

Quick Reference Celestial Navigation

COMPLETE SIGHT REDUCTION SYSTEM FOR SUN & STARS

STARFINDER

EQUIPMENT

- chart • Nautical Almanac (NA)
- chronometer (known fast/slow rate) or radio for time on WWV (5, 10, 15, & 20 MHz)
- star finder • sextant • stop watch
- sight reduction tables Pub 249
- plotting sheets • pencil • paper
- parallel rules • triangle • dividers

DEFINITIONS

- N.S.E.W = north, south, east, west
- LAT = latitude, 0-90° N or S of equator
- LONG = longitude, 0-180° E or W of 0°
- DR = 'dead' reckoning position LAT/LONG
- AP = assumed position A. LAT / A. LONG
- ★ = celestial body (sun or star)
- ★ GP = ★ geographical position; given in
- ★ DEC = declination (= LAT) 0-90° N or S;
- ★ GHA = Greenwich hour angle
- ★ LHA = local hour angle always 0-360° (= LONG) 0-360° W from Greenwich E to W from A. LONG to GHA LHA = GHA + E or - W LONG
- ★ GMT = Greenwich Mean Time (= UT or coordinated universal time)
- ★ HS = height of ★ (°) from sextant observation.
- ★ Ho = ht. of ★ (°) observed after correction
- ★ Hc = ht. of ★ (°) computed from tables
- ★ a = intercept distance TO or AWAY from ★
- ★ Zn = TRUE azimuth (= bearing) of ★ GP (Z = intermediate step to get Zn)
- ★ LOP = line of position that you are on

TIME

- (record as: xx hrs-xx min-xx secs)
- sun and stars appear to move E to W thru 360° of longitude in 24 hours
- 360÷24=15° = one time zone per hour
- zones are E & W of Greenwich (0° to 180°)
- center of zones: 0° 15° 30° etc. E or W Long.
- to find GMT from zone (local) time: if you are: W LONG add 1 hour per zone; E subtract 1 hour per zone
- (if on Daylight Savings subtract one hour)

ZONES	
W	E
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12

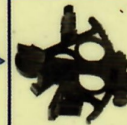


P.V.P.
€ 11.15

"SHOOTING" SUN & STARS to get Hs

- CAUTION: Set index arm sun shades first for sun only
 - 1) start stop watch on even minute GMT (radio)
 - 2) estimate ht. of sun above the horizon (°) (fist at arms length ≈ approx 10°)
 - 3) set sextant at approximate # of °
 - 4) find sun & horizon in scope
 - 5) 'rock' sextant side to side & turn drum until star or lower or upper limb of sun is tangent to horizon
 - 6) stop watch! add time to #1)
 - 7) read Hs from sextant
- arc (degrees) = 45°
vernier (min & tenths) = 13.6'
• zero line on drum = minutes
• where short lines 'line up' = tenths of minutes

SEXTANT



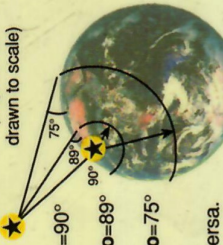
CORRECTIONS apply to Hs to get Ho

- INDEX ERROR (alignment of index mirror)
 - 1) set arc at 00° 00.0' and sight horizon
 - 2) turn micrometer drum until horizon is a straight line
 - 3) if: ' = 00° 00.0' no error or correction
 - if: ' on the arc (above 0), then subtract' from Hs
 - if: ' off the arc (below 0), then add' to Hs
- DIP (height of eye above sea level)
 - 1) before departure: measure from location on boat where you shoot.
 - 2) Find correction in Nautical Almanac (always minus)
- APPARENT ALTITUDE (App. Alt.) in Almanac
 - 1) apply INDEX and DIP corrections to Hs to get App. Alt.:
 - 2) find App. Alt. in ALTITUDE CORR. TABLE (Nautical Almanac) & apply corr. for refraction & semidiameter
 - 3) to get Ho in xx° xx.x' (tenths of ')

KEY TO UNDERSTANDING CELESTIAL NAVIGATION

WHAT YOUR SEXTANT TELLS YOU

- 1) The height or angle of ★ above horizon (Ho); and
 - 2) How far you are from ★ geographical position (★GP) in ° of arc (1° = 60 minutes of arc = 60 miles)
- GP is location on the earth's surface where the sun or star is directly overhead & therefore where the Ho = 90°
- (angles not drawn to scale)



IF YOU ARE: • at ★GP Ho=90°
IF YOU MOVE:
• 1° (60 mi) Ho=89°
• 15° (900 mi) Ho=75°

• The closer you are to ★GP, the higher the ★, and vice versa.

