

Celestial Navigation Exam References

(March 21, 2020)

Sun

11/5/93 Sun LL IE 1.7 off DR Lat N 31°25.7
WE +1 sec Long W 68°59.0
HE 8 ft Log 395.6
Temp 73°F Barometer 1033 mb

	<u>Time</u>		<u>Altitude</u>
ZT	082839	Hs	27°15.9
WC	<u>- 1</u>	IC	+ 1.7
ZT	082838	DC	<u>- 2.7</u>
+MTD	<u>+ 5</u>	Ha	27°14.9
GMT	132838	AC1	+ 14.4
		AC2	<u>+ 0.1</u>
		Ho	27°29.4

	<u>GHA</u>	<u>Dec</u>
13	19°05.6	S 15°46.8//+0.8
2838	+ 7°09.5	
d	<u> </u>	<u>+ 0.4</u>
GHA	26°15.1	S 15°47.2
	<u>+360°</u>	
	386°15.1	
-ALong	<u>- 69°15.1</u>	
LHA	317°	

ALat 31° N

	<u>Hc</u>	
15	28°10.7 //-45.0	Z = 131.6° = 132°
47.2	<u>- 0°35.4</u>	
Hc	27°35.3	Zn = Z = 132°T
Ho	<u>27°29.4</u>	
	5.9 AWAY	

Planet Saturn (& Jupiter)

Reduce and plot the following shot:

6/21/93	Saturn	IE 1.0 off	DR Lat N 35°50.0
		WE +2 sec	Long W 67°20.0
		HE 8 ft	Log 392.5
		Temp 76°F	Barom 1014mb

	<u>Time</u>		<u>Altitude</u>
ZT	042826	Hs	41°19.7
WC	- <u>2</u>	IC	+ 1.0
ZT	042824	DC	- <u>2.7</u>
+MTD	+ <u>4</u>	Ha	41°18.0
GMT	082824	AC1	- 1.1
		AC2	+ <u>0.1</u>
		Ho	41°17.0

	<u>GHA</u>	<u>Dec</u>
08	056°43.7//+2.5	S 12°40.7//+0.0
2824	+ 007°06.0	
v/d	+ <u>1.2</u>	<u>0.0</u>
GHA	063°50.9	S 12°40.7
	+ 360°	
	<u>423°50.9</u>	
-Along	- <u>67°50.9</u>	
LHA	356°	
ALat	36° N	

	<u>Hc</u>	
12	41°51.1 //-59.8	Z = 174.7 = 175°
40.7	- <u>0°40.6</u>	
Hc	41°10.5	Zn = Z
Ho	<u>41°17.0</u>	= 175°
	6.5 TOWARD	

Planet Venus (& Mars)

Reduce and plot the following shot:

7/1/93	Venus	IE 1.4 off	DR Lat N 38°37.3
		WE +3 sec	Long W 71°10.6
		HE 6 ft	Log 610.1
		Temp 72°F	Barom 1007mb

	<u>Time</u>		<u>Altitude</u>
ZT	041000	Hs	27°39.1
WC	- <u>3</u>	IC	+ 1.4
ZT	040957	DC	- <u>2.4</u>
+MTD	+ <u>5</u>	Ha	27°38.1
GMT	090957	AC1	- 1.8
		AC2	+ 0.1
		AC3	+ <u>0.2</u>
		Ho	27°36.6

	<u>GHA</u>		<u>Dec</u>
09	001°02.3// -0.2		N 16°18.4// +0.7
0957	+ 002°29.3		
v/d	- <u>0.0</u>		+ <u>0.1</u>
GHA	003°31.6		N 16°18.5
	+ <u>360°</u>		
	363°31.6		
-Along	- <u>71°31.6</u>		
LHA	292°		

ALat 39° N

	<u>Hc</u>	
16	26°57.4 // +35.1	Z = 90.8° = 91°
18.5	+ <u>0°10.8</u>	
Hc	27°08.2	Zn = Z
Ho	<u>27°36.6</u>	= 91°
	28.4 TOWARD	

Stars

Reduce and plot the following shot:

11/5/93	Sirius	IE 1.4 off	DR	Lat N 31°41.2
		WE +1 sec		Long W 69°12.6
		HE 6 ft		Log 372.6
		Temp 74°F		Barom 1032mb

