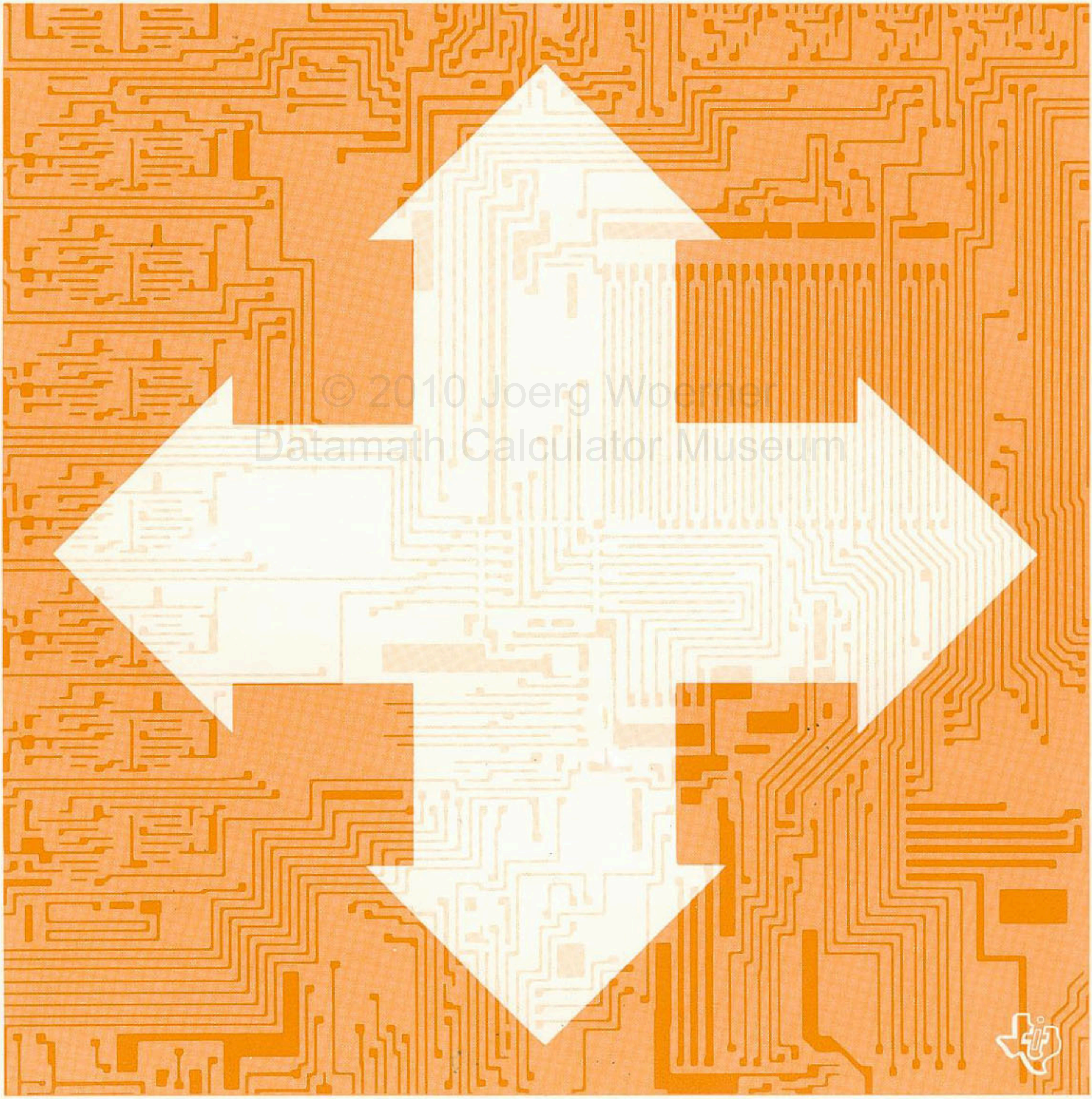
TI Programmable 58/59

Marine Navigation

Using the power of your *Solid State Software*™ module



ACKNOWLEDGMENT

Texas Instruments expresses sincere gratitude to Mr. Mortimer Rogoff for his contributions to the Coastal Navigation and Sailing & Tactics sections of the Navigation Library. The two sections are based on Mr. Rogoff's book, *Calculator Navigation*, published by W. W. Norton & Co., Inc.

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CALCULATOR NAVIGATION

Welcome to the world of calculator navigation! There are few skills as prized and envied as the ability to navigate a ship anywhere in the world. The programs described in this booklet are intended to aid the navigator whether he is an amateur yachtsman or a master mariner. A basic knowledge of the principles of navigation is assumed. However, material in this booklet may be supplemented with more detailed explanations found in such texts as: *The American Practical Navigator,* H.O. Pub. No. 9; *Dutton's Navigation and Piloting,* U.S. Naval Institute Press; and *Piloting/Navigation with the Pocket Calculator,* Tab Books.

USING THIS LIBRARY

Your calculator contains a removable *Solid State Software** module which places a large library with a variety of programs at your fingertips the instant you turn the calculator on. Each *Solid State Software* module contains up to 5000 program steps. Within seconds, you can replace the Master Library Module with an optional module, ranging from Applied Statistics to Aviation, to tailor your calculator to solve a series of professional problems with minimal effort. Your *Solid State Software* library does not take up valuable memory space needed for your own programs. In fact, you can call a library program as a subroutine from a program of your own without interruption.

After this brief introduction, you will find the description, user instructions, example problems and principal equations (when necessary) for each of the 30 programs in the Navigation Library. Each program is easily identified by the "NG" number in the upper corner of the page. This number corresponds with the call number you use to tell the calculator which program in the *Solid State Software* module you wish to use.

The primary reference point in this manual for each program is the User Instructions. These user instructions are also available for you in the handy pocket guide furnished with the library. The program description and sample problems should be used when you first run a program, to help you understand its full capabilities and limitations.

When using the *Solid State Software* programs as subroutines to your own programs, you will also want to check Register Contents for the program and check Program Reference Data provided in Appendix A.

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CALCULATOR NAVIGATION

REMOVING AND INSTALLING MODULES

The Master Library module is installed in the calculator at the factory, but can easily be removed or replaced with another. It is a good idea to leave the module in place in the calculator except when replacing it with another module. Be sure to follow these instructions when you need to remove or replace a module.

CAUTION

Be sure to touch some metal object before handling a module to prevent possible damage by static electricity.

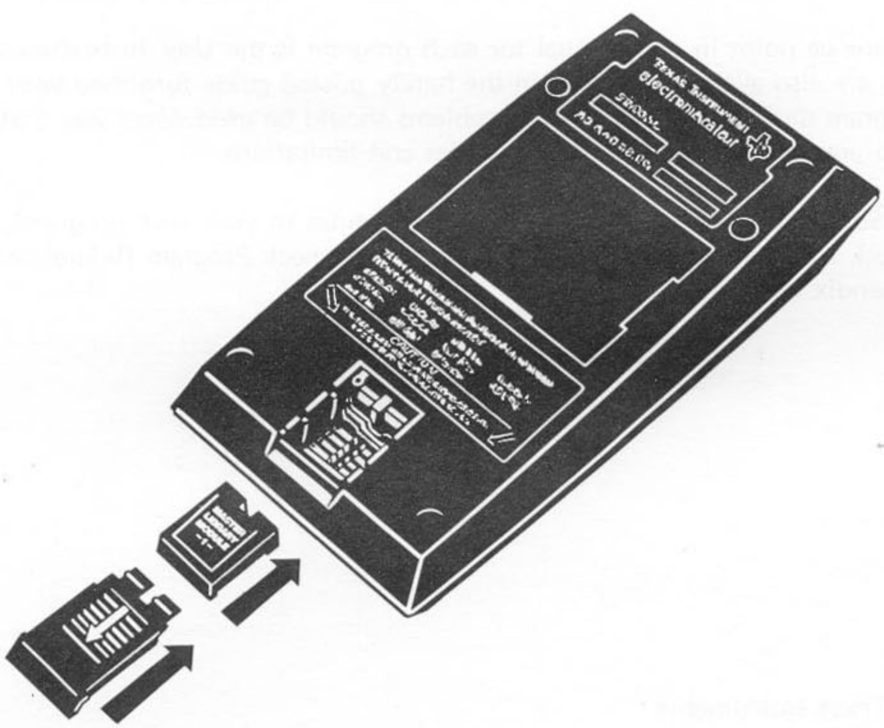
1. **Turn the calculator OFF.** Loading or unloading the module with the calculator ON may cause the keyboard or display to lock out. Also, shorting the contacts can damage the module or calculator.

