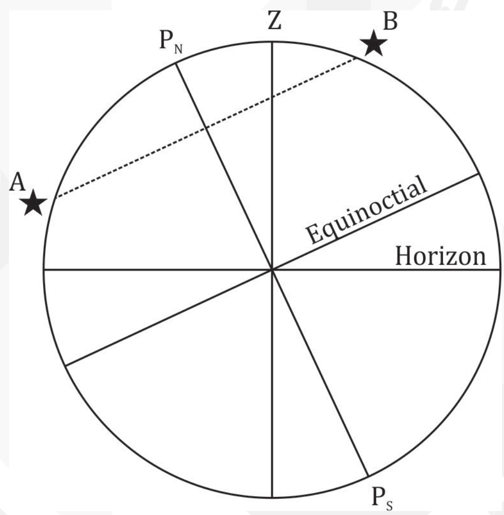
Meridian Passage

Meridian passage of a heavenly body occurs when the body is on the same great circle of meridian as the observer's. As all heavenly bodies circle around the pole, they will cross the observer's meridian and also the observer's anti-meridian. At those moments, the body is either due north or due south (0° or 180°) of the observer, and the local hour angle (LHA) of a heavenly body is 0° or 180°.

- Upper meridian passage occurs when the heavenly body is on the same meridian as the observer, so the LHA is 0°;
- Lower meridian passage occurs when the heavenly body in on the anti-meridian of the observer, so the LHA is 180°.

The number of bodies appearing on the lower meridian is small unless the observer is at a very high latitude, so the navigator's main concern is the upper meridian passage. Therefore, the term "Meridian Passage" always refers to the upper meridian transit unless indicated for lower meridian transit.



Celestial body A is on lower meridian passage, bearing 0° from obeserver.

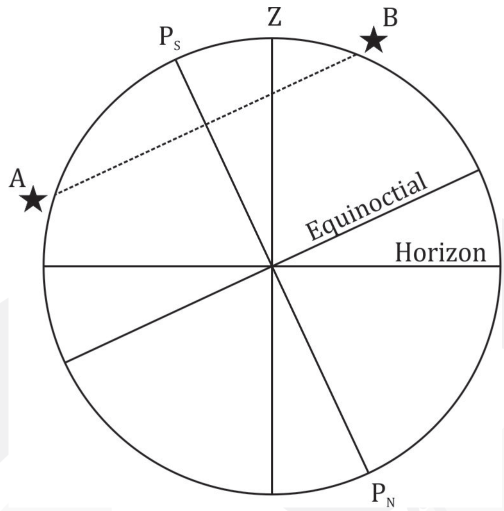
Celestial body B is on upper meridian passage, bearing 180° from observer.

Meridian Passage in Northern Hemisphere

In the northern hemisphere, if the declination is also north, then the true bearing of the celestial body is 0° or 180°, depending on whether the declination is greater than or less than the latitude.

$$\text{If Dec. is north (Same Name) and } \begin{matrix} \text{Dec.} \rangle \text{ Lat.} & \Rightarrow \text{True bearing: } 0^\circ \\ \text{Dec.} \langle \text{ Lat.} & \Rightarrow \text{True bearing: } 180^\circ \end{matrix}$$

If the declination of the celestial body is south, the name of declination is contrary to latitude; the true bearing of the heavenly body is 180°.



Celestial body A is on lower meridian passage, bearing 180° from obeserver.

Celestial body B is on upper meridian passage, bearing 0° from observer.

Meridian Passage in Southern Hemisphere

In the southern hemisphere, the bearings of heavenly bodies on meridian passage are reversed, as shown below:

$$\text{If Dec. is south (Same Name) and} \begin{array}{ll} \text{Dec.} \rangle \text{ Lat.} & \Rightarrow \text{True bearing: } 180^\circ \\ \text{Dec.} \langle \text{ Lat.} & \Rightarrow \text{True bearing: } 0^\circ \end{array}$$

For lower meridian passage in the northern hemisphere, the bearing of the heavenly body from the observer is always 0°, because the heavenly body is on another side of the North Pole. Conversely, in the southern hemisphere, the bearing of a heavenly body is always 180° from observer.

When the heavenly body is at the meridian passage, it is at the maximum altitude. This occurs when the observer is stationary, but when the ship is moving, the heavenly body does not always reach its maximum altitude at meridian passage.