	<u>Time</u>		<u>Altitude</u>
ZT	053222	Hs	32°22.7
WC	- <u>1</u>	IC	+ 1.4
ZT	053221	DC	- <u>2.4</u>
+MTD	+ <u>5</u>	Ha	32°21.7
GMT	103221	AC1	- 1.5
		AC2	<u>0.0</u>
		Ho	32°20.2

	<u>GHA</u>	<u>Dec</u>
GHA Aries 10	194°38.8	
3221	+ <u>8°06.6</u>	
GHA Aries	202°45.4	
SHA Sirius	+ <u>258°46.4</u>	S 16°42.4
	461°31.8	
	- <u>360°</u>	
GHA Sirius	101°31.8	
-Along	- <u>69°31.8</u>	
LHA Sirius	32°	

ALat 32°N

	<u>Hc</u>	
16	33°02.5 // -50.7	Z = 142.6° = 143°
42.4	- <u>0°35.8</u>	
Hc	32°26.7	Zn = 360° - Z
Ho	<u>32°20.2</u>	= 360° - 143°
	6.5 AWAY	= 217°

Moon

Reduce and plot the following shot:

11/5/93	Moon UL	IE 1.4 off	DR	Lat N 31°41.2
		WE +1 sec		Long W 69°12.6
		HE 10 ft		Log 373.8
		Temp 74°F		Barom 1032mb

	<u>Time</u>		<u>Altitude</u>
ZT	054538	Hs	63°07.3
WC	- <u>1</u>	IC	+ 1.4
ZT	054537	DC	- <u>3.1</u>
+MTD	+ <u>5</u>	Ha	63°05.6
GMT	104537	AC1	+ 36.3
		AC2	0.0
		HP	+ 3.5 (56.9)
		UL	- <u>30.0</u>
		Ho	63°15.4

	<u>GHA</u>	<u>Dec</u>	<u>HP</u>
10	83°31.5//+10.0	N 18°07.5// -6.8	56.9
4537	+ 10°53.1		
v/d	+ <u>07.6</u>	- <u>5.2</u>	
GHA	94°32.2	N 18°02.3	
-Along	- <u>69°32.2</u>		
LHA	25°		
ALat	32° N		

18	<u>Hc</u>	
	63°28.4 //+35.1	Z = 115.8° = 116°
02.3	+ <u>01.3</u>	
Hc	63°29.7	Zn = 360° - Z
Ho	<u>63°15.4</u>	= 360° - 116°
	14.3 AWAY	= 244°

Polaris

Reduce and plot the following shot:

6/23/93	Polaris	IE	1.2 on	DR	Lat N 36°36.3.0
		WE	0 sec		Long W 20°23.8
		HE	8 ft		Log 1293.7
		Temp	84°F		Barom 1008mb

	<u>Time</u>		<u>Altitude</u>
ZT	194523	Hs	36°42.3
WC	- 0	IC	- 1.2
ZT	194523	DC	- 2.7
+MTD	+ 1	Ha	36°38.4
GMT	204523	AC1	- 1.3
		AC2	+ 0.1
		Ho	36°37.2

	<u>GHA</u>
GHA Aries 20	211°59.7
4523	+11°22.6
GHA Aries	223°22.3
-Long	- 20°23.8
LHA Aries	202°58.5

In the Polaris Tables of the Nautical Almanac on Appendix page C-35 lookup:

$a_0 = +1^\circ 43.4$ minutes for LHA Aries = 202°58.5

$a_1 = +0.6$ minutes by interpolation for latitudes from 30° to 40°

$a_2 = +0.9$ minutes for June

and calculate your latitude from Equation (13) as follows:

$$\begin{aligned}\text{Lat} &= \text{Ho} + a_0 + a_1 + a_2 - 1^\circ \\ &= 36^\circ 37.2 \\ &\quad + 1^\circ 43.4 \\ &\quad + 0.6 \\ &\quad + \underline{0.9} \\ &= 38^\circ 22.1 \\ &\quad \underline{-1^\circ} \\ &= 37^\circ 22.1\end{aligned}$$

Appendix A

Symbols & Abbreviations

a₀ - Polaris Latitude factor for Aries.

a₁ - Polaris Latitude factor for latitude.

a₂ - Polaris Latitude factor for month.