2. Slide out the small panel covering the module compartment at the bottom of the back of the calculator. (See Diagram below.)

3. Remove the module. You may turn the calculator over and let the module fall out into your hand.

4. Insert the module, notched end first with the labeled side up into the compartment. The module should slip into place effortlessly.

5. Replace the cover panel, securing the module against the contacts.



Don't touch the contacts inside the module compartment as damage can result.

RUNNING *SOLID STATE SOFTWARE* PROGRAMS

The Navigation Library contains a variety of useful programs. To help you get started in using the *Solid State Software* programs install your Navigation Library module and follow through a couple of brief examples with us:

First of all, to eliminate any possibility of having any pending operations or previous results interferring with your current program, turn your calculator off for a couple of seconds, and back on again. This off/on sequence is the assumed starting point for each example problem in this manual. Now press the key sequence [2nd] [Pgm] [0] [1] [SBR] [=] to call and run the *"diagnostic"* program. Notice the display goes blank except for a faint "[" at the far left which indicates that calculations are taking place. After about 15 seconds, "5." will appear in the display. This displayed number indicates that the Navigation Library Module is installed in the calculator and that the calculator and module are operating properly. If the display is flashing after the diagnostic, refer to "In Case of Difficulty" in the SERVICE INFORMATION Appendix of the Owner's Manual.

The diagnostic program is a highly specialized one that works internally to check the operation of your software library. Once you're sure things are working, you can continue with another program in the library.

Assume that you know the two legs of the voyage you are about to take are 60 and 92 miles and you need to know the equivalent distances in nautical miles as well as the total distance. Program NG-30 is the appropriate program for this problem. Look through the nonmagnetic black and gold label cards* and find card NG-30 titled UNIT CONVERSIONS. Insert this card in the window above the top row of keys on your calculator. You can now see that the miles to nautical miles (mi. → n. mi.) conversion is performed by pressing the [B] key. Now to solve the problem.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 30		Call Program 30
60	[B]	52.1385744	Mi. → n. mi.
	[+]	52.1385744	
92	[B]	79.94581408	Mi. → n. mi.
	[=]	132.0843885	Total distance in n. mi.

If you have the optional PC-100A printer** you may obtain a printed record of any input and output data that you wish. The programs in this library include instructions for printing most of your data. Data that is printed is marked by a dagger "†" in the examples. You may print anything else you wish by pressing [2nd] [Prt] on your calculator, or the PRINT key on the printer.

To use the printer, mount your calculator on the PC-100A using the Calculator Mounting procedure in the PC-100A Owner's Manual. The switch called out in Step 2 should be set to "OTHER" for your calculator. Always turn the calculator and printer off before mounting or unmounting your calculator.

*The cards are supplied in a prepunched sheet. Carefully remove the individual cards from the sheet and insert them in the card carrying case for convenient storage.

**Note: The TI Programmable 58 and TI Programmable 59 will not operate on the PC-100 print cradle.

CALCULATOR NAVIGATION

Before you begin using the *Solid State Software* programs on your own, here are a few things to keep clearly in mind until you become familiar with your calculator.

1. Press [CLR] before running a program if you are not sure of the status of the calculator. (To be completely sure of calculator status, turn it off and on again — but remember that this clears the program memory.)

2. The programs in this library may not be run in a fix-decimal format. You may remove this format by pressing [INV] [2nd] [fix].

3. There is no visual indication of which *Solid State Software* program has been called. If you have any doubts, the safest method is to call the desired program with [2nd] [Pgm] mm, where mm is the two-digit program number. The calculator remains at this program number until another program is called, [RST] is pressed or the calculator is turned off.

4. A flashing display normally indicates an improper key sequence or that a numerical limit has been exceeded. When this occurs, always repeat the program sequence and check that each step is performed as directed by the User Instructions. Any unusual limits of a program are given in the User Instructions or related notes. The In Case of Difficulty portion of Appendix A in the Owner's Manual may be helpful in isolating a problem.

5. Some of the *Solid State Software* programs may run for several minutes depending on input data. If you desire to halt a running program, press the [RST] key. This is considered as an emergency halt operation which returns control to the main memory. A program must be recalled to be run again.

USING *SOLID STATE SOFTWARE* PROGRAMS AS SUBROUTINES

Any of the *Solid State Software* programs may be called as a subroutine to your own program in the main memory. Either of two program sequences may be used: 1) [2nd] [Pgm] mm (User Defined Key) or 2) [2nd] [Pgm] mm [SBR] (Common Label). Both send the program control to program mm, run the subroutine sequence, and then automatically return to the main program without interruption. Following [2nd] [Pgm] mm with anything other than [SBR] or a user-defined key is not a valid key sequence and can cause unwanted results.

It is very important to consider the Program Reference Data in Appendix A for any program called as a subroutine. You must plan and write your own program such that the data registers, flags, subroutine levels, parentheses levels, T-register, angular mode, etc., used by the called subroutine are allowed for in your program. In addition, a Register Contents section of each program description provides a guide to determine where data is or must be located to run the program.

A sample program that calls a *Solid State Software* program as a subroutine is provided in the *PROGRAMMING CONSIDERATIONS* section of the Owner's Manual.

If you need to examine and study the content of a *Solid State Software* program, you can download as described in the following paragraph.

DOWNLOADING *SOLID STATE SOFTWARE* PROGRAMS

If you need to examine a *Solid State Software* program, it can be downloaded into the main program memory.* This allows you to single step through a program in or out of the learn mode. It also allows using the program list or trace features of the optional printer. The only requirement for downloading a *Solid State Software* program is that the memory partition be set so there is sufficient space in the main program memory to receive the downloaded program. The key sequence to download a program is [2nd] [Pgm] mm [2nd] [Op] 09, where mm is the program number to be downloaded. This procedure places the requested program into program memory beginning at program location 000. The downloaded program writes over any instructions previously stored in that part of program memory. Remember to press [RST] before running or tracing the downloaded program.

Any program in the Navigation Library Module may be downloaded with your calculator set at the partitioning established when you first turn it on. If you need to change this partitioning see Appendix A for individual program requirements.

PROGRAM DESIGN NOTES

All directions (courses, headings, bearings, azimuths, etc.) are entered and displayed in decimal degrees. Position coordinates and celestial data (declination, GHA, etc.) appear in either the degree-minute-second or degree-minute-decimal minute format. (See the appropriate sections for the exact form.

All times are based on the 24 hour clock and must be in the same time zone. Using GMT in programs where time is a factor (required for celestial programs) is advised. In general, times are entered and displayed in the hour-minute-second format (HH.MMSS).

Occasionally, times, position coordinates, and other data may be displayed with 60 in the seconds position. Such outputs should simply be interpreted as full minutes. Note that when data is displayed in either the hour-minute-second or degree-minute-second format digits past the fourth decimal place are actually the fractional portion of the second.

Latitudes, longitudes, compass corrections, and celestial data are represented by positive values if north or west and are negative if south or east. This convention is easily recalled by remembering that traditionally, north is placed above south, and keeping in mind the phrase "east is least and west is best."

While every effort has been made to ensure the accuracy of these programs, in the final analysis, the navigator must assess the program results in light of all available information. Program output that clearly does not square with the other data on hand should be treated with caution. TI's programmable calculators, as powerful computational instruments, can aid the navigator by relieving him of considerable drudgery, but they can never relieve him of the obligation to exercise his own judgement.

*Unless the library is a protected, special-purpose library.

NAVIGATION LIBRARY DIAGNOSTIC

This program performs the following functions separately.

1. Diagnostic/Library Module Check
2. Linear Regression Initialization

Diagnostic/Library Module Check

This routine checks the operation of your calculator and most of its functions, including conversion and statistics functions that are preprogrammed in the calculator, trigonometric functions, data register operations, program transfers, and comparisons. It also uses other navigation library programs to verify that the module is connected and operating correctly. If this diagnostic routine runs successfully, in approximately 15 seconds the number 5. will be displayed. If the calculator is attached to a PC-100A print cradle, the following will be printed:

```
NAVIGATION
     5.
```

If there is a malfunction in the calculator or the *Solid State Software* module, a flashing number will be displayed. Refer to Appendix A of the Owner's Manual for an explanation of the various procedures to be followed when you have difficulties.

When you simply want to know which of your *Solid State Software* modules is in the calculator without physically looking at it, you can call the Library Module check portion of the routine directly. If the Navigation Library Module is in the calculator, the number 5. will be displayed. This number is unique to the Navigation Library (other optional libraries use other identifying digits).

