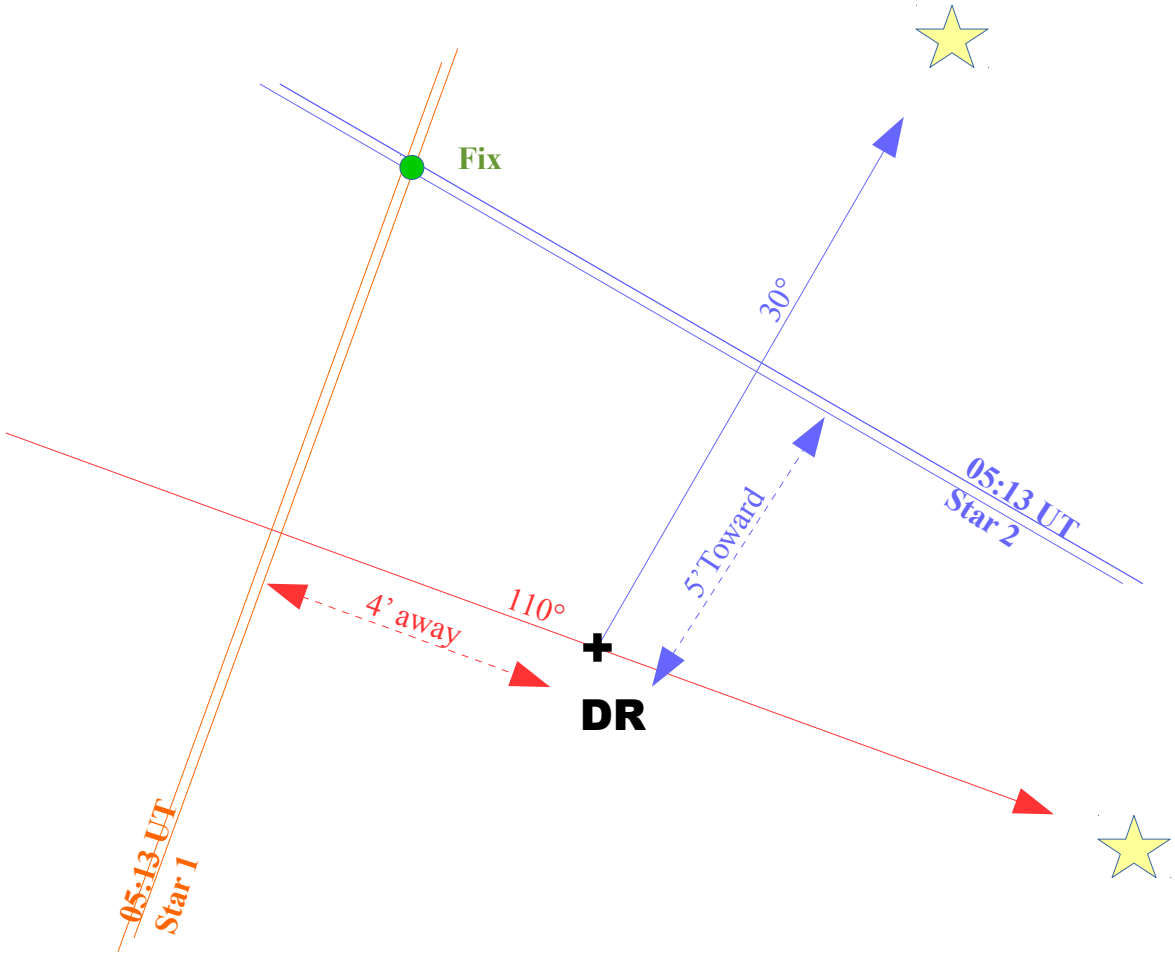
ATELIER 1 : CALCUL ET TRACÉ ELEMENTAIRES DE DROITES DE HAUTEUR

Exercice 1.1 - Drawing Line of position on plotting sheet

At 05h13min, DR position, 19°20′ N, 116°50′ E., two observations of stars were taken as follows:
1. Star 1 - Bearing 110° T, intercept 4′ away.
2. Star 2 - Bearing 030° T, intercept 5′ toward.
Find the ship's position

Correction partielle
Ce tracé est à faire sur un plotting sheet pour lire la position (latitude/longitude) du point



Exercice 1.2 – Sight seeing reduction/ LOP with stars

Correction partielle

In the evening, 17th July 1981, at DR position 40° 25'N, 32° 40'W, the chronometer showed 10h 21min 07s, chronometer error 4min 09s fast.
Observed Star Dubhe with sextant altitude 43° 32,0' and star Deneb with sextant altitude 38° 12,3' ; index error 2,3' on the arc ; height of eye 15 m.
Find intercepts and positions lines.

Define GMT

Chronometer Time	10h 21min 07s	
Chronometer Error	- 4min 09s	*Fast - / Slow +*
Time GMT [12h]	10h 16min 58s	
GMT	**22h 16min 58s**	*Time on 24h*

Intercept for Dubhe

Define LHA* et D* for Dubhe

GHAγ	265° 38,0'	*NA - à l'heure ronde =22h00*
+ΔGHAγ	4° 15,2	*Pour Δt= 156min 58s*
= GHAγ	269° 53,2'	*À l'heure précise =22h 15min 58s*
+ SHA*	194° 21,9'	*NA*
GHA*	104° 15,1'	*464°15,1' [360*
- Ge	- 32° 40,0'	
LHA*	**71°35,1'**	

D* = 61° 51, 4'N

Calculate hc

$$\sin h_c = \sin\phi_e \cdot sinD + \cos\phi_e \cdot \cos D \cdot \cos LHA$$
$$= \sin(40°25') \cdot \sin(61°51,4') + \cos(40°25') \cdot \cos(61°51,4') \cdot \cos(71°35,1')$$
$$= 0,685$$
$$\rightarrow h_c = 43°14,7'$$

Hc = 43° 14,7'

Calculate Zc

$$\cos AZ_c = \frac{\sin D - \sin\phi_e \cdot \sin h_c}{\cos\phi_e \cdot \cos h_c}$$
$$= \frac{\sin(61°51,4') - \sin(40°25') \cdot \sin(43°14,7')}{\cos(40°25') \cdot \cos(43°14,7')} \approx 0,78901$$
$$\rightarrow AZ_c \approx 38°'$$
$$LHA = 71°35,1' \rightarrow Z_c = 360° - AZ_c$$