- If the ship is moving towards the body, the maximum altitude occurs after meridian passage.
- If the ship is moving away from the body, the maximum altitude occurs before the meridian passage.
- If the ship is moving east or west, the maximum altitude occurs at the meridian passage.

However, the exact moment when the heavenly body reaches its maximum altitude is difficult to know just by visual observation. Also, when the ship is underway, the longitude of the ship at the meridian passage will not be known beforehand. So practically, the navigator should work out the time of meridian passage and the longitude where it occurs in advance, and the altitude can be taken at that moment.

Time of Meridian Passage of the Sun

The sun is on the observer's meridian at 1200 Local Apparent Time each day, which is not necessarily the same as the Local Mean Time (time of the clock). It might occur before or after 1200 LMT. The difference between the LAT and LMT is given in the Nautical Almanac as the value of the "**equation of time**", which is at the foot of right-hand daily page, and the "Mer. Pass." is *the time of the meridian passage over the Greenwich Meridian and also the Local Mean Time of the meridian passage of the true sun for any observer's meridian*. The UT can be converted by applying the observer's longitude in time, as follows:

$$\text{UT} = \text{LMT} + \text{Westerly longitude in time}$$
$$\text{UT} = \text{LMT} - \text{Easterly longitude in time}$$

Example 1

Find the zone time of meridian passage when the sun is passing the observer's meridian 103° E at noon time on 16th April, 2008:

LMT mer. pass.	16th	$12^h 00^m$	(Nautical Almanac)
Longitude in time (103°E)		$6^h 52^m$	($103° \div 15° = 6^h 52^m$)
UT	16th	$05^h 08^m$	
Zone(-7)		$+7^h$	
Zone Time	16th	$12^h 08^m$	

Example 2

Find the zone time of meridian passage when the sun is passing the observer's meridian 78°29´ W at noon time on 24th October, 2008:

LMT mer. pass.	24th	$11^h 44^m$	(Nautical Almanac)
Longitude in time (78°29′W)		$5^h 14^m$	($78°29' \div 15° = 5^h 14^m$)
UT	24th	$16^h 58^m$	
Zone(+5)		-5^h	
Zone Time	24th	$11^h 58^m$	

Time of Meridian Passage of the Moon

Due to the rapid motion of the moon, the value of the meridian passage of the moon given in the Nautical Almanac is *not* the LMT of the meridian passage at any meridian of the sun, but only the LMT at the Greenwich meridian. The "longitude correction" is then applied to obtain the LMT of the meridian passage at the observer's meridian.

$$\text{LMT}_{\text{Observer}} = \text{LMT}_{\text{Greenwich}} \pm \text{Longitude correction}$$

The longitude correction is found by taking the difference between the times of meridian passage for the given day and the meridian passage for the next day if in westerly longitude, and the meridian passage for the preceding day if in easterly longitude.

FOLLOWING DAY	for	WEST LONGITUDE
PROCEEDING DAY	for	EAST LONGITUDE

Use table II at the back of the Nautical Almanac to extract the longitude correction, or simply use the following calculation:

$$\text{Longitude Correction} = \frac{\text{Daily Difference} \times \text{Longitude}}{360°}$$

As with the sun, apply the longitude in time to obtain the UT of meridian passage of the moon. The terms "Upper" and "Lower" in the Mer. Pass. table of the moon mean the upper meridian and lower meridian, *not* the upper limb and lower limb, so only the meridian passage for the "upper" is normally considered.

Example 3 Find the zone time of meridian passage when the moon is passing over the longitude 78° W on 19^{th} July, 2008:

LMT mer. pass. Long. 0°	19^d	00^h40^m	
LMT mer. pass. Long. 0°	20^d	01^h27^m	(Following day)
different		47^m	

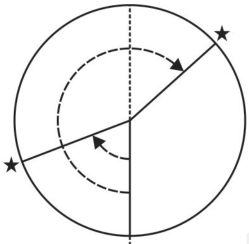
LMT mer. pass. Long. 0°	19^d	00^h40^m	
Longitude correction		$+10^m$	$(78° \times 47^m \div 360° \simeq 10^m)$
LMT mer. pass. Long. 78° W	19^d	00^h50^m	
Longitude in time (78° W)		$+5^h12^m$	$(78° \div 15° \simeq 5^h12^m)$
UT	19^d	06^h02^m	
Zone (+5)		-5^h	
Zone time	19^d	1^h02^m	