Linear Regression Initialization

This routine initializes the calculator for linear regression by clearing data registers R_{01} through R_{06} and the T-register. It should be used whenever linear regression or other built-in statistics functions are to be started. You can also use the routine at any time to clear these registers selectively without disturbing any other registers.

Solid State Software TI ©1977

NAVIGATION LIBRARY DIAGNOSTIC NG-01

DIAGNOSTIC: [SBR] [=]

LINEAR REGRESSION INITIALIZATION: [SBR] [CLR]

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Diagnostic/Module Check			
1a	Select Program		[2nd] [Pgm] 01	
1b	Run Diagnostic		[SBR] [=]	5.[1]
	or			
1c	Library Module Check		[SBR] [2nd] [R/S]	5.[2]
	Initialize Linear Regression			
2a	Select Program		[2nd] [Pgm] 01	
2b	Initialize Linear Regression		[SBR] [CLR]	0.

NOTES:
1. This output is obtained if the calculator is operating properly.
2. The number 5. indicates the Navigation Library.
3. The Navigation Library programs are numbered 1 through 30. Program number 0 is the calculator's program memory.

Example 1:

Diagnostic

PRESS	DISPLAY	OPTIONAL PRINTOUT
[2nd] [Pgm] 01		
[SBR] [=]	5.	NAVIGATION
		5.

Example 2:

Library Module Check

PRESS	DISPLAY	OPTIONAL PRINTOUT
[2nd] [Pgm] 01		
[SBR] [2nd] [R/S]	5.	NAVIGATION
		5.

Example 3:

Initialize Linear Regression

PRESS	DISPLAY
[2nd] [Pgm] 01	
[SBR] [CLR]	0.

Register Contents

R_{00}		R_{05}	L.R. Init	R_{10}		R_{15}		R_{20}	
R_{01}	L.R. Init	R_{06}	L.R. Init	R_{11}		R_{16}		R_{21}	Used
R_{02}	L.R. Init	R_{07}		R_{12}		R_{17}			
R_{03}	L.R. Init	R_{08}		R_{13}		R_{18}			
R_{04}	L.R. Init	R_{09}		R_{14}		R_{19}			

COASTAL NAVIGATION

The programs of this section are designed primarily for short range navigation where factors such as the current and vessel speed remain constant throughout the leg. Another limitation is that leg times must be less than 24 hours when using any program that computes the time on a leg or time between observations.

The **DEAD RECKONING** and **RHUMBLINE NAVIGATION** programs may be used for long range planning. For these programs coordinates are entered and displayed in the degree-minute-decimal minute (DDDMM.m) format. If your data is in seconds rather than decimal minutes, simply enter it in that form (DDDMM.SS) and press [2nd] [D.MS] before pressing the appropriate user defined key. The opposite conversion may be performed on program outputs by pressing [INV] [2nd] [D.MS].

The **LAT/LON** programs at the end of this section are for short range navigation only. Each requires that the **CHART INITIALIZATION (LAT/LON)** program be used to load constants applicable to the area being navigated. Latitude and longitude are entered and displayed in the degree-minute-second (DDD.MMSS) format. If your data is in decimal minutes, enter it in that form (DDDMM.m), press [INV] [2nd] [D.MS], *then* divide by 100, press [=], and press the appropriate user defined key. (Watch the decimal point!) These programs are limited in that they will generate incorrect answers if the international date line lies between navigational objects or vessel positions and cannot follow a course through a pole.

In the programs calling for magnetic variation and/or deviation, compass courses and bearings are entered and displayed. If you wish to make these conversions mentally, then enter zero or omit the step according to program instructions. However, all directions must then be entered using the same reference north and all output will be with respect to that reference direction.

When separate bearings are taken to fix a position, the bearings should differ by at least 10 degrees. Otherwise, gross errors may result as readings can only be accurate to the nearest degree at best. An angular separation near 90 degrees is ideal.

TIME-SPEED-DISTANCE WITH CURRENT SAILING

This program is actually three routines in one, the first of which operates independently of the remaining two.

TIME-SPEED-DISTANCE

Given any two of the three quantities time sailed (Δt), speed made good (SMG), and distance sailed (Dist), this routine is capable of finding the third value. Varying forms of the basic equation Dist = SMG $\times$ Δt are used in calculations.

PLANNING WITH CURRENT SAILING

This routine may be used to plan a trip of multiple legs. Given the expected speed over the bottom (or the desired time of arrival), the distance of the leg, and the departure or starting time of the leg, the calculator will determine the estimated time of arrival (or the speed to make good) and the time of each leg while keeping track of the cumulative distance and time as well. Aside from the time-speed-distance equations above, ETA = ETD + Δt is the only formula used by this routine.

Once the above entries have been made (computation is necessary only when SMG is not entered), the true course to steer (C_t) and the necessary speed through the water (S) may be found by entering the drift (Dr) and set (St) of the current along with the course to make good.

C_t and S are derived from the vector equation

$$\vec{V} = \overrightarrow{VMG} - \overrightarrow{Cr}$$

where:

$\overrightarrow{VMG}$ has magnitude SMG and direction CMG,

$\overrightarrow{Cr}$ has magnitude Dr and direction St, and

$\vec{V}$ has magnitude S and direction C_t.

Solid State Software				TI ©1977
CURRENT SAILING				NG-02
INIT		Dr, St	CMG→Ct; S	ATA; →tD; Δt
ETD	Δtn	SMG	DIST	→ETA

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 02	
2	Select degree mode.		[2nd] [Deg]	
	TIME-SPEED-DISTANCE			
3	Initialize.		[2nd] [A′]	0.
4	Enter time interval and speed made good to calculate distance.	Δt (HH.MMSS) SMG (knots)	[B] [C] [D]	0. 0. Dist (nau. mi.)
	OR			
5	Enter time interval and distance to calculate SMG .	Δt (HH.MMSS) Dist (nau. mi.)	[B] [D] [C]	0. 0. SMG (knots)
	OR			
6	Enter distance and speed made good to calculate time.	Dist (nau. mi.) SMG (knots)	[D] [C] [B]	0. 0. Δt (HH.MMSS)
7	Display: time, SMG, Dist.		 [B] [B] [C] [C] [D] [D]	 Δt (HH.MMSS) SMG (knots) Dist (nau. mi.)
	PLANNING			
8	Initialize		[2nd] [A′]	0.
9	Enter ETD.	ETD (HH.MMSS)	[A]	ETD (HH.hh)
10	Enter speed to make good.	SMG (knots)	[C]	0.
11	Enter leg distance.	Dist (nau. mi.)	[D]	0.
12	Calculate ETA.		[E]	ETA (HH.MMSS)
13	Compute.		[2nd] [E′]	ETA
14a	Display total distance		[R/S]	tD (nau. mi.)
14b	and time (optional).		[R/S]	Δt (HH.MMSS)
15	Display leg time (optional).		[B] [B]	Δt_n (HH.MMSS)
	Return to step 10 for next leg.			
	OR			
16	Enter ETD.	ETD (HH.MMSS)	[A]	ETD (HH.hh)
17	Enter leg distance.	Dist (nau. mi.)	[D]	0.
18	Enter ATA and compute.	ATA (HH.MMSS)	[2nd] [E′]	ATA (HH.MMSS)
19a	Display total distance		[R/S]	tD (nau. mi.)
19b	and time (optional).		[R/S]	Δt (HH.MMSS)
20	Display leg time (optional).		[B] [B]	Δt_n (HH.MMSS)
21	Display SMG		[C] [C]	SMG (knots)
	Return to step 17 for next leg.			

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	PLANNING WITH CURRENT SAILING To find the speed and true course to steer through the water for a leg, insert the following between steps 10 and 11 (or 19 and 20).			
22a	Enter drift and	Dr (knots)	[2nd] [C′]	Prev. Dr (knots)
22b	set of current.	St (DDD.dd)	[2nd] [C′]	Prev. St (DDD.dd)
23a	Enter CMG to find true course to steer	CMG (DDD.dd)	[2nd] [D′]	C_t (DDD.dd)
23b	and required speed.		[R/S]	S (knots)

NOTES:
1. To correct an erroneous entry, simply reenter. Data not causing immediate computation may be entered in any order providing both parts of a step are performed in sequence.
2. Steps 22 and 23 may be performed any time after SMG has been entered or calculated.
3. If any value to be entered is zero, enter zero.

EXAMPLE: How long will it take to make good a distance of 115 nautical miles at a speed of 22 knots?

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 02		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [A′]	0.	Initialize
22†	[C]	0.	SMG
115†	[D]	0.	Dist
	[B]	5.133818182†	Δt (HH.MMSS)

† Printed if PC-100A is connected.