AC1 - Altitude Correction for all bodies.

AC2 - Refractive Altitude Correction for all bodies.

AC3 - Additional Altitude Correction for Venus & Mars.

ACL - Average Course Line for Running Fix.

ALat - Assumed Latitude.

ALong - Assumed Longitude.

AP - Assumed Position based on ALat & ALong.

Aries - Imaginary line in the sky used for calculating GHA of stars.

AWAY - Direction that a negative I is plotted from the direction of GP.

°C - Compass Course.

COG - Course Over Ground; 0°-360°.

Course - Course steered through the water; 0°-360°.

CTS - Course To Steer.

d - Dec interpolation factor in Nautical Almanac.

d - Hc interpolation factor in HO229 & HO249.

D - Distance traveled through water.

DC - Dip correction for height of eye (HE) in Nautical Almanac.

Dec - Declination of body: angle north or south of equator.

Celestial Navigation for Sailors

Deviation - Error in compass reading relative to magnetic direction.

DMA - Defense Mapping Agency.

DOG - Distance Over Ground.

DR - Dead Reckoning position based on course & distance.

Drift - Velocity of current in knots.

DT - Daylight Savings Time; opposite of ST.

E - East.

EP - Estimated Position based on DR plus other information.

EFix - Electronic Fix based on LORAN or GPS.

Eq - Equator.

Fix - Position at intersection of two or more LOPs.

GHA - Greenwich Hour Angle; westerly angle from Greenwich to GP of the body.

GMT - Greenwich Mean Time; same as UT1; is the reference point for all celestial data and is based on the daily rotation of the earth relative to the Sun; within 1 second of UTC.

GP - Ground Position of Body.

GPS - Electronic positioning system based on satellites.

Ha - Apparent altitude of body; equation (5).

Hc - Calculated Altitude of body based on LHA, ALat & Dec.

Hci - Hc Increment for Dec minutes; equation (8).

HE - Height of observers eye above water.

Heading - Direction that bow of boat is pointed; 0° - 360° .

Ho - Observed altitude of body; equations (6a), (6b), (6c) & (6d).

HO229 - Sight Reduction Tables for Marine Navigation.

HO249- Sight Reduction Tables for Air Navigation.

Appendix A

HoMoTo - Memory Aid: *If Ho is More than Hc then I is Toward Zn.*

HP - Horizontal Parallax correction factor for Moon altitude.

Hs - Altitude of body measured by sextant.

I - Distance in nautical miles between LOPs based on Hc & Ho.

IC - Index correction for sextant based on IE.

IE - Sextant zero error between index mirror & horizon.

Knots - Nautical miles per hour.

LAN - Local Apparent Noon: time when Sun passes your Longitude.

Lat - Latitude: angle north or south of earth's equator.

LHA - Local Hour Angle: westerly angle between you & GP of body.

LL - Lower Limb: lower edge of Sun or Moon.

Log - Distance measuring instrument.

Log - Notebook for recording information.

Long - Longitude: angle east or west of Greenwich meridian; in Western Hemisphere, Longitude is (+); in Eastern Hemisphere, Longitude is (-).

LOP - Line of Position.

LORAN - Electronic positioning system based on ground stations.

LT - Local Time; may or may not equal ZT.

LTD - Longitude Time Difference; earth's rotation time from Greenwich to a longitude.

M - Direction relative to Magnetic North; 0°-360°.

MA - Minutes of Arc: a portion of a degree.

MTD - Meridian Time Difference; earth's rotation time from Greenwich to a Zone Meridian.

N - North.

Celestial Navigation for Sailors

NM - Nautical Mile: 1 minute of latitude; 6076 feet.

OFF - Sextant 'Optical Zero' is below the printed zero.

ON - Sextant 'Optical Zero' is above the printed zero.

RFix - Running Fix: made by advancing one or more LOPs.

RB - Relative Bearing referenced to the bow of the boat; also referred to as Bow Angle.

RRB - Reciprocal of RB

S - Boat speed through the water.

S - South.

Set - Direction that current is flowing toward in degrees True.