- 3) So: 90° - Ho = ° of arc or distance you are from ★GP
- 4) But since you don't know the exact direction of ★GP, the line of position you are on (LOP) is a circle with a radius of 90° - Ho & with the ★GP at its center.
- 6) Where LOPs from 3 stars intersect = POSITION FIX
- 7) IF YOU NOW KNOW WHERE YOU ARE WHY CONTINUE?

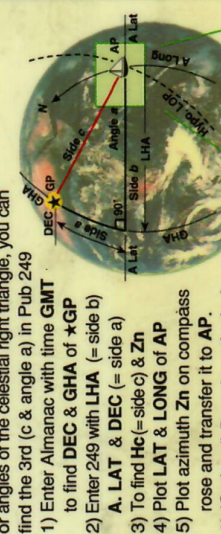


- BECAUSE A GLOBE IS TOO SMALL TO PLOT AN ACCURATE FIX, YOU MUST PLOT ON A PLOTTING SHEET, (a small section of globe)
- BECAUSE DISTANCE TO ★GP IS SO GREAT, YOU MUST PLOT FROM A HYPOTHETICAL REFERENCE POINT WHICH IS AN ASSUMED POSITION, WHICH YOU CHOOSE NEAR YOUR DR POSITION.

HOW TO USE YOUR ASSUMED POSITION

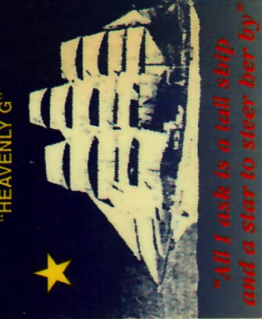
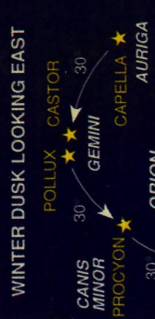
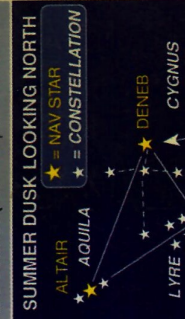
- 1) Use the location (Lat & Long) of your ASSUMED POSITION & the ★GP at the time of sight to compute (in the sight reduction tables) the height of ★(Hc) as it would appear from your ASSUMED POSITION (AP) at the time of sight.
- 2) Compare corrected sextant height of ★ (Ho) with the computed height Hc to determine if you are closer to or farther away from (intercept distance) ★GP than your AP
IF: Ho = Hc: your LOP is exactly thru your AP (unlikely)
Ho is less (★ is lower): your LOP is farther AWAY
Ho is more: you are closer TO ★GP than your AP
(HoMoTo: if Ho is More go Toward ★GP from your AP)
- 3) Your LOP passes thru an intercept point perpendicular to ★ azimuth (Zn). It appears as a straight line but is actually part of a circle with ★ at center.

• BASIC THEORY if you know 2 sides (a & b) or angles of the celestial right triangle, you can find the 3rd (c & angle a) in Pub 249



- 1) Enter Almanac with time GMT to find DEC & GHA of ★GP
- 2) Enter 249 with LHA (= side b)
- 3) To find Hc (= side a)
- 4) Plot LAT & LONG of AP
- 5) Plot azimuth Zn on compass rose and transfer it to AP.
- 6) (Optional) Draw hypothetical LOP perpendicular to Zn thru AP
- 7) Compare Ho & Hc to get intercept
- 8) Measure miles along Zn you are TOWARD or AWAY from ★GP (# min diff Hc & Ho = # miles)
- 9) Plot LOP; Use 3 stars for a FIX.

- For best fix use more than three stars
- Summer dusk stars = winter dawn stars
- From Big Dipper or Orion use pointers, and distance (first = 10°) to find 18 stars



"All I ask is a tall ship and a star to steer her by"

DATA **SUNLINE EXAMPLE** **PENCIL YOUR ENTRIES HERE**

Body	SUN
DR LAT	37° 08' N
DR LONG	125° 40' W
Date (local)	4 JULY 91
Radio (hr-m)	14-18:00
watch (m-s)	01-01
Time (local)	14-19:01
Zone	+8
GMT	22-19:01
Date (GMT)	4 JULY 91
GHA (hr)	148° 54.6'
Incr (m-s)	4° 45.3'
GHA	153° 39.9'
A.Long	125° 39.9' W
LHA	28° 00.0'
Dec. (hr)	N 22° 51.7'
d +-	-0.2
d corr.	-0.1'
Dec.*	N 22° 51.6'
Hs	62° 05.9'
Index +-	-2.1'
Dip	-3.4'
Sum +-	-5.5'
Hs (Ap Alt)	62° 00.4'
Alt. Corr.	+15.5'
Ho*	62° 15.9'
Tab. Dec.	22° N
Hc	61° 33'
Dec. Diff.	52+
d	37
corr+-	+32
Hc	62° 05'
Ho*	62° 16'
Z	114°
Zh	246°
A.Lat	37° N
A.Long	125° 39.9' W