EXAMPLE: Planning to make good a speed of 15 knots on the first leg (25 nautical miles) and 19 on the second (13 nautical miles), you intend to depart at 17:32. Find the ETA and time for each leg as well as the total time and distance.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 02		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [A']	0.	Initialize
17.32†	[A]	17.53333333	ETD
15†	[C]	0.	SMG
25†	[D]	0.	Dist
	[E]	19.12†	ETA
	[2nd] [E']	19.12†	ATA (HH.MMSS)
	[B] [B]	1.4†	Δt_1 (HH.MMSS)
19†	[C]	0.	SMG
13†	[D]	0.	Dist
	[E]	19.53031579†	ETA
	[2nd] [E']	19.53031579†	ATA (HH.MMSS)
	[R/S]	38.†	tD
	[R/S]	2.21031579†	Δt (HH.MMSS)
	[B] [B]	0.41031579†	Δt_2 (HH.MMSS)

EXAMPLE: Departing at 8:20, you wish to complete the first leg (25 nautical miles) at 10:35 and the second (13 nautical miles) at 11:30. Determine the total time and distance and the speed to make good for each leg.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 02		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [A']	0.	Initialize
8.2†	[A]	8.333333333	ETD_1
25†	[D]	0.	$Dist_1$
10.35	[2nd] [E']	10.346†	ATA_1
	[B] [B]	2.15†	Δt_1 (HH.MMSS)
	[C] [C]	11.11111111†	SMG
13†	[D]	0.	$Dist_2$
11.3	[2nd] [E']	11.3†	ATA_2
	[R/S]	38.†	tD
	[R/S]	3.1†	Δt (HH.MMSS)
	[B] [B]	0.55†	Δt_2 (HH.MMSS)
	[C] [C]	14.18181818†	SMG

† Printed if PC-100A is connected.

EXAMPLE: The true course to make good for the first leg above is 213°. You know the current to set 175° at 2 knots. Find the necessary speed and course through the water.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 02		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [A']	0.	Initialize
8.2†	[A]	8.333333333	ETD
25†	[D]	0.	Dist
10.35	[2nd] [E']	10.346†	ATA
2†	[2nd] [C']	0.*	Dr
175†	[2nd] [C']	0.*	St
213	[2nd] [D']	220.3582237†	CMG→C_t (DDD.dd)
	[R/S]	9.614264921†	S

Register Contents

R_{00}	R_{05}	R_{10}	R_{15}	R_{20} Used
R_{01} ETD	R_{06} Dr	R_{11}	R_{16}	R_{21} Used
R_{02} Dist	R_{07} St	R_{12} SMG	R_{17}	
R_{03} tD	R_{08}	R_{13}	R_{18}	
R_{04}	R_{09}	R_{14} Δt_n	R_{19} Δt	

† Printed if PC-100A is connected.

*Previous entries will be displayed if corrections are made or another problem has been run.

DISTANCE SHORT OF, BEYOND, OR TO HORIZON

There are five distances which may be found by this program. Each distance is displayed in nautical miles and may be converted to feet if desired. The possible computations are:

D_h = the distance to apparent horizon for a given height of the eye,

D_v = the distance of visibility of an object of known height at a given height of the eye,

D_b = the distance to an object of known height, the base of which is obscured by the horizon when the vertical angle between the top of the object and the apparent horizon is measured by a sextant,

D_d = the distance to an object when the vertical angle between its waterline and the apparent horizon (depression angle) has been measured by a sextant, and

D = the distance to an object of known height when the vertical angle between its waterline and top (subtended angle) is measured with a sextant.

The sextant altitude is corrected for eye height and index error by the program.

The height of an object (in feet) may also be found provided its subtended angle and distance (in feet) from the observation point are known by the observer.

The equations used for computation are:

$$D_h = 1.144\sqrt{EYE}, \qquad D_v = 1.144\,(\sqrt{EYE} + \sqrt{H}),$$

$$D_b = \sqrt{\left(\frac{\tan Ho}{0.000246}\right)^2 + \frac{H - EYE}{0.74736}} - \frac{\tan Ho}{0.000246}, \qquad D_d = \frac{EYE}{\tan\,(Hs + IC + (0.97\sqrt{EYE}/60)},$$

$$D = H/\tan\,(Hs + IC), \text{ and} \qquad H = D \tan\,(Hs + IC).$$

The variables used above are:

H = object height,

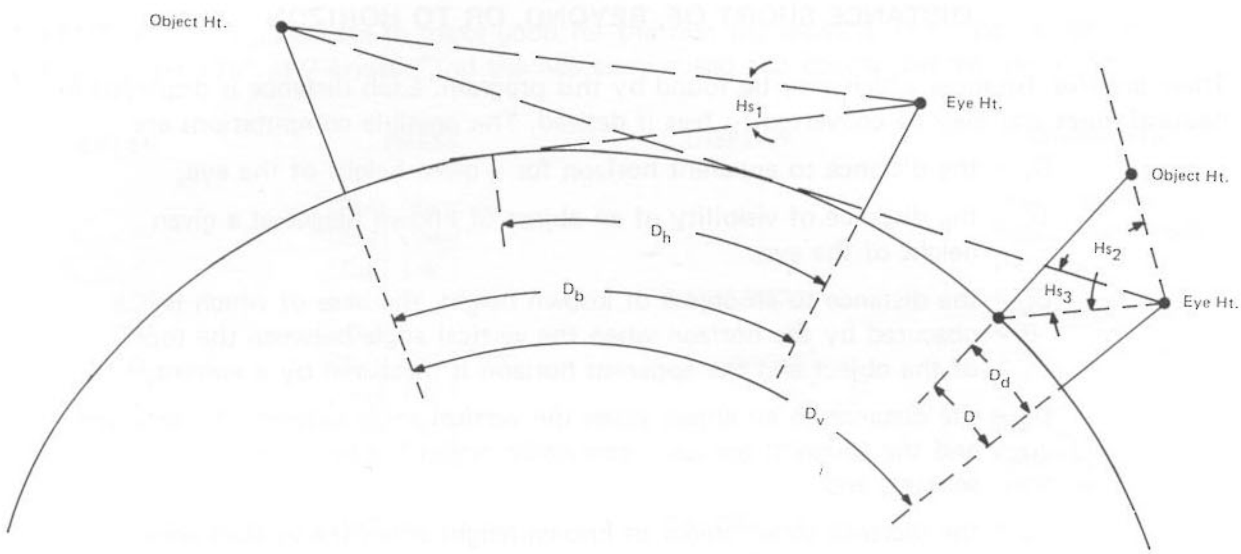
EYE = eye height,

$Ho = Hs + IC - (0.97\sqrt{EYE}/60)$,

Hs = sextant altitude, and

IC = index correction.

REMARK: A small vertical sextant altitude ($Hs < 10'$) between object and horizon may yield unreliable results due to atmospheric conditions.



In the figure above, Hs_1 is used to find D_b, Hs_2 corresponds to D and Hs_3 determines D_d. D_h and D_v do not require sextant measurements.

Solid State Software TI ©1977

HORIZON DISTANCES				NG-03
H	IC	→D_v; ft	→D_d; ft	D→H
EYE	Hs	→D_h; ft	→D_b; ft	→D; ft

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 03	
2	Select degree mode.		[2nd] [Deg]	
	Find D_h			
3	Enter eye height.	EYE (ft.)	[A]	EYE (ft)
4	Display D_h in nau. mi., in feet (optional).		[C] [R/S]	D_h (nau. mi.) D_h (ft.)
	Find D_v			
5	Enter eye height.	EYE (ft.)	[A]	EYE (ft.)
6	Enter object height.	H (ft.)	[2nd] [A']	H (ft.)
7	Display D_v in nau. mi., in feet (optional).		[2nd] [C']	D_v (nau. mi.) D_v (ft.)
	Find D_b			
8	Enter eye height.	EYE (ft.)	[A]	EYE (ft.)
9	Enter object height.	H (ft.)	[2nd] [A']	H (ft.)
10	Enter sextant altitude above horizon.	Hs (DDMM.m)	[B]	Hs (DD.dd)
11	Enter index correction.	IC (M.m)	[2nd] [B']	IC (.dd)
12	Display D_b in nau. mi., in feet (optional).		[D] [R/S]	D_b (nau. mi.) D_b (ft.)
	Find D_d			
13	Enter eye height.	EYE (ft.)	[A]	EYE (ft.)
14	Enter depression angle	Hs (DDMM.m)	[B]	Hs (DD.dd)
15	Enter index correction.	IC (M.m)	[2nd] [B']	IC (.dd)
16	Display D_d in nau. mi., in feet (optional).		[2nd] [D'] [R/S]	D_d (nau. mi.) D_d (ft.)
	Find D.			
17	Enter object height.	H (ft.)	[2nd] [A']	H (ft.)
18	Enter subtended angle.	Hs (DDMM.m)	[B]	Hs (DD.dd)
19	Enter index correction.	IC (M.m)	[2nd] [B']	IC (.dd)
20	Display D in nau. mi., in feet (optional).		[E] [R/S]	D (nau. mi.) D (ft.)
	Find object height.			
21	Enter subtended angle	Hs (DDMM.m)	[B]	Hs (DD.dd)
22	Enter index correction.	IC (M.m)	[2nd] [B']	IC (.dd)
23	Enter distance to object in feet and compute object height in feet.	D (ft.)	[2nd] [E']	H (ft.)