Zc = 322°

Calculate ho

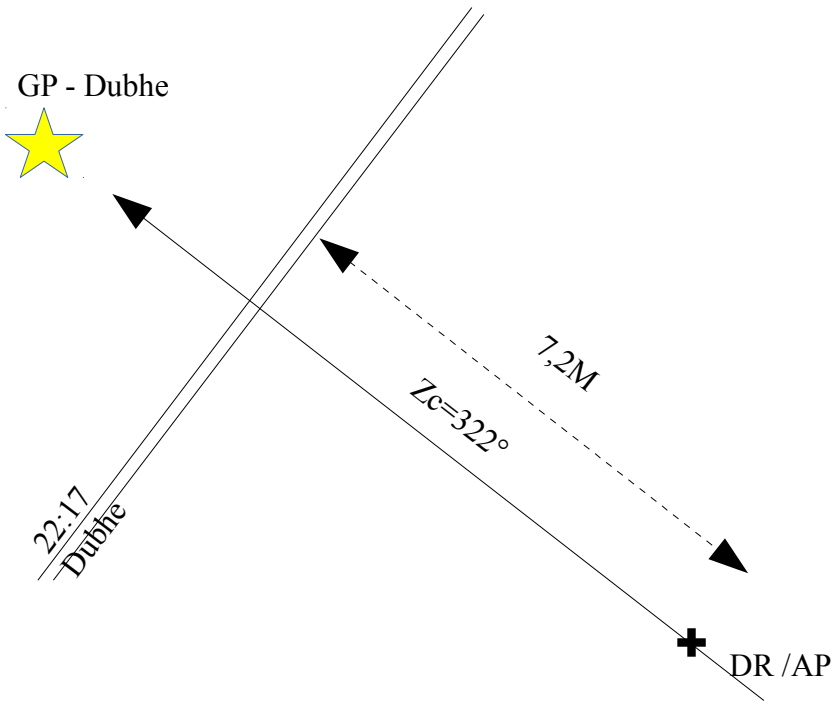
hs	**43°32,0'**
+ IC	-2,3'
+ Dip	-6,8'
ha	**43° 22,9'**
+Alt. Main correction	-1,0'
-30' for upper limb (Moon)	
+U,L, correction for Moon	
+Additionnal correction for Venus	
+Additional refraction correction (non standard Temp/pression)	
ho	**43°21,9'**

Calculate the intercept/LOP

ho	43°21,9	
- hc	- 43° 14,7'	
= **i**	+ **7,2'**	**Zc= 322°**

Draw the LOP

XDD



Exercice 1.3 – Sight seeing reduction / LOP with the SUN

At 0900 LMT, 25th October 1981, DR position 43°15′ N, 38°25′ W, the chronometer shows 11h 40min 32s, chronometer error is 2m 20s slow.
Sextant altitude of the sun's lower limb is 24°02.3′ ; index error 1.5′ off the arc; height of eye 12 m.
Find intercept and position line:

Define GMT

Ge/15 = 2h 33min 40s

Chronometer Time	11h 40min 32s
Chronometer Error	2min 20s
Time GMT [12h]	11h 42min 52s
GMT	11h 42min 52s

Fast - / Slow +

Time on 24h

Approx LMT 09h00
\+ *Ge 2h 33min 40s*
Approx GMT 11h 33 min 40s

Define LHA/GHH et D

GHA_a	348° 58,5'
$+\Delta GHA_a$	10° 43,0'
= GHA_a	359° 41,5'
- Ge	- 38° 25,0'
LHA_a	**321° 16,5'**

NA - à l'heure ronde =11h00
Pour Δt= 42min 52s / d=0,9
À l'heure précise =22h 15min 58s

D	12° 09,0' S
+ΔD	+ 0,6'
D	**12° 09,6' S**

Calculate hc

$$\sin h_c = \sin\phi_e \cdot sinD + \cos\phi_e \cdot \cos D \cdot \cos LHA$$
$$= \sin(43°15') \cdot \sin(-12°09,6') + \cos(43°15') \cdot \cos(-12°09,6') \cdot \cos(321°16,5')$$
$$= 0,411$$
$$\rightarrow h_c = 24°16,7'$$

Hc = 24° 16,7'

Calculate Zc

$$\cos AZ_c = \frac{\sin D - \sin\phi_e \cdot \sin h_c}{\cos\phi_e \cdot \cos h_c}$$
$$= \frac{\sin(-12°09,6') - \sin(43°15') \cdot \sin(24°16,7')}{\cos(43°15') \cdot \cos(24°14,6')} \approx -0,741'$$
$$\rightarrow AZ_c \approx 137,8°$$
$$LHA > 180° \Rightarrow astre\ à\ l'Est \rightarrow Z_c = 138°$$

Zc = 138°

Calculate ho

hs	**24°02,3'**	
+ IC	+ 1,5'	
+ Dip	-6,1'	12 m de hauteur
ha	**23° 57,7'**	
+Alt. Main correction	14,1''	**LL**
ho	**24° 11,8'**	

Calculate the intercept/LOP

ho		24° 11,8'	
- hc	-	24° 16,7'	
= **i**	-	**4,9'**	**Zc= 129°**

Draw the LOP

ATELIER 2 : TRANSPORT DE DROITES

Exercice 2.1 : Canevas de Mercator & UPS *(AST-RF001)*

DR : 40° 05,0'N / 131°45,0'W
Two celestial observations of stars were taken simultaneous as follows:

- star 1 - Bearing 110° T, intercept 4 away.
- Star 2 Bearing 030° T, intercept 5 toward.

Plot the line of position and define the position

Exercice 2.2 : Sight reduction for stars *(AST-RF002)*

Un navire suit une route fond au 235° à la vitesse surface Vs = 14 nds,
le courant est nul.
A 07:38 Tcf, φe = 45°44' N et Ge = 012° 00' W.
On a trouvé pour les observations de 3 étoiles :

- Alkaid Tcf = 07h 32min 15s : Zc = 300° / Ho – Hc = 0,5'
- Arcturus Tcf = 07h 38min 03s : Zc = 261° /Ho – Hc = 2,2'
- Schedar Tcf = 07h 44min 07s : Zc = 041° / Ho – Hc = -3.7

Tracer le point d'étoiles pour 07h38 min Tcf

Exercice 2.3 : Sigh reduction and running fix for the Sun *(AST-RF003)*

At 0900 zone time, on 23 September 1981, your DR position is LAT 28°48.0'N, LONG 153°11.5'W.
You are steering course over ground 257°T at a speed of 18.0 knots.
You observed 3 following morning sun lines (lower limb).

Zone Time	**Sextant Altitude**
09h 15min 14s	39° 50,4'
09h 50min 04s	46° 11,2'
10h 20min 17s	51° 09,8'

The height of the eye is about 10,5 m.
The index error (IE) is -2,1'

Determine the latitude and longitude of your 10 h 20min running fix.

Exercice 2.4 : Sight reduction & running fix for stars *(AST-RF004)*

On May 16th 1981, the navigator takes and records the following sights :

	Sextant altitude Hs	**Observation Time (ZT)**	**Estimated position**
Kochab	47°19,1'	20h 07min 43s	39° 05,1' N, 157° 08,0' W
Spica	32°34,8'	20h 11min 26s	39° 06,3 N, 157° 10,0' W

Height of eye is 48 feet and index correction (IC) is +2,1'

Determine the position at 20h 11min ZT

ATELIER 3 : PROBLEMES DIVERS

Exercice 3.1 Sight reduction Sun/Sun (S2)

On June 6th 2025, you are sailing in Mediterranean Sea.
You are steering course over ground 120°T at a speed of 10 knots
Your dead reckoned position is 40° 01,0' N / 005° 43,0' E at 12h 10min UT
Your sextant have an index correction 1,4' on the arc.
You make the following sight at the eight of 9,5m
Make a fix at 11h 59 min UT.