Example 4 Find the zone time of meridian passage when the moon is passing over the longitude 128° E on 17^{th} April, 2008:

LMT mer. pass. Long. 0°	17^d	22^h10^m	
LMT mer. pass. Long. 0°	16^d	21^h28^m	(Proceeding day)
different		42^m	

LMT mer. pass. Long. 0°	17^d	22^h10^m	
Longitude correction		-15^m	$(128° \times 42^m \div 360° \simeq 15^m)$
LMT mer. pass. Long. 128° E	17^d	21^h55^m	
Longitude in time (128° E)		-8^h32^m	$(128° \div 15° \simeq 8^h32^m)$
UT	17^d	13^h23^m	
Zone (−9)		$+9^h$	
Zone time	17^d	22^h23^m	

Time of Meridian Passage of the Star



When the star is on meridian passage, the LHA is 0°, and the GHA of the star is the same as the longitude of the observer, but is expressed in hour-angle from the Greenwich Meridian.

$$GHA^{*} = \text{Westerly Longitude}$$
$$GHA^{*} = 360° - \text{Easterly Longitude}$$

By knowing the SHA of the star, extracted from the Nautical Almanac, the GHA of Aries can be found by the formula:

$$GHA^{♈} = GHA^{*} - SHA^{*}$$

The UT of meridian passage is extracted from the Nautical Almanac at a particular GHA of Aries, and longitude in time is applied to get LMT of meridian passage, or zone number to get the zone time.

Example 5

Find the UT, LMT and the zone time of meridian passage of the star Deneb in longitude 70°42´W on 21^{st} July, 2008:

When the star is on the same meridian as observer, GHA of star is same as longitude of observer; therefore, GHA of the star is 70°42.0´.

GHA^{*}	70°42.0′	
SHA^{*}	49°33.6′	(Nautical Almanac)
$GHA^{♈}$	21°08.4′	
$GHA^{♈}$ on 21^{st} at $5^h 00^m$	14°20.3′	(Nautical Almanac)
	6°48.1′	$= 27^m 08^s$ (Increments table)

$\therefore$ UT mer. pass. on 21^{st}: $05^h 27^m 08^s$

UT mer. pass.	21^{st}	$05^h 27^m 08^s$
Longitude in time (70°42′W)		$4^h 42^m 48^s$
LMT mer. pass.	21^{st}	$00^h 44^m 20^s$

UT mer. pass.	21^{st}	$05^h 27^m 08^s$
Zone (+5)		5
Zone Time	21^{st}	$00^h 27^m 08^s$

Example 6

Find the UT, LMT and zone time of meridian passage of the star Arcturus in longitude 115°44´E on 24^{th} October, 2008:

When the star is on same meridian as the observer, GHA of star is the same as longitude of observer, but longitude is east; therefore:

$$GHA^{*} = 360° - \text{Longitude} = 360° - 115°44.0′ = 244°16.0′$$

GHA*	244°16.0′	
SHA*	145°59.2′	
GHA♈	98°16.8′	
GHA♈ on 24^{th} at $4^h 00^m$	92°56.0′	
	5°20.8′	$= 21^m 20^s$

∴ UT mer. pass. on 24^{th}: $04^h 21^m 20^s$

UT mer. pass.	24^{th}	$04^h 21^m 20^s$
Longitude in time (115°44′E)		$7^h 42^m 56^s$
LMT mer. pass.	24^{th}	$12^h 04^m 16^s$

UT mer. pass.	24^{th}	$04^h 21^m 20^s$
Zone (−8)		$+8^h$
Zone Time	24^{th}	$12^h 21^m 20^s$

Time of Meridian Passage of the Planet

The time of meridian passage for the planets Venus, Mars, Jupiter and Saturn over the Greenwich Meridian is given in the daily page of the Nautical Almanac for the middle day of the three days on the page. A longitude correction must then be applied in the same way as for the moon; however, the difference in the times between successive days is just several minutes and does not much affect the change of declination, so the longitude correction can sometimes be ignored.