NOTES:

1. To convert nautical miles to feet at any time; press [C], enter quantity to be converted, and press [R/S] to display quantity in feet.
2. Data may be entered in any order provided immediate computation is not involved.
3. Any entry error may be corrected by keying in the proper value and pressing the appropriate user defined key.

EXAMPLE: You know that a lighthouse, the base of which is hidden by the horizon, stands 280 feet above sea level. The sextant reading is 23.4′ above the horizon at an eye height of 22 feet. The index correction required by the sextant is 1.2′. What is the distance to the lighthouse? to the horizon? Compute the visibility of the lighthouse for the above eye height.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 03		Select Program
	[2nd] [Deg]		Select Degree Mode
22†	[A]	22.	EYE
280†	[2nd] [A′]	280.	H
23.4	[B]	0.39†	Hs
1.2	[2nd] [B′]	0.02†	IC
	[D]	6.412908745†	D_b (nau. mi.)
	[C]	5.365835629†	D_h (nau. mi.)
	[2nd] [C′]	24.50861704†	D_v (nau. mi.)

EXAMPLE: The sextant altitude subtended by the base and top of a 53 foot light tower is 56.2′ and the depression angle is 19.8′. Your eye height is 22 feet and your sextant requires an index correction of −1.8′. Determine the distance to the tower by finding both D and D_d using only the required information.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 03		Select Program
	[2nd] [Deg]		Select Degree Mode
53†	[2nd] [A′]	53.	H
56.2	[B]	.9366666667†	Hs
1.8	[+/−] [2nd] [B′]	−0.03†	IC
	[E]	0.5511734098†	D (nau. mi.)
	[R/S]	3348.995779†	D (ft.)
22†	[A]	22.	EYE
19.8	[B]	0.33†	Hs
	[2nd] [D′] *	.5519797696†	D_d (nau. mi.)
	[R/S]	3353.895317†	D_d (ft.)

† Printed if PC-100A is connected.
*It is not necessary to reenter IC.

EXAMPLE: Determine the height of the light tower in the last example using D for the distance.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 03		Select Program
	[2nd] [Deg]		Select Degree Mode
56.2	[B]	.9366666667†	Hs
1.8	[+/–] [2nd] [B′]	–0.03†	IC
3349	[2nd] [E′]	53.0000668†	D → H (ft.)

Register Contents

R_{00} IC	R_{05}	R_{10}	R_{15} Used
R_{01} EYE	R_{06}	R_{11}	R_{16}
R_{02} H	R_{07}	R_{12}	R_{17}
R_{03} Hs	R_{08}	R_{13}	R_{18}
R_{04}	R_{09}	R_{14}	R_{19}

† Printed if PC-100A is connected.

VELOCITY NEEDED TO CHANGE RELATIVE POSITION

The speed and course necessary for a (maneuvering) vessel to change its position relative to a second (guide) vessel may be obtained from this program. The pilot must supply the speed and course of the guide vessel, the initial and desired distances and bearings from the guide vessel to the maneuvering vessel, and the time interval in which the maneuver is to be completed.

The required information is derived from the vector equation

$$\overrightarrow{V_m} = (\overrightarrow{P_2} - \overrightarrow{P_1})/\Delta t + \overrightarrow{V_g}$$

where:

$\overrightarrow{V_g}$ ($\overrightarrow{V_m}$) = the guide (maneuvering) vessel velocity vector with magnitude S_g (S_m) and direction C_{tg} (C_{tm}),

$\overrightarrow{P_1}$ ($\overrightarrow{P_2}$) = the position vector with magnitude D_1 (D_2) and direction B_{t1} (B_{t2}),

S_g = the speed of the guide vessel through the water,

S_m = the required speed of the maneuvering vessel,

C_{tg} = the true course of the guide vessel,

C_{tm} = the true course to be held by the maneuvering vessel,

D_1 = the initial distance between vessels,

D_2 = the desired distance between vessels,

B_{t1} = the initial true bearing from guide vessel to maneuvering vessel,

B_{t2} = the desired true bearing, and

Δt = the time allowed for the maneuver.

REMARK: If relative bearings are entered, they must be converted to true bearings by the formula: $B_t = B_r + C_{tg}$. The program will make this conversion on command only.

Solid State Software			TI ©1977	
VELOCITY TO CHANGE REL POSITION			NG-04	
	REL	REL		
S_g, C_{tg}	D_1, B_1	D_2, B_2	Δt	$\rightarrow S_m$; C_{tm}

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 04	
2	Select degree mode.		[2nd] [Deg]	
3a 3b	Enter speed of guide vessel and its true course.	S_g (knots) C_{tg} (DDD.dd)	[A] [A]	Prev. S_g (knots) Prev. C_{tg} (DDD.dd)
4a 4b	Enter initial distance and bearing between vessels.	D_1 (nau. mi.) B_1 (DDD.dd)	[B] [B]	Prev. D_1 (nau. mi.) Prev. B_1 (DDD.dd)
5	IF B_1 IS RELATIVE convert to true bearing.		[2nd] [B′]	B_{t1} (DDD.dd)
6a 6b	Enter desired distance and bearing between vessels	D_2 (nau. mi.) B_2 (DDD.dd)	[C] [C]	Prev. D_2 (nau. mi.) Prev. B_2 (DDD.dd)
7	IF B_2 IS RELATIVE convert to true bearing.		[2nd] [C′]	B_{t2} (DDD.dd)
8	Enter allowed time.	Δt (HH.MMSS)	[D]	Δt (HH.hh)
9	Compute required speed and true course of maneuvering vessel.		[E] [R/S]	S_m (knots) C_{tm} (DDD.dd)

NOTES:
1. The data for Steps 3, 4, and 6 may be entered or corrected by reentry in any order (part b must follow a). In making a correction, both parts of the step must be performed in sequence even if only one value was entered incorrectly.
2. If the value of any data is zero, enter zero.

EXAMPLE: The guide vessel is proceding along a true course of 215° at a speed of 12 knots. You wish to change your position from 15 nautical miles due west of the guide (270° true) to 17 miles dead ahead (0° relative) in 1 hour and 30 minutes. What course and speed should you maintain?

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 04		Select Program
	[2nd] [Deg]		Select Degree Mode
12†	[A]	0.*	S_g
215†	[A]	0.*	C_{tg}
15†	[B]	0.*	D_1
270†	[B]	0.*	B_{t1}
17†	[C]	0.*	D_2
0†	[C]	0.*	B_{r2}
	[2nd] [C']	215.†	$B_{r2} \rightarrow B_{t2}$
1.3†	[D]	1.5	Δt
	[E]	19.41070428†	S_m
	[R/S]	190.0384179†	C_{tm} (DDD.dd)

Register Contents

R_{00}	R_{05}	R_{10}	R_{15}	R_{20} Used
R_{01} B_1	R_{06}	R_{11}	R_{16}	R_{21} Used
R_{02} D_1	R_{07}	R_{12}	R_{17} S_g	R_{22} Used
R_{03} B_2	R_{08}	R_{13}	R_{18} C_{tg}	
R_{04} D_2	R_{09}	R_{14} Δt	R_{19}	

* If another example has been calculated or if corrections are made, the previous entry will be displayed.
† Printed if PC-100A is connected.

VELOCITY, VMG, AND CURRENT VECTORS

Given any two of the following;

1. drift (Dr) and set (St) of the current,
2. speed (S) and magnetic course (C_m) steered through the water, and
3. speed (SMG) and course (CMG) made good;

calculation of the remaining pair of values is made possible by this program.

The velocity made good vector is the vector sum of the velocity and current vectors. The unknown values are derived from this equation.