Time sight (UT)	Hs	Position	
09h 59 min 05s	62° 37,5'	40° 01' N	05° 43' E
11h 58min 31s	72° 43,2'	39° 51' N	06° 05,5' E

Solution partiielle exercice 3.1 : 39° 43,7'N / 006°10,2'E

date 30/06/25 U.T. = 9.59.05 exercise S2-a

D.R. Latitude φ = 40° 01' N D.R. Longitude λ = 05° 53' E Course = 120° speed = 10,0

Sextant correction c + 0,1' index correction γ + 1,4' height of eye above the surface of the sea (in meters) = 9,5 mt.

Meridian Angle P

U.T.		°	'
hour	GHA =	314	4,0
min./sec.	GHA =	14	46,3
v -0,1' →	v corr.* =		- 0,1'
	GHA =	328	50,2
	+λ(+/-) =	5	43,0
	LHA =	334	33,2
	Pe/w =	25	26,8 E

Conversion LHA into Meridian Angle : LHA < 180° → Meridian Angle Pw = LHA; LHA > 180° → Meridian Angle Pe = 360° - LHA

Declination δ

δ = 23 8,6' N
d = - 0,1'
d correct. * -0,1'
δ = 23 8,5' N

** from " Increments and corrections tables "*

Azimuth Za - *with Az. Tables*

from tab. AT1: AT1 = -17,6
from tab. AT2: AT2 = 9,9
AT1 + AT2 = -7,7
Azimuth Angle Z = S 59,5 E
Azimuth Zn = 120,5°

AT1 - positive if Meridian Angle is greater than 90°; negative if Meridian Angle is smaller than 90°

AT2 - positive if latitude has same name as declination; negative if latitude has contrary name to declination

Table AT-3 provides the azimuth angle Z in degrees with decimals. Z will be from N / S to E / W according the following rules:

from North or South: same pole of latitude if (AT1 + AT2) is positive and contrary pole if (AT1 + AT2) is negative; eastward if Meridian Angle is East; westward if Meridian Angle is West

sin hc = (sin latitude φ x sin declination δ) + (cos latitude φ x cos declination δ x cos meridian angle P)

hc - calculated height

sin φ (latitude)	=	0,64301	x	cos φ (latitude) =	0,76586 x
sin δ (declin.)	=	0,39301		cos δ (declin.) =	0,91954 x
				cos P (Meridian Angle) =	0,90299
m	=	0,25271		*n* =	063591
+ *n*	=	0,63591			
sin hc	=	0,88862			
hc (calculated height)		62° 42,0'			

" m " is negative if latitude has contrary name to declination - " n " is negative if Meridian Angle is greater than 90°

Rules for converting Z into Azimuth Zn

Z =	N_°E	Zn =	Z
Z =	N_°W	Zn =	360°-Z
Z =	S_°E	Zn =	180°-Z
Z =	S_°W	Zn =	180°+Z

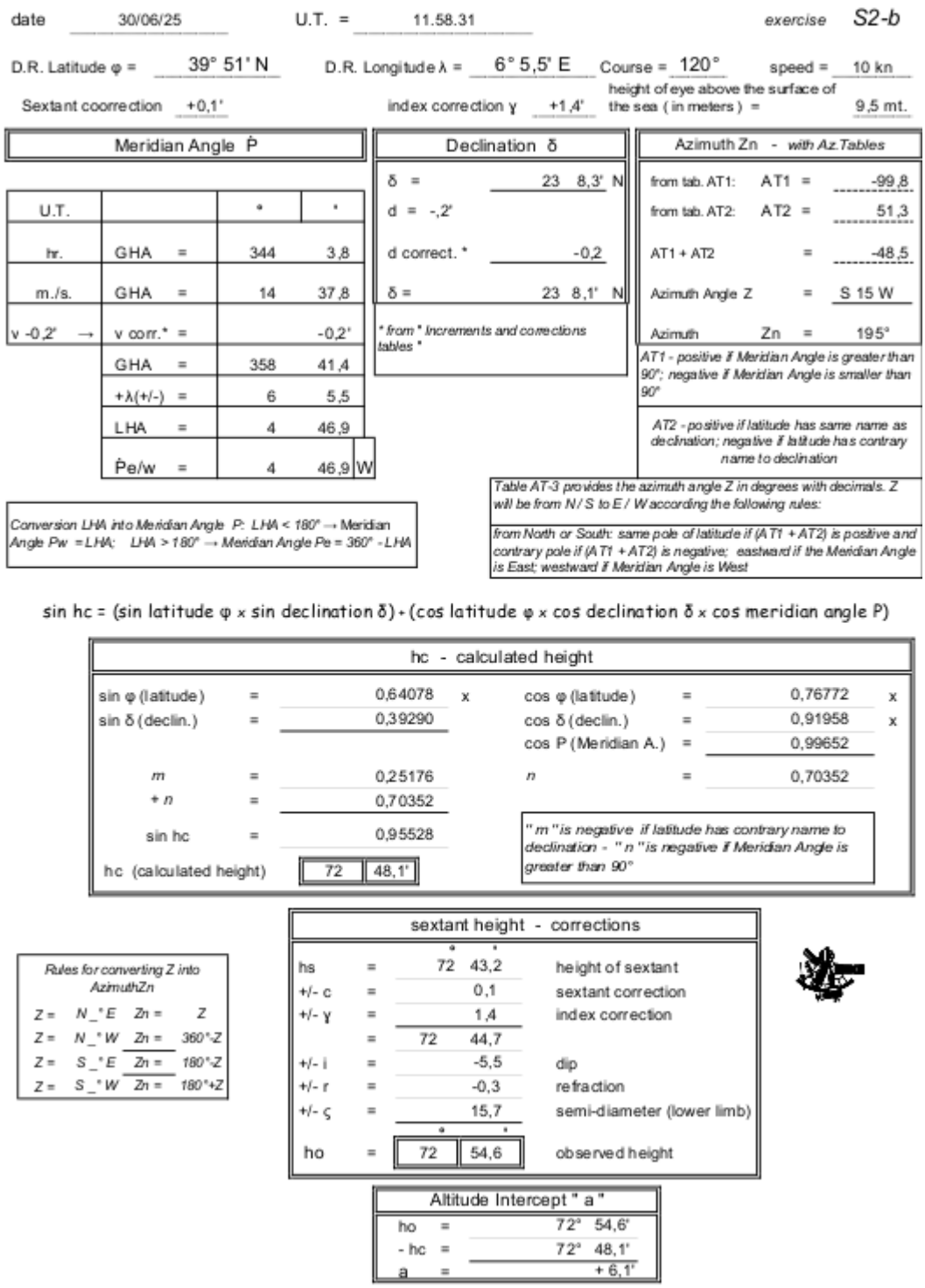
sextant height - corrections

		°	'	
hs	=	62	37,5	height of sextant
+/- c	=		0,1	sextant correction
+/- γ	=		1,4	index correction
	=	62	39	
+/- i	=		-5,5	dip
+/- r	=		-0,5	refraction
+/- ς	=		15,7	semi-diameter (lower limb)
ho	=	62	48,8	observed height