Example 7

Find the UT and zone time of meridian passage of Jupiter on 17^{th} April, 2008 in longitude 160° W:

LMT mer. pass.	16^{th}	$5^h 54^m$	
LMT mer. pass.	19^{th}	$5^h 43^m$	(Following period)
difference		11^m	

LMT mer. pass.	17^{th}	$5^h 50^m$	(by interpolating)
LMT mer. pass.	16^{th}	$5^h 54^m$	
difference		4^m	

LMT mer. pass.	17^{th}	$5^h 50^m$	
Longitude correction (W+, E–)		$+2^m$	($160° \times 4^m \div 360° \approx 2^m$)
LMT mer. pass. long. 160°W	17^{th}	$5^h 52^m$	
Longitude in time (160° W)		$10^h 40^m$	
UT	17^{th}	$16^h 32^m$	
Zone(+11)		11^h	
Zone time	17^{th}	$5^h 32^m$	

The above example without longitude correction:

LMT mer. pass.	17th	5^h50^m
Longitude in time (160°W)		10^h40^m
UT	17th	16^h30^m
Zone(+11)		11^h
Zone time	17th	5^h30^m

Example 8 Find the UT and zone time of meridian passage of Venus on 20th July, 2008 in longitude 110° E:

LMT mer. pass.	18th	12^h53^m	(Proceeding period)
LMT mer. pass.	21st	12^h56^m	
difference		3^m	

LMT mer. pass.	20th	12^h55^m	(by interpolating)
LMT mer. pass.	21st	12^h56^m	
difference		1^m	

LMT mer. pass.	20th	12^h55^m	
Longitude correction (W+, E–)		$+0^m$	$(110° \times 1^m \div 360° \approx 0^m)$
LMT mer. pass. long. 110°E	20th	12^h55^m	
Longitude in time (110°E)		7^h20^m	
UT	20th	5^h35^m	
Zone(–7)		7^h	
Zone time	20th	12^h35^m	

Time of Lower Meridian Passage of Heavenly Body

The calculation is the same as for the upper meridian passage, but:

Sun and planets Add 12 hours to the time of upper meridian passage given in the Nautical Almanac.

Moon The LMT of lower meridian passage can be extracted directly from the Nautical Almanac.

Stars The LHA is 180°, rather than 0°; apply to the longitude to obtain the GHA of the body at the lower meridian passage as follows:

$$GHA^* = 180° + \text{Westerly Longitude}$$
$$GHA^* = 180° - \text{Easterly Longitude}$$

Example 9 Find the zone time of lower meridian passage of the sun observed from longitude 43° E on 18th July, 2008:

LMT upper mer. pass.	17th	$12^h 06^m$	(Nautical Almanac)
		12	
LMT lower mer. pass.	18th	$00^h 06^m$	
Longitude in time (W+, E–)		$-2^h 52^m$	(longitude 43°E)
UT lower mer. pass.	17th	$21^h 14^m$	
Zone(–3)		+3	
Zone Time	18th	$00^h 14^m$	

Example 10 Find the zone time of lower meridian passage of the sun observed from longitude 140° W on 17th April, 2008:

LMT upper mer. pass.	16th	$12^h 00^m$	(Nautical Almanac)
		12	
LMT lower mer. pass.	17th	$00^h 00^m$	
Longitude in time (W+, E–)		$9^h 20^m$	(longitude 140°W)
UT lower mer. pass.	17th	$9^h 20^m$	
Zone(+9)		9^h	
Zone Time	17th	$00^h 20^m$	

Example 11 On 24th October, 2008, in longitude 73°35´W, the star Dubhe was observed on meridian below the pole. Find the zone time:

LHA	180°	
Longitude	73°35.0′	
GHA*	253°35.0′	
SHA*	193°56.1′	
GHA♈	59°38.9′	
GHA♈ on 25th at $1^h 00^m$	48°47.8′	
	10°51.1′	$= 43^m 17^s$ (Increments table)

∴ UT lower mer. pass. on 25th: $01^h 43^m 17^s$

UT mer. pass.	25th	$01^h 43^m 17^s$
Longitude in time (73°35′W)		$4^h 54^m 20^s$
LMT mer. pass.	24th	$20^h 48^m 57^s$

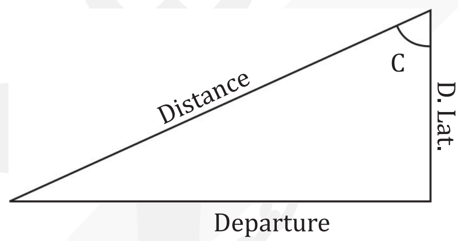
UT mer. pass.	25th	$01^h 43^m 17^s$
Zone (+5)		-5^h
Zone Time	24th	$20^h 43^m 17^s$