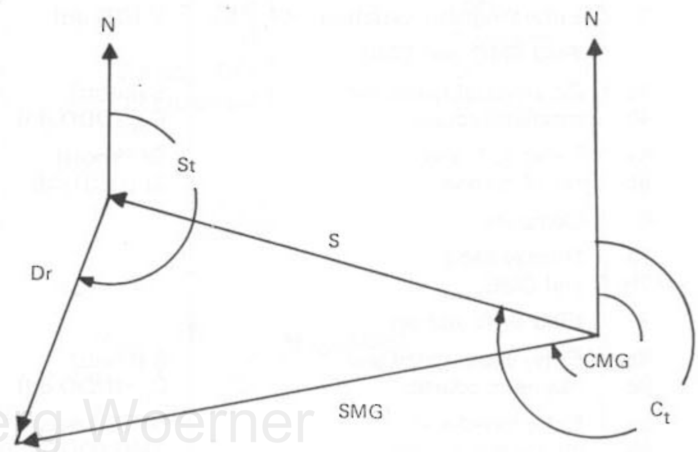
$$\overrightarrow{VMG} = \vec{V} + \overrightarrow{Cr}$$

where:

$\overrightarrow{VMG}$ has magnitude SMG and direction CMG,

$\vec{V}$ has magnitude S and direction C_t, and

$\overrightarrow{Cr}$ has magnitude Dr and direction St.



REMARK:

If the result is the zero vector, the display will flash.

Solid State Software				TI ©1977
VEL, VMG, AND CR VECTORS				NG-05
V				
S, Cm	Dr, St	SMG, CMG		COMPUTE

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 05	
2	Select degree mode.		[2nd] [Deg]	
3	Enter magnetic variation (+W, −E).	V (DD.dd)	[2nd] [A′]	V (DD.dd)
	Find SMG and CMG			
4a	Enter vessel speed and	S (knots)	[A]	Prev. S (knots)
4b	magnetic course.	C_m (DDD.dd)	[A]	Prev. C_m (DDD.dd)
5a	Enter drift and	Dr (knots)	[B]	Prev. Dr (knots)
5b	set of current.	St (DDD.dd)	[B]	Prev. St (DDD.dd)
6	Compute.		[E]	0.
7a	Display SMG		[C]	SMG (knots)
7b	and CMG.		[R/S]	CMG (DDD.dd)
	Find drift and set.			
8a	Enter vessel speed and	S (knots)	[A]	Prev. S (knots)
8b	magnetic course.	C_m (DDD.dd)	[A]	Prev. C_m (DDD.dd)
9a	Enter speed and	SMG (knots)	[C]	Prev. SMG (knots)
9b	course made good.	CMG (DDD.dd)	[C]	Prev. CMG (DDD.dd)
10	Compute.		[E]	0.
11a	Display drift and		[B]	Dr (knots)
11b	set of current.		[R/S]	St (DDD.dd)
	Find speed and C_m.			
12a	Enter drift and	Dr (knots)	[B]	Prev. Dr (knots)
12b	set of current.	St (DDD.dd)	[B]	Prev. St (DDD.dd)
13a	Enter speed and	SMG (knots)	[C]	Prev. SMG (knots)
13b	course made good.	CMG (DDD.dd)	[C]	Prev. CMG (DDD.dd)
14	Compute.		[E]	0.
15a	Display speed and		[A]	S (knots)
15b	magnetic course.		[R/S]	C_m (DDD.dd)

NOTES:

1. Major data entry steps (i.e., 4 and 5, not 4a and 4b) may be performed in any order
2. Data may be corrected any time previous to computation by reentry; however, both parts of the step (a and b) must be performed in their proper sequence regardless of whether one or both of the entered values is to be changed.
3. Printer usage is optional.
4. If the value of any data is zero, enter zero.

EXAMPLE: Steering a magnetic course of 100° at a speed of 6 knots through the water, your CMG is 070° and your speed over the bottom is 4 knots. Knowing that the magnetic variation is 13.75°W, find the drift and set of the current.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 05		Select Program
	[2nd] [Deg]		Select Degree Mode
13.75†	[2nd] [A']	13.75	V
6†	[A]	0.*	S
100†	[A]	0.*	C_m
4†	[C]	0.*	SMG
70†	[C]	0.*	CMG
	[E]	0.	Compute
	[B]	2.432613202†	Dr
	[R/S]	293.6454366†	St (DDD.dd)

Register Contents

R_{00}	R_{05}	R_{10}	R_{15}	R_{20} Used
R_{01}	R_{06} Dr	R_{11}	R_{16} V	
R_{02}	R_{07} St	R_{12} SMG	R_{17} S	
R_{03}	R_{08}	R_{13} CMG	R_{18} C_m	
R_{04}	R_{09}	R_{14}	R_{19}	

*Previous entries will be displayed if corrections are made or if another example has been run.
† Printed if PC-100A is connected.

COURSE TO STEER AND SMG (PLANNING)

Given the desired course to make good (CMG), the vessel speed through the water (S), the drift (Dr) and set (St) of the current, and the magnetic variation (V) and deviation (De), this program will compute the compass course to steer and the resulting speed made good.

An additional function of this program is the calculation of the time required to sail a specified distance.

The primary equations used by the program are

$$C_t = CMG - \sin^{-1}\ [(Dr/S) \sin (St - CMG)]$$

and

$$SMG = S \cos (C_t - CMG) + Dr \cos (St - CMG).$$

REMARKS:

1. The drift must be less than the vessel speed.
2. The magnetic deviation may be disregarded in determining the course to steer.

Solid State Software				TI ©1977
COURSE TO STEER, SMG				NG-06
V			Dist → Δt	ts → ETA
S	CMG	Dr, St	→ Cm; De → Cc	→ SMG

USER INSTRUCTIONS

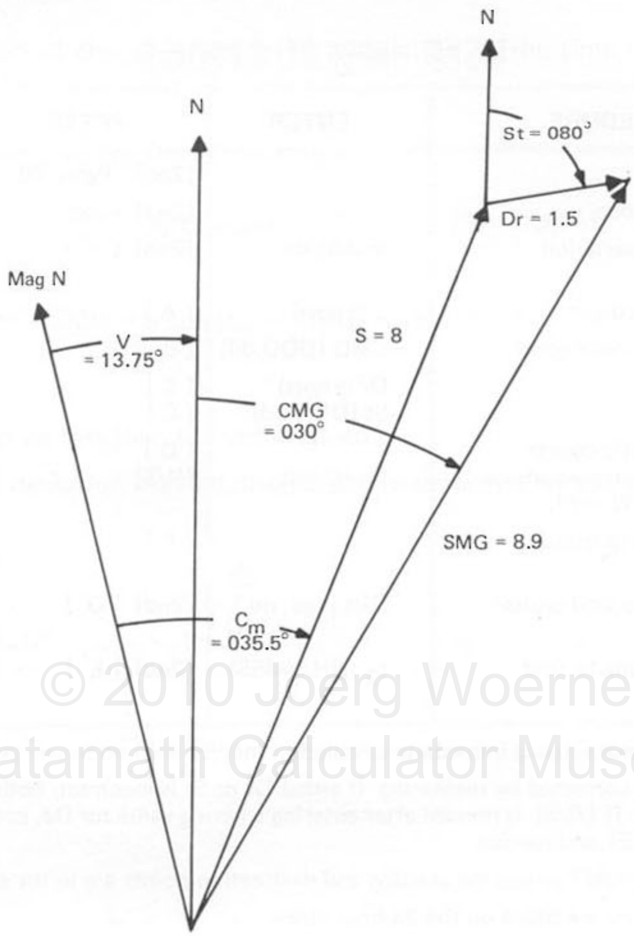
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 06	
2	Select degree mode.		[2nd] [Deg]	
3	Enter magnetic variation (+W, −E).	V (DD.dd)	[2nd] [A′]	V (DD.dd)
4	Enter vessel speed.	S (knots)	[A]	S (knots)
5	Enter course to make good.	CMG (DDD.dd)	[B]	CMG (DDD.dd)
6a 6b	Enter drift and set of current.	Dr (knots) St (DDD.dd)	[C] [C]	Prev. Dr (knots) Prev. St (DDD.dd)
7a 7b	Calculate magnetic course and correct to compass course if desired (De; +W, −E).	 De (D.dd)	[D] [R/S]	C_m (DDD.dd) C_c (DDD.dd)
8	Compute resulting speed made good.		[E]	SMG (knots)
9	Enter distance to find cruise time.	Dist (nau. mi.)	[2nd] [D′]	Δt (HH.MMSS)
10	Enter starting time to find arrival time.	t_S (HH.MMSS)	[2nd] [E′]	ETA (HH.MMSS)

NOTES:
1. Data entries not causing immediate calculation may be entered in any order (6b must follow 6a).
2. Data may be corrected by reentering. If either Dr or St is incorrect, both must be reentered in the proper order. If [R/S] is pressed after entering a wrong value for De, press [D] and reenter; if not, press [CE] and reenter.
3. Enter time in GMT unless the starting and destination points are in the same time zone.
4. All time entries are based on the 24-hour clock.
5. Use of printing unit is optional.
6. If the value of any data is zero, enter zero.