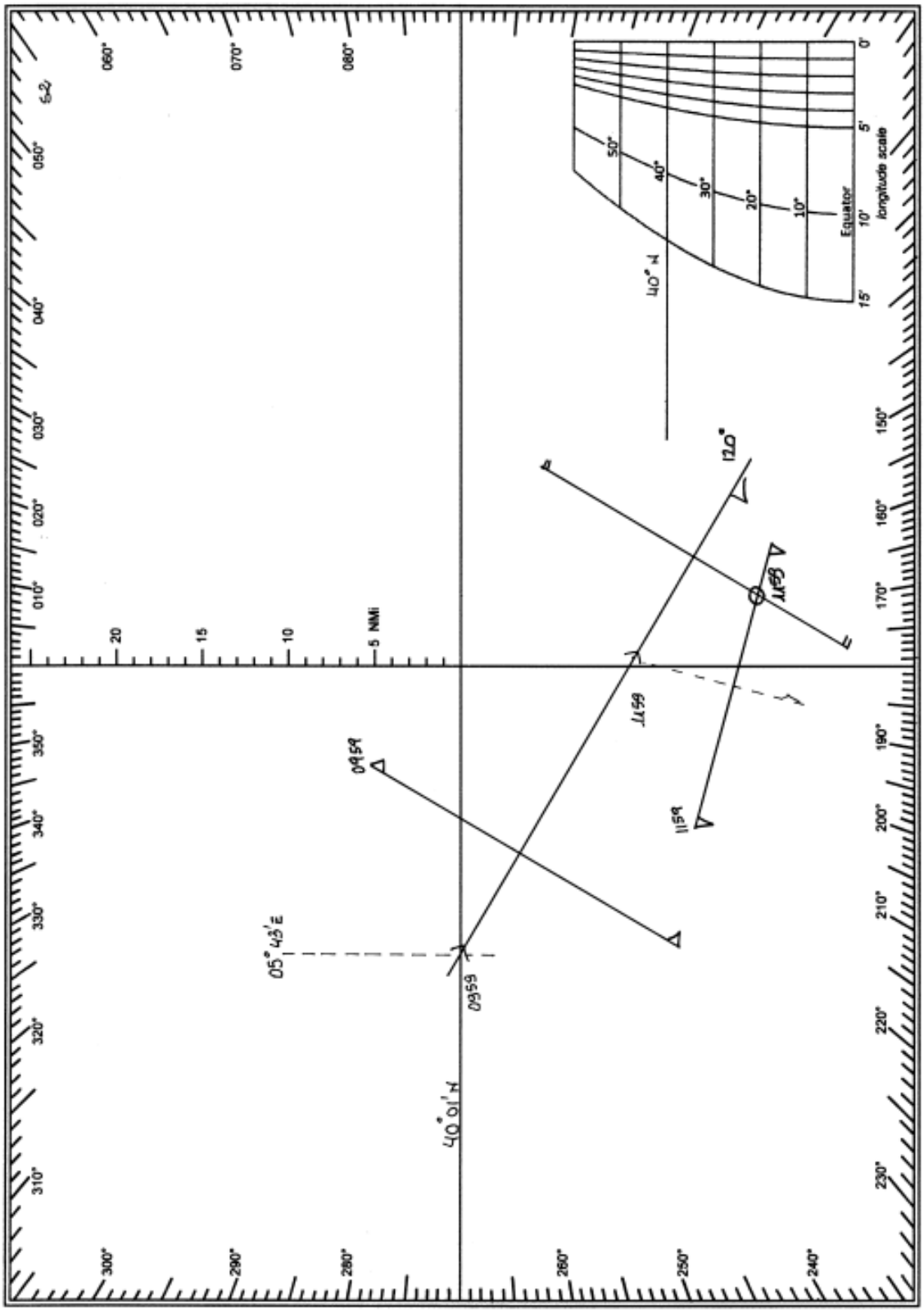
Altitude Intercept " a "

ho	=	62° 48,8'
- hc	=	62° 42,0'
a	=	+6,8'

Exercice 3.1 : Sight reduction Sun-Sun (correction1/3)



Exercice 3.1 : Sight reduction Sun-Sun (correction2/3)



Exercice 3.1 : Sight reduction Sun-Sun (correction 3/3)

Exercice 3.2 Sun sight reduction

date 30.06.2025 U.T. = 8.35.35 *exercise S7-a*

D.R. Latitude φ = 20° 02' N D.R. Longitude λ = 38° 45' E Course = 152° speed = 10 kn

Sextant correction c +0,2' index correction γ +0,8' height of eye above the surface of the sea (in meters) = 6 mt.

Meridian Angle Ṗ

U.T.		°	'
hour	GHA =	299	4,1
min./sec.	GHA =	8	53,8
v -0,1' →	v corr.* =		-0,1
	GHA =	307	57,8
	+λ(+/-) =	38	45,0
	LHA =	346	42,8
	Ṗe/w =	13	17,2 E

Conversion LHA into Meridian Angle : LHA < 180° → Meridian Angle Pw = LHA; LHA > 180° → Meridian Angle Pe = 360° - LHA

Declination δ

δ =	23	8,8' N
d =	-0,2'	
d correct. *		-0,1
δ =	23	8,7' N

** from " Increments and corrections tables "*

Azimuth Zn - *with Az. Tables*

from tab. AT1: AT1 =		-15,4
from tab. AT2: AT2 =		18,6
AT1 + AT2 =		3,2
Azimuth Angle Z =		N 73,5 E
Azimuth Zn =		73,5°

AT1 : positive if Meridian Angle is greater than 90°; negative if Meridian Angle is smaller than 90°

AT2 : positive if latitude has same name as declination; negative if latitude has contrary name to declination

Table AT-3 provides the Azimuth Angle Z in degrees with decimals. Z will be from N / S to E / W according the following rules:

from North or South: same pole of latitude if (AT1 + AT2) is positive and contrary pole if (AT1 + AT2) is negative; eastward if the Meridian Angle is East; westward if Meridian Angle is West

sin hc = (sin latitude φ x sin declination δ) + (cos latitude φ x cos declination δ x cos meridian angle P)

hc - calculated height

sin φ (latitude)	=	0,34257	x	cos φ (latitude)	=	0,93949 x
sin δ (declin.)	=	0,39306		cos δ (declin.)	=	0,91951 x
				cos P (Meridian A.)	=	0,97323
m	=	0,13465		*n*	=	0,84075
+ *n*	=	0,84075				
sin hc	=	0,97540				
hc (calculated height)		77 15,9'				

"m" is negative if latitude has contrary name to declination - "n" is negative if Meridian Angle is greater than 90°