Approximation Method for Obtaining Time and Longitude of Meridian Passage

As the ship is making way through the water, the longitude and the time at the meridian passage should be calculated in advance, so the navigator is prepared for the moment of obtaining the altitude. The Approximation method uses the DR position to calculate the longitude, and a time as precise as possible. The method can be repeated to gain more accuracy; however, a difference of a couple of minutes does not greatly affect the altitude of the heavenly body, so one or two approximate calculations are enough.

Example 12

At ZT 0900, on 21st July 2008, a ship was in position 33° N, 123° W, steaming on a course 240° at speed 15 knots. At what longitude and in what zone time will the sun be on meridian passage?



LMT mer. pass.	21st	$12^h 06^m$	(Nautical Almanac)
Longitude in time (123°W)		$8^h 12^m$	
UT mer. pass	21st	$20^h 18^m$	
Zone (+8)		8^h	
Zone time	21st	$12^h 18^m$	

First Approximation

$$\text{Steaming time} = 12^h 18^m - 09^h 00^m = 3^h 18^m;$$
$$\text{Distance} = 3^h 18^m \times 15\,\text{knots} = 49.5\,\text{miles}$$

Using plane sailing method or traverse table to obtain D. Long.

$$\text{D.Lat.} = \text{Distance} \times \cos C = 49.5 \times \cos 60° = 24.8'$$
$$\text{Dep.} = \text{Distance} \times \sin C = 49.5 \times \sin 60° = 42.9'$$
$$\text{Mean Lat. } (\text{Lat}_m) = 33°\text{N} - (24.8' \div 2) = 32°47.6'$$
$$\text{D.Long.} = \frac{\text{Dep.}}{\cos \text{Lat}_m} = \frac{42.9'}{\cos 32°47.6'} = 51.0'(\text{W})$$

$$\text{Longitude at Meridian Passage} = 123°\text{W} + 51.0'(\text{W}) = 123°51.0'\text{W}$$

Time of meridian passage at longitude 123°51.0´:

LMT mer. pass.	21st	$12^h 06^m$
Longitude in time (123°51.0′W)	21st	$8^h 15^m$
UT mer. pass		$20^h 21^m$
Zone (+8)		8^h
Zone time	21st	$12^h 21^m$

Second Approximation

$$\text{Steaming time} = 12^h 21^m - 09^h 00^m = 3^h 21^m;$$
$$\text{Distance} = 3^h 21^m \times 15\,\text{knots} = 50.3\,\text{miles}$$

Using plane sailing method or traverse table to obtain D.Long.

$$\text{D.lat.} = \text{Distance} \times \cos C_o = 50.3 \times \cos 60° = 25.2'$$
$$\text{Dep.} = \text{Distance} \times \sin C_o = 50.3 \times \sin 60° = 43.6$$
$$\text{Mean Lat. } (\text{Lat}_m) = 33° - (25.2' \div 2) = 32°47.4'$$
$$\text{D.Long.} = \frac{\text{Departure}}{\cos \text{Lat}_m} = \frac{43.6'}{\cos 32°47.4'} = 51.9'(\text{W})$$

$$\text{Longitude at Meridian Passage} = 123°\text{W} + 51.9'(\text{W}) = 123°51.9'\text{W}$$

Time of meridian passage at longitude 123°51.9′ W:

LMT mer. pass.	21st	$12^h 06^m$
Longitude in time (123°51.9′W)	21st	$8^h 16^m$
UT mer. pass		$20^h 22^m$
Zone (+8)		8^h
Zone time	21st	$12^h 22^m$

Third Approximation

$$\text{Steaming time} = 12^h 22^m - 09^h 00^m = 3^h 22^m;$$
$$\text{Distance} = 3^h 22^m \times 15\,\text{knots} = 50.5\,\text{miles}$$

Using plane sailing method or traverse table to obtain D.Long.