Register Contents

R_{00}	R_{05}	R_{10}	R_{15} Cm	R_{20} Used
R_{01}	R_{06} Dr	R_{11}	R_{16} V	
R_{02}	R_{07} St	R_{12} SMG	R_{17} S	
R_{03}	R_{08}	R_{13} CMG	R_{18} C_t	
R_{04}	R_{09}	R_{14}	R_{19}	

EXAMPLE: At a speed of 8 knots through the water, you desire to make good a course of 030° through a current having a set of 080° and a drift of 1.5 knots. Determine the compass course to steer and the resulting SMG. Starting at 23:17, what will be the run and arrival times if you make good a distance of 12.5 nautical miles. The magnetic variation is 13.75°W and the deviation is 4°E.



ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 06		Select Program
	[2nd] [Deg]		Select Degree Mode
13.75†	[2nd] [A′]	13.75	V
8†	[A]	8.	S
30†	[B]	30.	CMG
1.5†	[C]	0.*	Dr
80†	[C]	0.*	St
	[D]	35.49185346†	C_m (DDD.dd)
4†	[+/−] [R/S]	31.49185346†	De → C_c (DDD.dd)
	[E]	8.88122921†	SMG
12.5†	[2nd] [D′]	1.242686619†	Dist → Δt (HH.MMSS)
23.17†	[2nd] [E′]	.4126866189†	t_s → ETA (HH.MMSS)

*If another problem has been calculated or if corrections are made, previous entries will be displayed.
† Printed if PC-100A is connected.

DISTANCE OFF ONE OBJECT AND TIME OF NEAREST APPROACH

Given two observations of a single object, this program is designed to compute the distance made good (DMG) between observations, the distance off the object at the second observation point (D_2), the distance of nearest approach to the object (D_n), and the time of nearest approach (t_n). The list of additional data that must be supplied includes the vessel speed through the water (S), the compass course (C_c), the drift (Dr) and set (St) of the current, and the magnetic variation (V).

The velocity made good vector is the vector sum of the vessel velocity and current vectors ($\overrightarrow{VMG} = \vec{V} + \vec{Cr}$)

where:

$\overrightarrow{VMG}$ has magnitude SMG and direction CMG,

$\vec{V}$ has magnitude S and direction C_t, and

$\vec{Cr}$ has magnitude Dr and direction St.

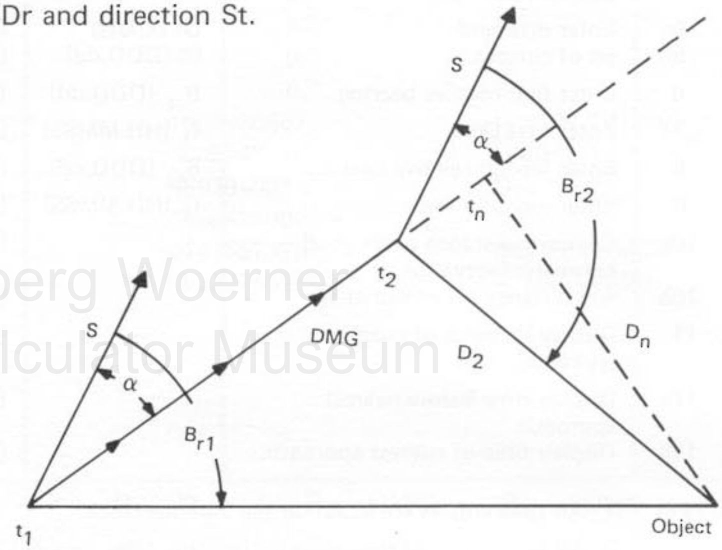
The required variables are derived from the input and the above, then:

$$DMG = SMG \times \Delta t,$$

$$D_2 = DMG \frac{\sin (B_{r1} - \alpha)}{\sin (B_{r2} - B_{r1})},$$

$$D_n = D_2 \sin (B_{r2} - \alpha),$$

$$\Delta t_n = D_2 \cos (B_{r2} - \alpha)/SMG,$$



and

$$t_n = t_2 + \Delta t_n.$$

Additional variables used in the above equations are:

$\Delta t = t_2 - t_1$,

t_1, t_2 = times of observations,

$\alpha = CMG - C_t$ and,

B_{r1}, B_{r2} = relative bearings to the object measured clockwise from the bow at t_1 and t_2.

REMARKS:

1. If $B_{r2} - B_{r1} = \pm 180°$, an incorrect answer will flash in the display register.
2. If the value of any data (other than De) is zero, enter zero.

Solid State Software		TI ©1977		
DIST OFF 1 OBJECT AND TNA				NG-07
V	Dr, St		→Dn	
S, Cc; De	Br	t	→DMG; D2	→Δtn; tn

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 07	
2	Select degree mode.		[2nd] [Deg]	
3	Enter magnetic variation (+W, −E).	V (DD.dd)	[2nd] [A′]	V (DD.dd)
4a	Enter vessel speed	S (knots)	[A]	S (knots)
4b	and compass course.	C_c (DDD.dd)	[A]	C_c (DDD.dd)
4c	Enter magnetic deviation if desired (+W, −E).	De (D.dd)	[R/S]	De (D.dd)
5a	Enter drift and	Dr (knots)	[2nd] [B′]	Prev. Dr (knots)
5b	set of current.	St (DDD.dd)	[2nd] [B′]	Prev. St (DDD.dd)
6	Enter first relative bearing.	B_{r_1} (DDD.dd)	[B]	Prev. B_{r_1} (DDD.dd)
7	Enter first time.	t_1 (HH.MMSS)	[C]	t_1 − prev t_2
8	Enter second relative bearing.	B_{r_2} (DDD.dd)	[B]	Prev. B_{r_2} (DDD.dd)
9	Enter second time.	t_2 (HH.MMSS)	[C]	Δt (HH.hh)
10a	Compute distance made good between observations		[D]	DMG (nau. mi.)
10b	and distance off object at t_2.		[R/S]	D_2 (nau. mi.)
11	Display distance of nearest approach.		[2nd] [D′]	D_n (nau. mi.)
12a	Display time before nearest approach.		[E]	Δt_n (HH.MMSS)
12b	Display time of nearest approach.		[R/S]	t_n (HH.MMSS)

NOTES:

1. All time entries are based on the 24-hour clock.
2. All times entered should be in the same zone (or GMT).
3. If t_n is displayed as a negative value, add 24 to obtain the correct result. If $t_n \geqslant 24$, subtract 24.
4. In entering data, Step 8(9) must follow Step 6(7).
5. Data may be corrected by reentry; however, if either of B_{r1} or B_{r2} (or t_1 or t_2) is to be changed, both must be reentered in the proper sequence. Also, if De must be corrected, both S and C_c must be reentered as well.
6. If Δt_n is displayed as a negative value, then t_n has already been passed.

EXAMPLE: At a speed of 6 knots, you are steering a compass course of 045°. The set of the current is 110° and the drift is 1 knot. At 13:00 the relative bearing to a lighthouse is 024° and at 13:10 it bears 060°. The magnetic variation is 13.75°W and the magnetic deviation is 3°E. Determine the DMG between observations, the distance off the lighthouse at 13:10, the distance of nearest approach, the time between 13:10 and the nearest approach and the time of nearest approach.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 07		Select Program
	[2nd] [Deg]		Select Degree Mode
13.75†	[2nd] [A′]	13.75	V
6†	[A]	6.	S
45†	[A]	45.	C_c
3†	[+/−] [R/S]	−3.	De
1†	[2nd] [B′]	0.*	Dr
110†	[2nd] [B′]	0.*	St
24†	[B]	0.*	B_{r1}
13†	[C]	0.*	t_1
60†	[B]	0.*	B_{r2}
13.1†	[C]	.1666666667	$t_2 \rightarrow \Delta t$ (HH.hh)
	[D]	1.05348416†	DMG
	[R/S]	.4693048811†	D_2
	[2nd] [D′]	.3656424802†	D_n
	[E]	.0247557326†	Δt_n (HH.MMSS)
	[R/S]	13.12375573†	t_n (HH.MMSS)

Register Contents

R_{00}	R_{05}	R_{10}	R_{15} D_2	R_{20} DMG	R_{26} Used
R_{01} B_{r1}	R_{06} Dr	R_{11}	R_{16} V	R_{21} Used	
R_{02} B_{r2}	R_{07} St	R_{12} SMG	R_{17} S	R_{22} α	
R_{03} Δt_n	R_{08}	R_{13}	R_{18} C_c	R_{23} D_n	
R_{04}	R_{09}	R_{14} Δt	R_{19} t	R_{24} t_n	

*If corrections are made or if another example has been run, previous entries will be displayed.
† Printed if PC-100A is connected.