Rules for converting Z into Azimuth Zn

Z =	N _° E	Zn =	Z
Z =	N _° W	Zn =	360°-Z
Z =	S _° E	Zn =	180°-Z
Z =	S _° W	Zn =	180°+Z

sextant height - corrections

		°	'	
hs	=	76	59,8	sextant height
+/- c	=		0,2	sextant correction
+/- γ	=		0,8	index correction
	=	77	00,8	
+/- i	=		-4,3	dip
+/- r	=		-0,2	refraction
+/- ς	=		15,7	semi-diameter (lower limb)
ho	=	77	12,0	observed height

Altitude Intercept " a "

ho =	77°	12,'
- hc =	77°	15,9'
a =		-3,9

Illustration 1: Exercice 3.2 - Sun reduction sight (1/3)

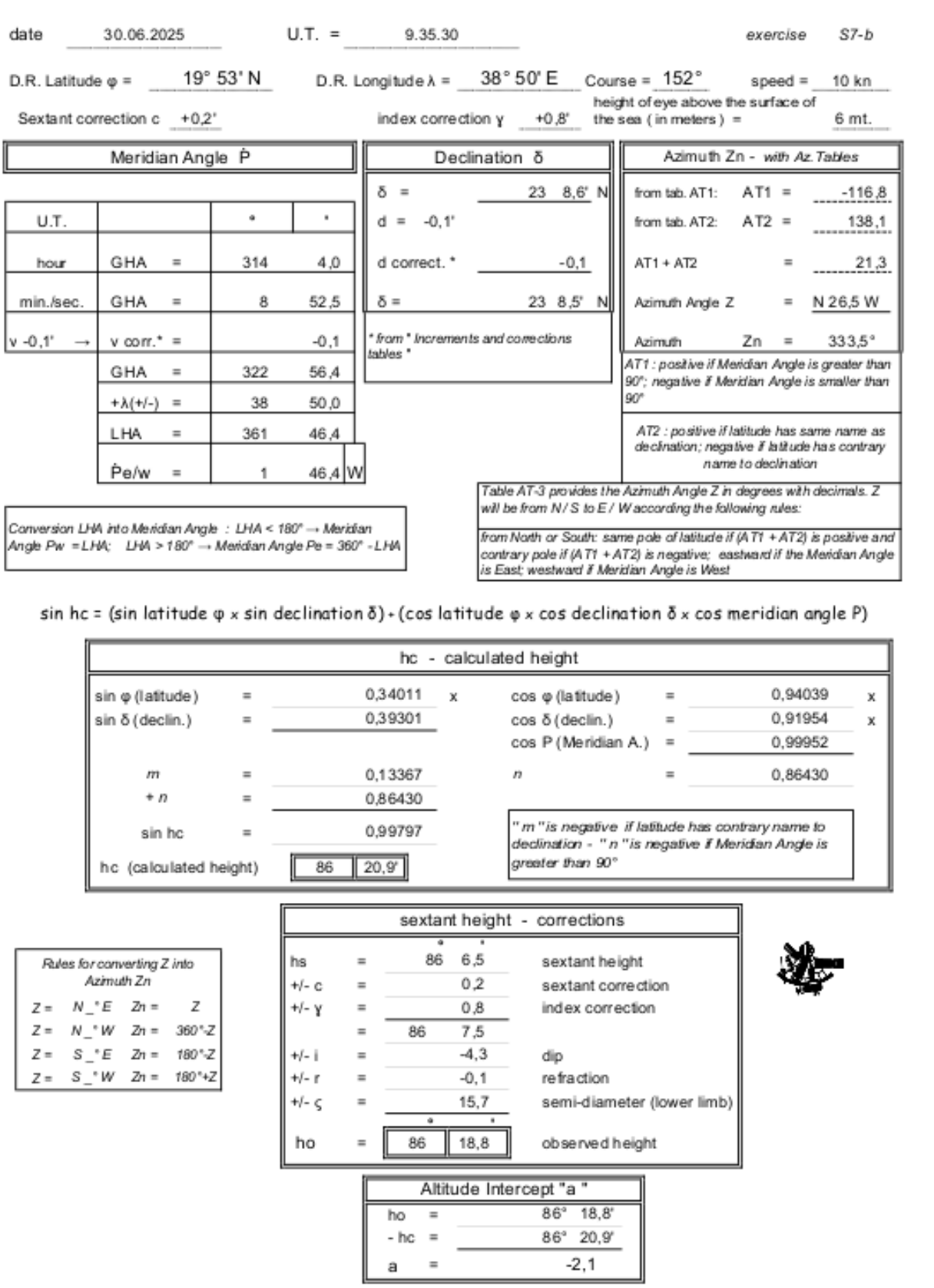


Illustration 2: Exercice 3.2 - Sun sight reduction (2/3)