$$\text{D.lat.} = \text{Distance} \times \cos C_o = 50.5 \times \cos 60° = 25.3'$$
$$\text{Departure} = \text{Distance} \times \sin C_o = 50.5 \times \sin 60° = 43.7$$
$$\text{Mean Lat. } (\text{Lat}_m) = 33° - (25.3' \div 2) = 32°47.4'$$

$$\text{D.Long.} = \frac{\text{Departure}}{\cos \text{Lat}_m} = \frac{43.7'}{\cos 32°47.4'} = 52'(\text{W})$$

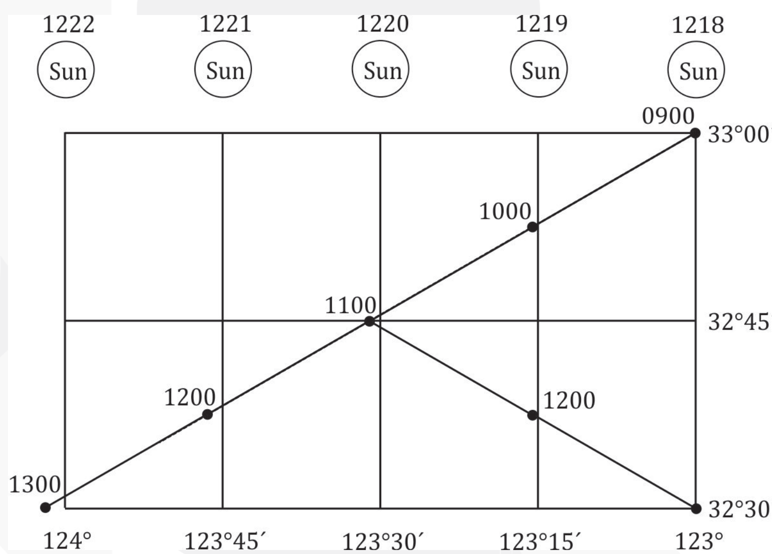
$$\text{Longitude at Meridian Passage} = 123°\text{W} + 52'(\text{W}) = 123°52'\text{W}$$

Time of meridian passage at longitude 123°52′W

LMT mer. pass.	21st	$12^h 06^m$
Longitude in time (123°52′W)	21st	$8^h 16^m$
UT mer. pass		$20^h 22^m$
Zone (+8)		8^h
Zone time	21st	$12^h 22^m$

In this case, the time of meridian passage is $12^h 22^m$, the same as the second approximation, so we can conclude that the time of meridian passage is $12^h 22^m$. When the times are not the same and accuracy is required, a fourth approximation can be made.

Another method can be used by plotting the ship's track on the chart, as shown in the figure below. The time of meridian passage when the ship and the sun are in same meridian can be obtained by visual inspection to the nearest half minute.



In the figure, the meridian is intentionally kept at 15′ intervals, e.g., 123°, 123°15′, 123°30′, etc., because the sun is apparently moving westward at 15′ of longitude in 1 minute of time. The time of meridian passage on the top of the plot can then be marked at 1 minute intervals for every corresponding meridian. The time of meridian passage of initial position, e.g., meridian 123°, is 1218 (ZT), as per calculation. The sun therefore will cross meridian 123°15′ at 1219, meridian 123°30′ at 1220, etc.

The ship's track is plotted with the time interval according to the speed, starting from initial position (33°N, 123°W). The sun will be on the ship's meridian at 1221.

If the ship alters course before meridian passage, as shown in the figure, the time of meridian passage can also be obtained from plotting. In the figure, the ship alters the course at 1100, and the time of meridian passage is 1219.

Alternative Method for Approximation

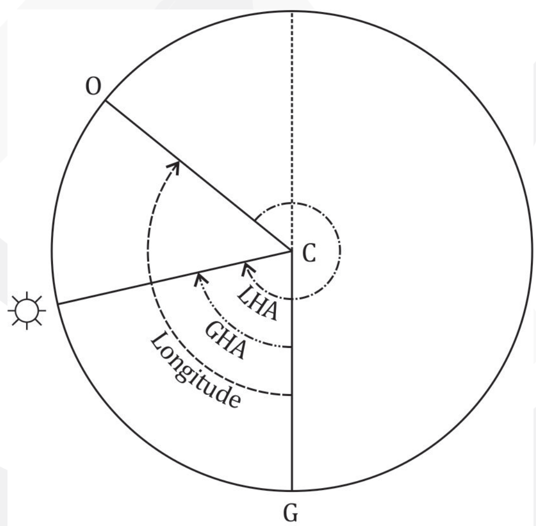
As we know, the sun is always to the east of the observer before meridian passage occurs, and the angle between the observer and the sun at the centre of the earth is Ω, which equals 360° − LHA. By knowing the speed of the sun over longitude and also the speed of the observer over longitude, the *closing time* of the sun and the observer can be found by the following formula:

$$\text{Closing Time} = \frac{\Omega}{\text{Speed of the Sun} \pm \text{Speed of Observer}}$$