*(round off to nearest minute)
DEFINITIONS: DR-dead reckoning
 GMT=Greenwich mean time
 LAT-latitude; LONG = longitude
 AP=assumed posit.; LOP=line of posit.
 LHA=local hour angle; Zn=azimuth
 GHA=G which hr.; Z=DEC=declination
 LAN=local apparent noon a=intercept
 GP=geog. position Hs=height sextant
 Ho=ht. corrected Hc=ht. computed

SUNLINE (LOP); refer to color-coded **DATA** Example at left

- shoot sun to get Hs at exact time GMT (hr-min-sec)
- correct Hs to get Ho
- Enter NAUTICAL ALMANAC with GMT to find *GP**
 - enter Daily Pages with DAY & HOUR of sight to find:
 - GHA & DEC (& 'd' factor for sun) to nearest hour
 - enter Yellow Pages (Increments and Corrections) with minutes & seconds
 - to find increment which is added to hourly GHA to get final GHA
 - to find 'd' correction to add or subtract from DEC (if declination is increasing or decreasing to next hour) to get final DEC ('v' correction moon and planets only)
- Choose an AP (A.Lat, A.Long) near your DR Lat, Long

1991 July 3, 4, 5 (W,T,F)

G.H.A.	Dec.		
d h m	o ' "	/ o ' "	/
4 21 133	54.7	N 22	51.9
22 148	54.6		51.7
S.D.	15.8	d	0.2

5) determine sun's LHA :
 a) LHA is 0-360° going W from your Assumed LONG to the sun's GHA, so:
 b) LHA = GHA + E or - W A. LONG
 c) assume a LONG which, when added to or subtracted from GHA will = whole ° LHA

6) Enter PUB 249 II or III SIGHT REDUCTION TABLE with: A.LAT., DEC., LHA to find Hc and Zn

DECLINATION (15°-23°) SAME NAME AS LATITUDE

LHA	Hc	Z	Hc	d	Z
27	61 39	38	117	62 17	37
28	60 56	37	116	61 33	37
29	60 12	37	114	60 49	36

a) to interpolate between whole degrees of DEC:
 • note 'd', & if Hc increases or decreases to next higher DEC
 • enter Table 5 with d, & additional minutes of DEC
 • add or subtract correction from Hc to get final Hc
 b) Zn (TRUE azimuth of GP)
 • in N. Lat. if LHA > 180° Zn = 180° - Z
 • in S. Lat. if LHA < 180° Zn = 180° + Z
 7) find difference between Hc & Ho (intercept) & plot LOP

PLOTTING AN LOP
 1) plot AP (A.LAT & A.LONG)
 2) using parallel rules: transfer Zn to AP & draw line to AP & draw line to GP
 3) using dividers: on latitude scale, measure miles diff. Ho & Hc (intercept min.=miles)



STAR FIX (see SUNLINE for procedure)
 1) To determine (precompute) stars which will be visible when you plan to shoot:
 a) enter Almanac TWILIGHT TABLE with DAY & A.LAT to find:
 b) Local Time of nautical twilight (dawn or dusk)
 c) convert to GMT, and enter Almanac to find:
 d) GHA of ARIES
 e) determine the LHA of ARIES ∩

2) Enter PUB 249 I with A.LAT & LHA of ARIES to find Hc & Zn of stars visible at local twilight

LAT 37° N

LHA ∩	Hc	Zn	Hc	Zn	Hc	Zn
217	23 17	050	41 54	068	41 47	108
218	23 54	050	42 38	068	42 33	109
219	24 31	051	43 23	068	43 18	110
					43 18	110
					21 16	153

Example:
 • 4 JULY 1991 dusk • A.LAT 37° N DR LONG 123° 39.5' W
 • Nautical Twilight 35 - 40° N LAT = 20-30-00 local time
 • GMT = 20-30 + zone 8 hours = 28-30 or 04-30 on 5 July!
 • GHA of ARIES = 342° 39.5'
 • LHA = 342° 39.5' - 123° 39.5' W LONG = 219°
 • Enter PUB 249 I with 37° N LAT & LHA 219 to find stars (ie: DENEBA: Hc = 24° 31', Zn = 051° True)

