMTfract \times 15.04$	3.0456
GHA_{fract} (in degrees + minutes)	3-02.7
$GHA_{tot} = GHAhr + GHAmin$	282-41.1
+/- 360 if needed	
$DR\lambda$ (-W,+E)	- 67-37.2
LHA γ (exact)	215-03.9

Latitude by Polaris

» **4) The IC and dip corrections are applied to hs to obtain ha. Entering the altitude correction tables with our h_a yields a -1.6 refraction correction.**

LHA γ (exact)	215-03.9
IC	-.5
Dip (Ht = 9)	-2.9
Sum	-3.4
hs	29-59.8
ha	29-56.4
Refr. Corr.	- 1.7

DIP

Ht. of Eye	Corrⁿ	Ht. of Eye	Ht. of Eye	Corrⁿ
m	′	ft.	m	′
2·4	−2·8	8·0	1·0	− 1·8
2·6	−2·9	8·6	1·5	− 2·2
2·8	−3·0	9·2	2·0	− 2·5
3·0	−3·1	9·8	2·5	− 2·8
3·2	−3·2	10·5	3·0	− 3·0
3·4	−3·3	11·2	See table ←	
3·6	−3·4	11·9		
3·8	−3·5	12·6	m	′

STARS AND PLANETS

App Alt.	Corrⁿ
° ′	′
9 55	−5·3
10 07	−5·2
10 20	−5·1
10 32	−5·0
10 46	−4·9
10 59	−4·8
11 14	−4·7
11 29	−4·6
11 44	−4·5
12 00	−4·4
12 17	−4·3
12 35	−4·2
12 53	−4·1
13 12	−4·0
13 32	−3·9
13 53	−3·8
14 16	−3·7
14 39	−3·6
15 03	−3·5
15 29	−3·4
15 56	−3·3
16 25	−3·2
16 55	−3·1
17 27	−3·0
18 01	−2·9
18 37	−2·8
19 16	−2·7
19 56	−2·6
20 40	−2·5
21 27	−2·4
22 17	−2·3
23 11	−2·2
24 09	−2·1
25 12	−2·0
26 20	−1·9
27 34	−1·8
28 54	−1·7
30 22	−1·6
31 58	−1·5
33 43	−1·4
35 38	−1·3
37 45	−1·2
40 06	−1·1
42 42	−1·0
45 34	−0·9
48 45	−0·8
52 16	−0·7

App. Alt.	Additional Corrⁿ
2004	
VENUS	
Jan. 1–Feb. 22 Sept. 23–Dec. 31	
°	′
0	
	+0·1
60	
Feb. 23–Apr. 14 Aug. 3–Sept. 22	
0	
	+0·2
41	
	+0·1
76	
Apr. 15–May 7 July 11–Aug. 2	
0	
	+0·3
34	
	+0·2
60	
	+0·1
80	
May 8–May 23 June 25–July 10	
0	
	+0·4
29	
	+0·3
51	
	+0·2
68	
	+0·1
83	
May 24–June 24	
0	
	+0·5
26	
	+0·4
46	
	+0·3
60	
	+0·2
73	
	+0·1
84	
MARS	
Jan. 1–Dec. 31	
0	
	+0·1
60	

App Alt.	Corrⁿ	App. Alt.	Additional Corrⁿ
22 17	−2·3	60	+0·2
23 11	−2·2	73	+0·1
24 09	−2·1	84	
25 12	−2·0	MARS	
26 20	−1·9	Jan. 1–Dec. 31	
27 34	−1·8	0	+0·1
28 54	−1·7	60	
30 22	−1·6		
31 58	−1·5		
33 43	−1·4		

Latitude by Polaris

» **5) Enter the Polaris tables. The a_o correction is found by applying the LHA of Aries to the upper third of the table. The LHA is also used to locate the column of data in which a_1 and a_2 are located. The DR latitude is entered in the middle portion to find a_1; the month of observation is entered in the bottom portion to find a_2 .**

Refr. Corr.		- 1.7
TB (ha < 10°)	+	-
a_0	+ 1 41.6	
a_1	+ 0.6	
a_2	+ 0.9	

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FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