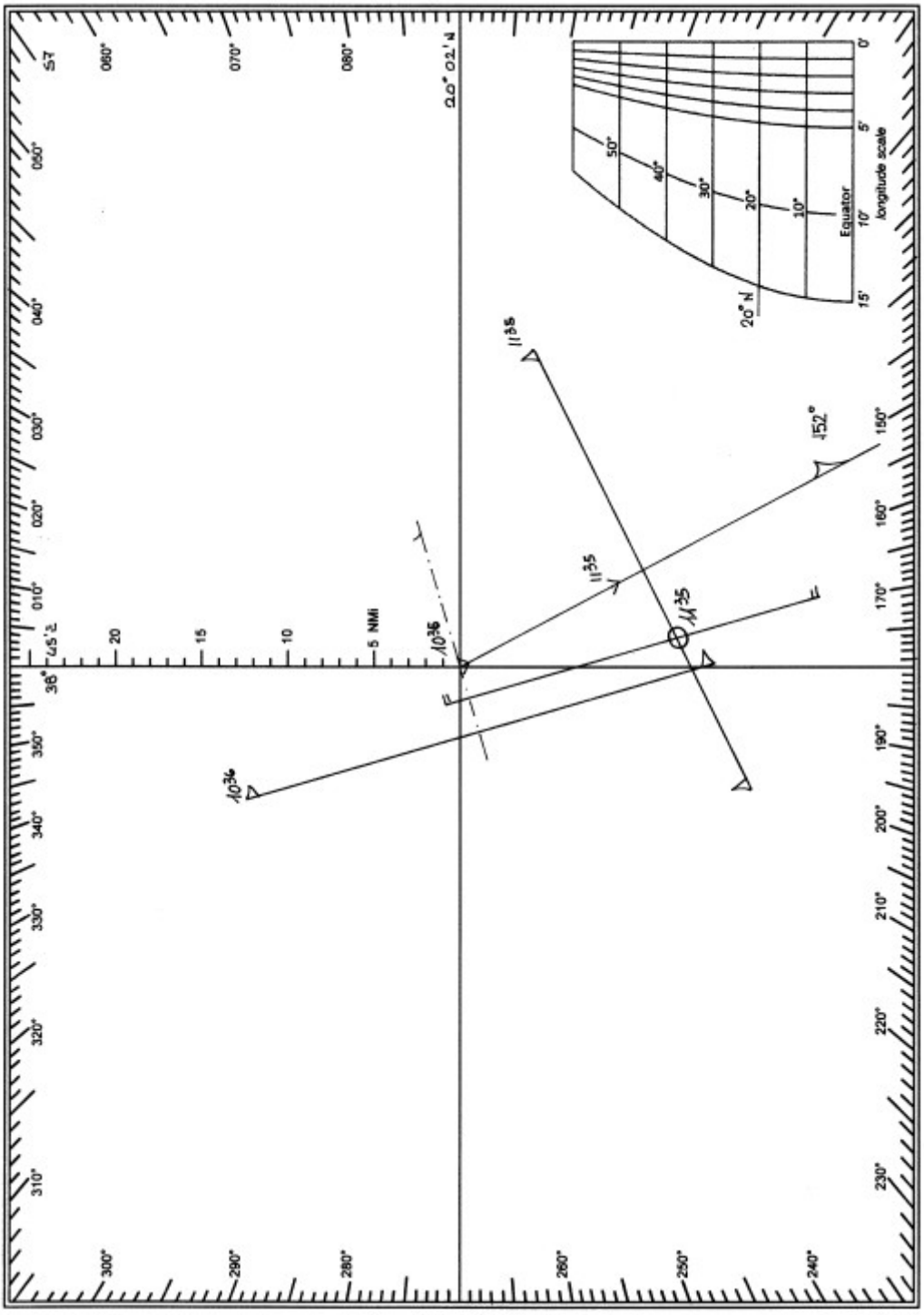


Illustration 3: Sun Sight reduction (3/3)

Exercice 3.3 Sighr reduction star & planets

St-P-1

Indian Ocean — date 28.06.2024 — Zone - 3 h

Latitude φ 10° 00' S — watch correction + 5 sec. — fix at : 05.40 local time

Longitude λ 44° 36' E — Course = 208° — speed = 16 kn.

height of eye above sea level: 15 mt. — sextant correction + 0,1' — index correction = + 1,1'

Star	Achernar	Enif
Watch	02.40.10	02.43.02
U.T.	02.40.15	2.43.07
declination δ =	57 06,5 S	9 59,2 N
GHA - Aries ♈ hr.	306 39,9	306 39,9
GHA - ♈ m.s.	10 05,4	10 48,5
GHA - Aries ♈	316 45,3	317 28,4
+λ *(long. E+ W-)*	44 36,0	44 36,0
LHA - Aries ♈	1 21,3	2 04,4
SHA	335 20,7	33 39,0
LHA - Star	336 42,0	35 43,4

Conversion LHA into Meridian Angle : LHA < 180°→ Meridian Angle Pw = LHA; LHA > 180°→ Meridian Angle Pe = 360° - LHA

Meridian Angle (Pe or Pw	23 18,0 E	35 43,4 W
from Azimuth Tables :		
AT1	-4,1	-2,5
AT2	39,1	-3,0
AT1 + AT2	35,0	-5,5
Z *(Azimuth Angle)*	S 16,2 E	N 61,7 W
Zn *(Azimuth)*	**163,8**	**298,3**

Rules for converting Z into Azimuth Zn:

Z = N_°E : Zn = Z — *Z = N_°W : Zn = 360°-Z* — *Z = S_°E : Zn = 180°-Z* — *Z = S_°W : Zn=180°+Z*

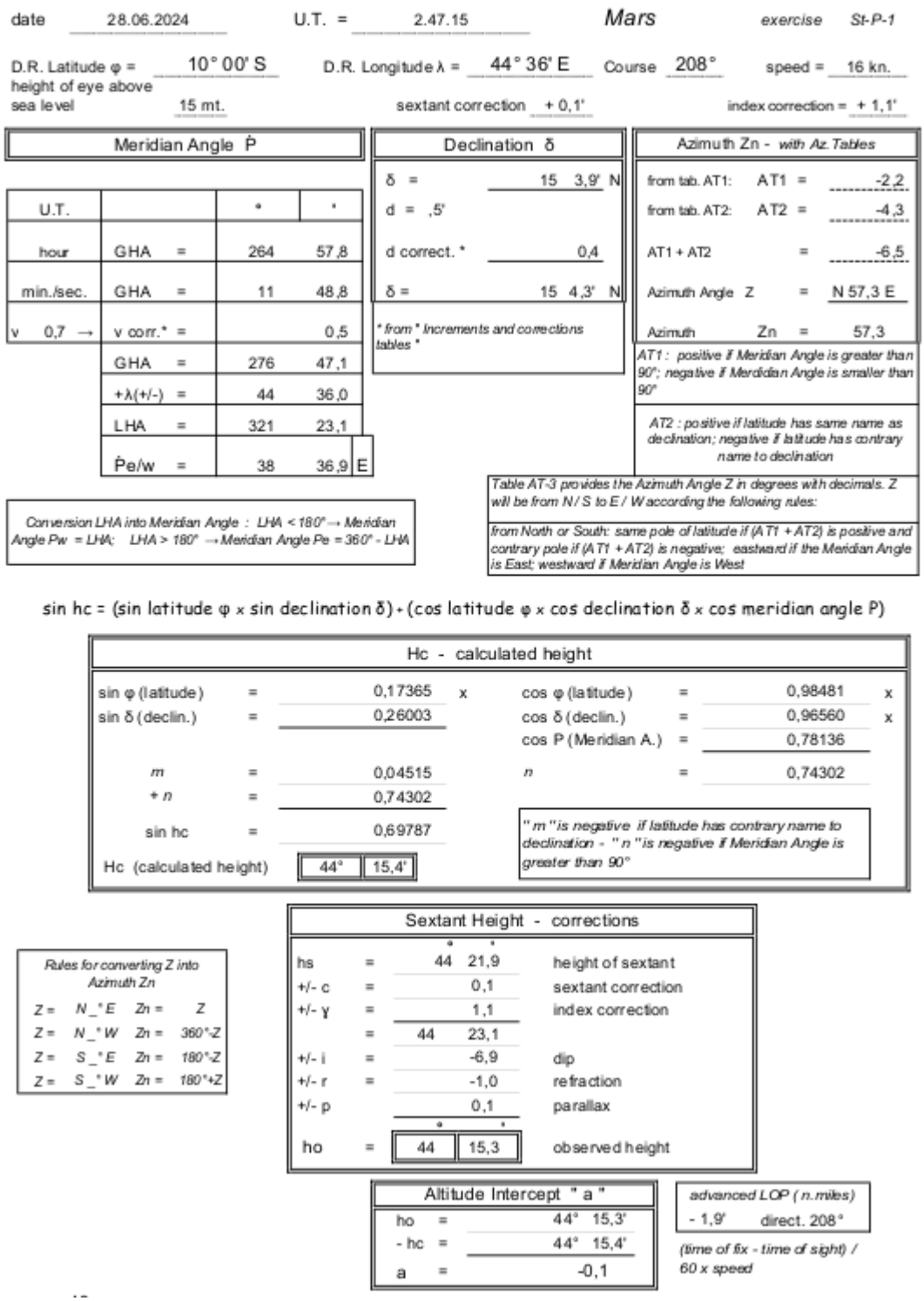
sin h = (sin φ x sin δ) + (cos φ x cos δ x cos P)

sin φ *latitude*	0,17365	0,17365
x sin δ *declination*	0,83970	0,17342
= m	0,14581	0,03011
cos φ *latitude*	0,98481	0,98481
x cos δ *declination*	0,54305	0,98485
x cos P *meridian angle*	0,91845	0,81185
= n	0,49119	0,78741