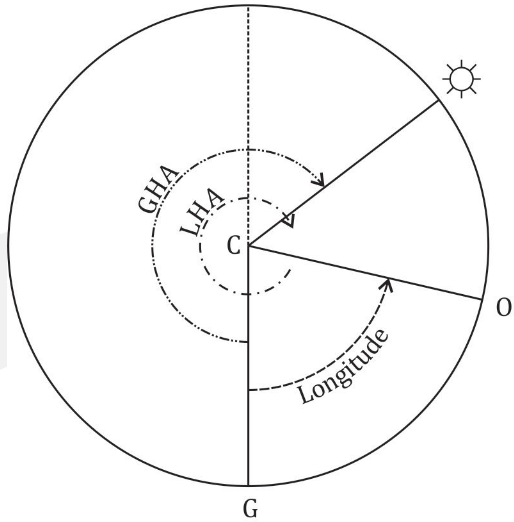
Closing Time: hours Speed of the Sun: knots
Ω: minutes Speed of Observer: knots

1. If the observer is travelling toward east, then closing time is reduced.

2. If the observer is travelling toward west, then closing time is increased.



West Longitude



East Longitude

Example 13 At ZT 0900, on 21st July 2008, a ship was in position 33° N, 123° W, steaming on a course 240° at speed 15 knots. At what longitude and in what zone time will the sun be on meridian passage?

Zone Time	21st	09^h00^m	
Zone (+8)		8^h	(Longitude 123°W)
UT	21st	17^h00^m	

GHA	21st	73°23.5′	
Longitude (W)		123°	
LHA		310°23.5′	
		360°	
Ω		49°36.5′	= 2976.5′

Speed of the ship over longitude

Speed = 15knots ⇒ Distance travelled in 1 hour = 15miles

Use plane sailing method or traverse table to obtain D. Long.

$$\text{D.Lat.} = \text{Distance} \times \cos C = 15 \times \cos 60^\circ = 7.5'$$
$$\text{Dep.} = \text{Distance} \times \sin C = 15 \times \sin 60^\circ = 13'$$
$$\text{Lat.}_m = 33^\circ\text{N} - (7.5' \div 2) = 32^\circ 56.25'$$
$$\text{D.Long.} = \frac{\text{Departure}}{\cos \text{Lat.}_m} = \frac{13'}{\cos 32^\circ 56.25'} = 15.5'$$

$$\therefore \quad \text{Speed of the ship over longitude} = 15.5\,\text{knots}$$

Speed of the sun over longitude is 15° per hour or 900 knots

$$\text{Closing Time} = \frac{\Omega}{\text{Speed of the sun} - \text{Speed of Observer}}$$
$$= \frac{2976.5'}{900 - 15.5} = 3^h 22^m$$

$$\text{Time of meridian passage} = \text{Zone Time} + \text{Closing Time}$$
$$= 09^h 00^m + 3^h 22^m$$
$$= 12^h 22^m$$

$$\text{Steaming time} = 3^h 22^m$$
$$\text{Distance} = 3^h 22^m \times 15\,\text{knots} = 50.5\,\text{miles}$$

$$\text{D.lat.} = \text{Distance} \times \cos C = 50.5 \times \cos 60^\circ = 25.3'$$
$$\text{Dep.} = \text{Distance} \times \sin C = 50.5 \times \sin 60^\circ = 43.7$$
$$\text{Mean Lat. } (\text{Lat}_m) = 33^\circ - (25.3' \div 2) = 32^\circ 47.4'$$
$$\text{D.Long.} = \frac{\text{Dep.}}{\cos \text{Lat}_m} = \frac{43.7'}{\cos 32^\circ 47.4'} = 52'(\text{W})$$

$$\text{Longitude at Meridian Passage} = 123^\circ\text{W} + 52'(\text{W}) = 123^\circ 52'\text{W}$$