LHA ARIES	120°–129°	130°–139°	140°–149°	150°–159°	160°–169°	170°–179°	180°–189°	190°–199°	200°–209°	210°–219°	220°–229°	230°–239°
°	a_0 ° ′	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
0	0 52·3	0 59·8	1 07·2	1 14·4	1 21·1	1 27·1	1 32·2	1 36·4	1 39·4	1 41·2	1 41·7	1 40·9
1	53·1	1 00·6	08·0	15·1	21·7	27·6	32·7	36·7	39·6	41·3	41·7	40·8
2	53·8	01·3	08·7	15·8	22·3	28·2	33·1	37·1	39·8	41·4	41·6	40·6
3	54·6	02·0	09·4	16·5	23·0	28·7	33·6	37·4	40·0	41·5	41·6	40·5
4	55·3	02·8	10·1	17·1	23·6	29·3	34·0	37·7	40·2	41·5	41·5	40·3
5	0 56·1	1 03·5	1 10·9	1 17·8	1 24·2	1 29·8	1 34·4	1 38·0	[illegible]	1 41·6	1 41·5	1 40·1
6	56·8	04·3	11·6	18·5	24·8	30·3	34·8	38·3	[illegible]	41·6	41·4	39·9
7	57·6	05·0	12·3	19·1	25·4	30·8	35·2	38·6	40·8	41·7	41·3	39·6
8	58·3	05·8	13·0	19·8	25·9	31·3	35·6	38·9	40·9	41·7	41·2	39·4
9	59·1	06·5	13·7	20·4	26·5	31·8	36·0	39·1	41·0	41·7	41·1	39·2
10	0 59·8	1 07·2	1 14·4	1 21·1	1 27·1	1 32·2	1 36·4	1 39·4	1 41·2	1 41·7	1 40·9	1 38·9
Lat. °	a_1 ′	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
0	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·6	0·6
10	·3	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·6
20	·4	·4	·4	·4	·5	·5	·5	·6	·6	·6	·6	·6
30	·4	·4	·4	·5	·5	·5	·5	·6	·6	·6	·6	·6
40	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6
45	·5	·5	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6	·6	·6
60	·7	·7	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6
62	0·8	0·8	0·8	0·7	0·7	0·7	0·7	0·6	0·6	0·6	0·6	0·6
64	·8	·8	·8	·8	·8	·7	·7	·6	·6	·6	·6	·6
66	·9	·9	·9	·8	·8	·7	·7	·6	·6	·6	·6	·6
68	0·9	0·9	0·9	0·9	0·8	0·8	0·7	0·7	0·6	0·6	0·6	0·6
Month	a_2 ′	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
Jan.	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5
Feb.	·8	·8	·7	·7	·7	·6	·6	·5	·5	·5	·4	·4
Mar.	0·9	0·9	0·9	0·8	·8	·8	·7	·7	·6	·6	·5	·5
Apr.	1·0	1·0	1·0	1·0	0·9	0·9	0·9	0·8	0·8	0·7	0·6	0·6
May	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8	·8	·7
June	·8	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	·9	·8
July	0·7	0·7	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0	0·9	0·9
Aug.	·5	·5	·6	·7	·7	·8	·8	0·9	0·9	0·9	·9	·9
Sept.	·4	·4	·4	·5	·5	·6	·6	·7	·7	·8	·8	·9
Oct.	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·7
Nov.	·2	·2	·2	·2	·2	·2	·3	·3	·4	·4	·5	·6
Dec.	0·3	0·2	0·2	0·2	0·2	0·1	0·2	0·2	0·2	0·3	0·3	0·4

AZIMUTH

Latitude by Polaris

- 5) Enter the Polaris tables. The a_o correction is found by applying the LHA of Aries to the upper third of the table. The LHA is also used to locate the column of data in which a_1 and a_2 are located. The DR latitude is entered in the middle portion to find a_1; the month of observation is entered in the bottom portion to find a_2 .
- 6) The a_1,a_2, a_3 are combined and then summed with the refraction correction and the -60' additional. This value is applied to the ha value to yield the observer's latitude (30°37.9'N).

Refr. Corr.		- 1.7
TB (ha < 10°)	+	-
a_0	+ 1 41.6	
a_1	+ 0.6	
a_2	+ 0.9	
Add'l		- 60.0
Sub Total	+ 1 43.1	- 61.7
Tot corr. to ha (+/-)	+ 41.4	
ha	29-56.4	
Latitude	30-37.8 N	
True Azimuth		°T
Gyro Brg.		°pgc

Useful tips

- Swing the arc with the sextant carefully to make sure you have the correct altitude. Measuring too high of an altitude is common.
- Make sure you account for Daylights Savings Time (noon happens an hour later)