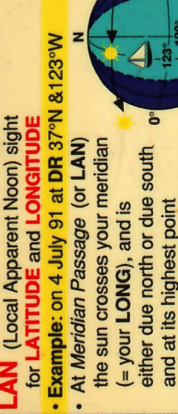
3) To locate and shoot stars
 a) note each Hc and True bearing Zn ;
 b) be on deck before twilight
 c) pre set sextant at star Hc, look in direction of TRUE Zn (don't forget to convert Zn from TRU to COMPASS bearing)
 d) find star, bring it tangent to horizon; mark time of sight with stop watch
 e) record Hs and time
 4) Computations (see SUNLINE for details)
 a) record time from watch; convert to GMT
 b) record Hs from sextant; correct to get Ho
 c) enter Almanac DAY & time GMT to find GHA
 d) and determine new LHA of ARIES & A.LONG
 e) reenter PUB 249 I with: A.LAT., & LHA ARIES to find Hc and Zn of star
 f) find difference between Hc & Ho (intercept)
 g) plot AP, then plot LOP thru intercept point
 i) repeat for at least 3 stars to get FIX at the intersection of LOPS

6) to get RUNNING FIX from sun TO or AWAY from GP
 5) at intercept point draw LOP perpendicular to Zn & course made good from the time of LOP 1 to LOP 2 (remember to account for current, set & drift) where the advanced LOP 1 crosses LOP 2 = Running FIX at the time of LOP 2

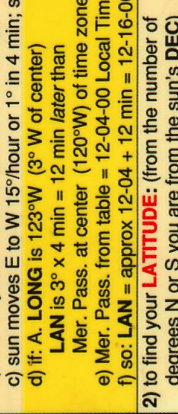


REMEMBER: 60' = 1° !! Double check tables and calculations!

LAN (Local Apparent Noon) sight for **LATITUDE** and **LONGITUDE**
 • Example: on 4 July 91 at DR 37°N & 123°W
 • At Meridian Passage (or LAN) the sun crosses your meridian (= your LONG), and is either due north or due south and at its highest point
 1) To find Local Time of LAN
 a) enter Almanac with DAY to find Meridian Passage at center of your time zone (4 July, zone +8, center 120°)
 b) find # of A. LONG is E or W of center
 c) sun moves E to W 15°/hour or 1° in 4 min; so:
 d) if: A. LONG is 123°W (3° W of center) LAN is 3° x 4 min = 12 min later than Mer. Pass. at center (120°W) of time zone
 e) Mer. Pass. from table = 12-04-00 Local Time
 f) so: LAN = approx 12-04 + 12 min = 12-16-00
 2) to find your LATITUDE: (from the number of degrees N or S you are from the sun's DEC)
 a) Enter Almanac with GMT of Meridian Passage at your DR LONG to find sun's DEC N or S
 b) To find degrees you are from the sun's DEC
 1) begin shooting sun about 1/2 hour before LAN
 2) at first sight: note exact time and Hs (sextant °) (will be used later to determine exact LONG)
 3) at approx. time of LAN sun appears to 'hang' at its highest point - note Hs & correct to get Ho
 4) 90° - Ho = x° you are N or S of sun's DEC = x
 5) use diagram below to determine whether to add or subtract x & sun's DEC to find your LAT.



Example: (Center diagram):
 • LAN (12-16-00) • Ho = 75° • 90° - 75° = 15° = 'x'
 • DEC = 22° 52' N • LATITUDE = 22° 52' N + 15° = 37° 52' N
 3) to find your LONGITUDE (which = the sun's GHA when it crosses your meridian at LAN)
 a) after recording Hs at LAN reset sextant at Hs 1 of 1st sight - note time sun drops to Hs 2 after LAN
 b) divide elapsed time between two sights in half to find exact time (GMT) of LAN
 c) enter Almanac to find GHA of sun for that GMT:
 GHA sun = W LONG; 360° - GHA = E. LONG
 Example: • Hs 1 = 73° 29' at 11-46-00
 • Hs 2 = 73° 29' at 12-46-00
 • 60 minutes + 2 = 30 min
 • LAN = 11-46-00 + 30 = 12-16-00
 • GHA at 20-16-00 GMT = 123° 06.4'
 • your LONGITUDE = 123° 06.4' - W



Example: (Center diagram):
 • LAN (12-16-00) • Ho = 75° • 90° - 75° = 15° = 'x'
 • DEC = 22° 52' N • LATITUDE = 22° 52' N + 15° = 37° 52' N
 3) to find your LONGITUDE (which = the sun's GHA when it crosses your meridian at LAN)
 a) after recording Hs at LAN reset sextant at Hs 1 of 1st sight - note time sun drops to Hs 2 after LAN
 b) divide elapsed time between two sights in half to find exact time (GMT) of LAN
 c) enter Almanac to find GHA of sun for that GMT:
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 • 60 minutes + 2 = 30 min
 • LAN = 11-46-00 + 30 = 12-16-00
 • GHA at 20-16-00 GMT = 123° 06.4'
 • your LONGITUDE = 123° 06.4' - W