SHA - Sidereal Hour Angle: westerly angle from Aries to GP of a star.

SOG - Speed Over Ground.

SSB - Single Side Band: high frequency, long distance radio.

ST - Standard Time; opposite of DT; usually equals ZT.

Sunrise - Moment when top edge of Sun appears at your horizon in the morning; $H_s = 0^\circ$.

Sunset - Moment when top edge of Sun at your horizon in the evening; $H_s = 0^\circ$.

Civil Twilight - Period of time when top of Sun is between 0° and 6° below your horizon.

Nautical Twilight - Period of time when top of Sun is between 6° and 12° below your horizon.

TOWARD - Positive I is plotted TOWARD the direction of the Zn.

°T - Direction relative to North Pole of earth; 0° - 360° .

True - Direction relative to North Pole of earth; 0° - 360° .

UL - Upper Limb: upper edge of Sun or Moon.

UT1 - Same as GMT.

UTC - Coordinated Universal Time is broadcast over SSB radio from WWV; is within 1 second of GMT.

Appendix A

v - GHA interpolation factor in Nautical Almanac.

Variation - Difference between True and Magnetic North.

W - West.

WC - Watch Correction: WE applied to time to get GMT.

WE - Watch Error: amount that your watch differs from GMT.

Z - Azimuth Angle to GP of body referenced to North or South poles of earth; internal angle of celestial triangle.

ZD - Zenith Distance: angle between your position and GP of body.

Zenith - Point in the sky directly overhead.

Zn - Azimuth angle to body clockwise from True North; 0 to 360°.

Zone - Time Zone of earth; numbered 0 to 12; west (+); east (-).

ZT - Zone Time.

ZTD - Zone Time Difference; earth's rotation time from a zone meridian to a point within the same zone.

Appendix B

Equations

- (1) Corrected GMT = Observed GMT + WC
- (2) $LTD = \frac{\text{Longitude}}{15^\circ \text{ of rotation per hour}}$
- (3) MTD = LTD rounded to a whole number
- (3a) MTD = Longitude of Zone Meridian \div 15°
- (4) GMT = ZT + MTD
- (5) Ha = Hs + IC + DC
- (6a) Ho = Ha + AC1 + AC2 *(all bodies except Moon, Venus & Mars)*
- (6b) Ho = Ha + AC1 + AC2 + AC3 *(Venus & Mars)*
- (6c) Ho = Ha + AC1 + AC2 + HP *(Moon Lower Limb)*
- (6d) Ho = Ha + AC1 + AC2 + HP - 30.0 *(Moon Upper Limb)*
- (7) LHA = GHA - Longitude *In Western Hemisphere, Longitude is (+)
In Eastern Hemisphere, Longitude is (-).*
- (8) $Hci = \frac{\text{Dec minutes}}{60 \text{ minutes per degree}} \times d$
- (9a) *In the Northern Hemisphere, if LHA < 180°, then* **Zn = 360° - Z**
- (9b) *If LHA > 180°, then* **Zn = Z**
- (9c) *In the Southern Hemisphere, if LHA > 180°, then* **Zn = 180° - Z**
- (9d) *If LHA < 180°, then* **Zn = 180° + Z**
- (10) I = Hc - Ho
- (11) GHA Aries = Whole Hour GHA Aries + Minute/Second GHA Aries
- (12) GHA Star = GHA Aries + SHA Star
- (13) Lat = Ho + a₀ + a₁ + a₂ - 1° *(from Polaris observation)*

Celestial Navigation for Sailors

(14) $ZTD = LTD - MTD$

(15) $ZD = 90^\circ - Ho$ *(at Local Apparent Noon)*

(16) $ZT \text{ of LAN} = \text{Meridian Passage Time} + ZTD.$ *(at any longitude)*

(17) $Lat = Dec + ZD$

(18) $Distance = Drift \times Time$

(19) $\sin(Hc) = \cos(LHA) \times \cos(Lat) \times \cos(Dec) + \sin(Lat) \times \sin(Dec)$

(20) $\cos(Z) = \frac{\sin(Dec) - \sin(Hc) \times \sin(Lat)}{\cos(Hc) \times \cos(Lat)}$

(21) $RA = 360^\circ - SHA$