" m " is negative if latitude has contrary name to declination - " n " is negative if meridian angle is greater than 90°

m +/- n (sin h)	0,63700	0,75730
hc *(calculated height)*	39 34,1	49 13,6
hs	39 45,0	49 16,7
+c sextant correction	0,1	0,1
+γ index correction	1,1	1,1
	39 46,2	49 17,9
+ dip	-6,9	-6,9
+ refraction	-1,2	-0,8
ho *(observed height)*	39 38,1	49 10,2
ho *(observed height)*	39 38,1	49 10,2
- hc *(calculated height)*	39 34,1	49 13,6
Intercept " a "	**+ 4,0**	**- 3,4**
*n.miles * for advanced LOP*	*0*	*- 0,8*

Exercice 3.3 Sight reduction Stars & planets '1/3



Exercice 3.3 - Stars & planet star reduction

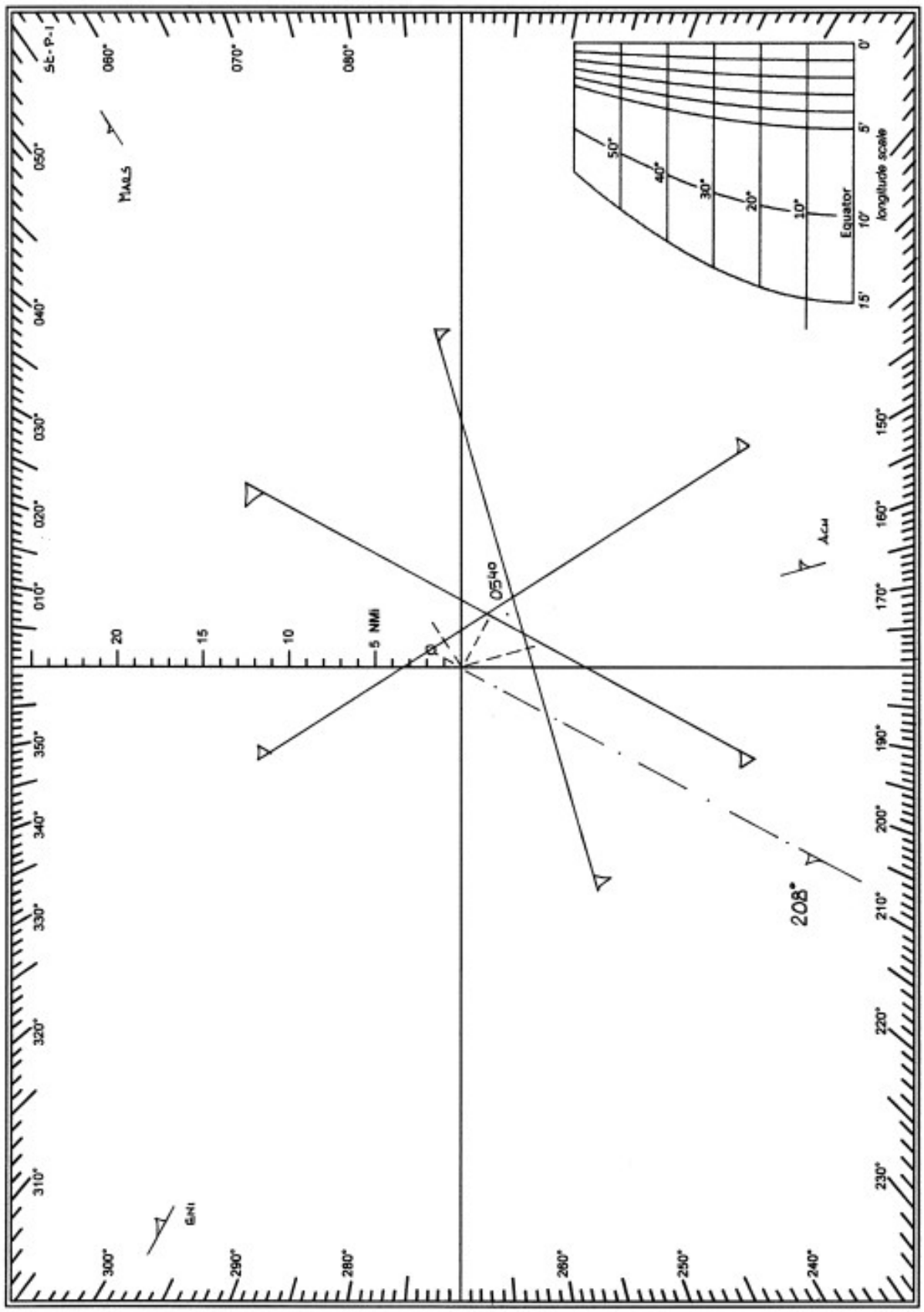


Illustration 4: Exercice 3.3 - sight reduction stars & planet (3/3)

Exercice 3.4 Sight reduction stars (ST7)

St-7

North Atlantic Ocean date 28.06.2024 Zone 0

Latitude φ 50° 03' N watch correction = - 4 sec. fix at : 03.25 Local Time
Longitude λ 09° 02' W course = 143° speed = 13 kn
dip 24 mt. sextant correct. + 0,3' index correction = - 1,8'

Star	Capella	Alpheratz	Altair	Vega	Kochab
Watch	03h 20m 08s	03.22.12	03.25.04	03.27.15	03.30.24
U.T.	03 20 04	03 22 08	03 25 00	03 27 11	03 30 20
declination δ =	46 01,3 N	29 13,4 N	8 55,9 N	38 48,3 N	74 03,5 N
GHA - Aries ♈ - hr.	321 42,4	321 42,4	321 42,4	321 42,4	321 42,4
increment (min/sec) - ♈	5 01,8	5 32,9	6 16,0	6 48,9	7 36,3
GHA - Aries ♈	326 44,2	327 15,3	327 58,4	328 31,3	329 18,7
+λ (long. E+ W-)	9 02,0	9 02,0	9 02,0	9 02,0	9 02,0
LHA - Aries ♈	317 42,2	318 13,3	318 56,4	319 29,3	320 16,7
SHA	280 23,0	357 35,2	62 00,1	80 33,1	137 19,0
LHA - Star	238 05,2	315 48,5	20 56,5	40 02,4	97 35,7

Conversion LHA into Meridian Angle : LHA < 180° → Meridian Angle Pw = LHA; LHA > 180° → Meridian Angle Pe = 360° - LHA

Meridian Angle (P̂e-P̂w)	121 54,8 E	44 11,5 E	20 56,5 W	40 02,4 W	97 35,7 W
from Azimuth Tables :					
AT1	7,4	-12,3	-31,2	-14,2	1,6
AT2	12,2	8,0	4,4	12,5	35,3
AT1 + AT2	19,6	-4,3	-26,8	-1,7	36,9
Z (Azimuth Angle)	N 38,4 E	S 74,7 E	S 30,2 W	S 83,7 W	N 22,9 W
Zn (Azimuth)	**38,4**	**105,3**	**210,2**	**263,7**	**337,1**

Rules for converting Z into Azimuth Zn :
Z = N_°E : Zn = Z *Z = N_°W : Zn = 360°-Z* *Z = S_°E : Zn = 180°-Z* *Z = S_°W : Zn = 180°+Z*

sin h = (sin φ x sin δ) + (cos φ x cos δ x cos P̂)

sin φ *latitude*	0,76661	0,76661	0,76661	0,76661	0,76661
x sin δ *declination*	0,71960	0,48822	0,15526	0,62667	0,96154
= m	0,55165	0,37427	0,11902	0,48041	0,73713
cos φ *latitude*	0,64212	0,64212	0,64212	0,64212	0,64212
x cos δ *declination*	0,69439	0,87272	0,98787	0,77928	0,27466
x cos P̂ *meridian angle*	0,52864	0,71701	0,93394	0,76560	0,13217
= n	0,23571	0,40181	0,59243	0,38310	0,02331

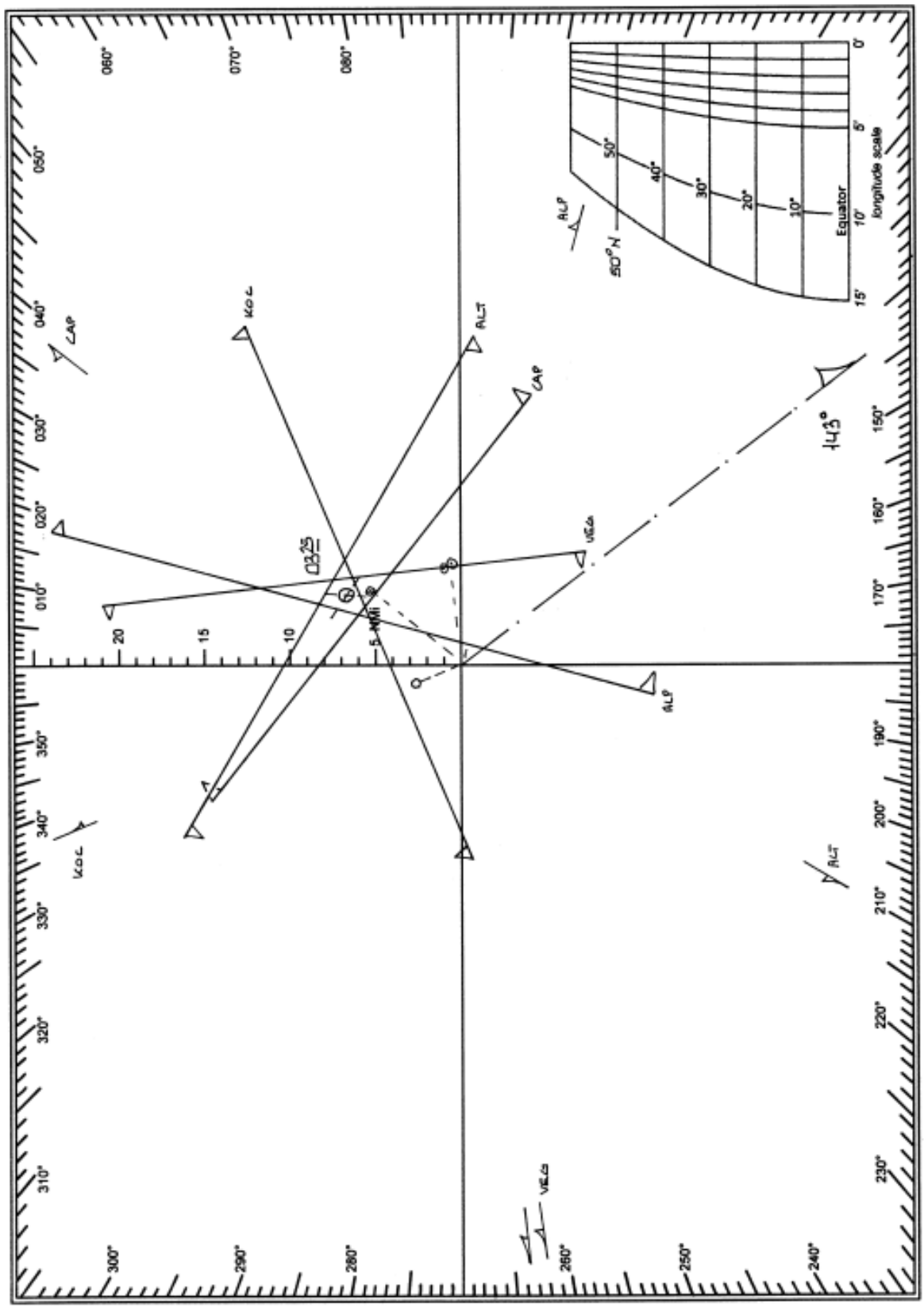
"m" is negative if latitude has contrary name to declination - "n" is negative if meridian angle is greater than 90°

m +/- n (sin h)	0,31594	0,77608	0,71145	0,86351	0,71382
hc *(calculated height)*	18° 25,1'	50° 54,2'	45° 21,2'	59° 42,8'	45° 32,8'
hs	18 45,0	51 06,0	45 23,4	59 47,7	45 46,8
+c sextant correction	0,3	0,3	0,3	0,3	0,3
+γ index correction	-1,8	-1,8	-1,8	-1,8	-1,8
	18 43,5	51 04,5	45 21,9	59 46,2	45 45,3
+ dip	-8,7	-8,7	-8,7	-8,7	-8,7
+ refraction	-2,9	-0,8	-1,0	-0,6	-0,9
ho *(observed height)*	18 31,9	50 55,0	45 12,2	59 36,9	45 35,7
ho *(observed height)*	18 31,9	50 55,0	45 12,2	59 36,9	45 35,7
- hc *(calculated height)*	18 25,1	50 54,2	45 21,2	59 42,8	45 32,8
Intercept "a"	**+ 6,8**	**+ 0,8**	**- 9,0**	**- 5,9**	**+ 2,9**
*n.miles * for advanced LOP*	*+ 1,1*	*+ 0,7*	*-*	*- 0,4*	*- 1,1*
direction = course	*143°*	*143°*	*143°*	*143°*	*143°*

** (time of fix - time of sight) / 60 x speed*

73

Calculs exercice 3.4



Tracé exercice 3.4