DMG, SMG, CMG FROM TWO OBJECTS

The objective of this program is the evaluation of the distance (DMG), speed (SMG), and course made good (CMG) during the time interval between two observations. At each observation, the compass bearings to both object one (B_{c1}, B'_{c1}) and object two (B_{c2}, B'_{c2}) are to be taken. The magnetic variation (V) as well as the distance (D) and true bearing (B_t) from object one to object two are required for computation.

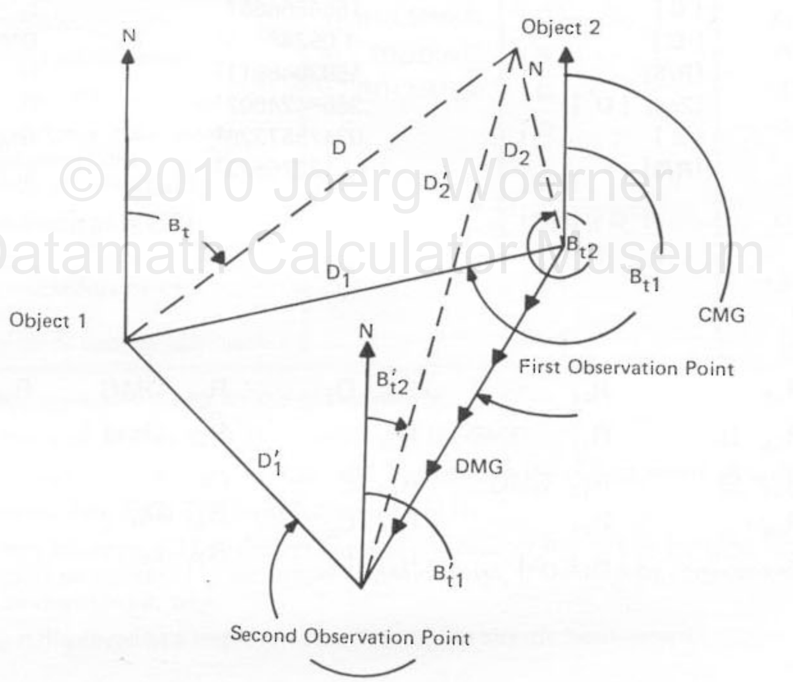
Compass bearings are converted to true bearings ($B_t = B_c - V - De$) by the program, then the distances off objects one (D_1) and two (D_2) are given by the equations

$$D_1 = \left| D \frac{\sin (B_t - B_{t2})}{\sin (B_{t2} - B_{t1})} \right| \qquad \text{and} \qquad D_2 = \left| D \frac{\sin (B_t - B_{t1})}{\sin (B_{t2} - B_{t1})} \right| .$$

Distances D_1' and D_2' are found similarly.

The distance and course made good are derived from the result of the vector equation

$$\vec{P} = \vec{P_1} - \vec{P_1'}$$



where:

- $\vec{P_1}$ has magnitude D_1 and direction B_{t1},
- $\vec{P_1'}$ has magnitude D_1' and direction B'_{t1}, and
- $\vec{P}$ has magnitude DMG and direction CMG.

The speed made good is found by dividing the course made good by the time between observations.

REMARK: The magnetic deviation may be omitted in program calculations.

Solid State Software			TI ©1977	
DMG, SMG, CMG FROM 2 OBJECTS				NG-08
V; De	B_{c2}			→SMG;CMG
D, B_t (1→2)	B_{c1}	t	→D_1; D_2	→DMG

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 08	
2	Select degree mode.		[2nd] [Deg]	
3a	Enter magnetic variation (+W, −E).	V (DD.dd)	[2nd] [A′]	V (DD.dd)
3b	Enter magnetic deviation if desired (+W, −E).	De (D.dd)	[R/S]	De (D.dd)
4a	Enter distance and	D (nau. mi.)	[A]	Prev. D (nau. mi.)
4b	true course from object 1 to object 2.	B_t (DDD.dd)	[A]	Prev. B_t (DDD.dd)
5	Enter first bearing to object 1,	B_{c1} (DDD.dd)	[B]	Prev. B'_{t1} (DDD.dd)
6	to object 2.	B_{c2} (DDD.dd)	[2nd] [B′]	0.
7	Enter first time.	t_1 (HH.MMSS)	[C]	t_1 − prev. t_2
8a	Display first distance to object 1,		[D]	D_1 (nau. mi.)
8b	to object 2.		[R/S]	D_2 (nau. mi.)
9	Enter second bearing to object 1,	B'_{c1} (DDD.dd)	[B]	B_{t1} (DDD.dd)
10	to object 2.	B'_{c2} (DDD.dd)	[2nd] [B′]	0.
11	Enter second time to find time interval.	t_2 (HH.MMSS)	[C]	Δt (HH.hh)
12a	Display second distance to object 1,		[D]	D'_1 (nau. mi.)
12b	to object 2.		[R/S]	D'_2 (nau. mi.)
13	Compute distance made good between observations.		[E]	DMG (nau. mi.)
14a	Display speed and		[2nd] [E′]	SMG (knots)
14b	course made good.		[R/S]	CMG (DDD.dd)

NOTES:

1. All time entries should be based on the 24-hour clock and in the same time zone (or GMT).
2. If midnight falls between the two observations, add 24 to t_2 before entering.
3. In entering data, Step 3 must be performed first, Step 9(10) must follow Step 5(6).
4. Data may be corrected by reentry; however, both parts of a step (a and b) must be performed in sequence even if only one value is to be changed. This also applies to Steps 5 and 9 (6 and 10).
5. Steps 8 and 12 are optional.
6. If either bearing is 000°, enter 0.

EXAMPLE: Steering a compass course of 092°, you sight a lighthouse bearing 172° (compass) at 12:00. At the same time a buoy bears 089° (compass). Fifteen minutes later the lighthouse is at 274° (compass) and the bearing of the buoy is 338° (compass). You know that the true bearing from the lighthouse to the buoy is 047° and that the distance between them is 1.2 nautical miles. Given a magnetic variation of 13.75°W and a deviation of 3°E, determine the distance, speed and course made good during the above time interval.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] Pgm] 08		Select Program
	[2nd] [Deg]		Select Degree Mode
13.75†	[2nd] [A']	13.75	V
3†	[+/–] [R/S]	–3.	De
1.2†	[A]	0.*	D
47†	[A]	0.*	B_t
172†	[B]	0.*	B_{c1}
89†	[2nd] [B']	0.*	B_{c2}
12†	[C]	12.*	t_1
	[D]	.6272029857†	D_1'
	[R/S]	1.102331061†	D_2'
274†	[B]	161.25	B_{c1}'
338†	[2nd] [B']	0.	B_{c2}'
12.15†	[C]	0.25	$t_2 \rightarrow \Delta t$
	[D]	1.313814708†	D_1'
	[R/S]	.7894707146†	D_2'
	[E]	1.569121726†	DMG
	[2nd] [E']	6.276486905†	SMG
	[R/S]	106.2655663†	DMG (DDD.dd)

Register Contents

R_{00}	R_{05}	R_{10}	R_{15} V + De	R_{20} Used	R_{25} B_t
R_{01} B_{t_1}	R_{06} D_1, D_1'	R_{11}	R_{16}	R_{21} Used	
R_{02} B_{t_1}'	R_{07} D_2, D_2'	R_{12} SMG	R_{17} D_1	R_{22} Used	
R_{03} B_{t_2}	R_{08}	R_{13} CMG	R_{18} B_{t_2}'	R_{23} Used	
R_{04}	R_{09}	R_{14} Δt	R_{19} t	R_{24} D	

*Display will differ if corrections are made or a previous problem has been run.
† Printed if PC-100A is connected.

COURSE MADE GOOD FROM THREE BEARINGS

This program will calculate the course made good (CMG) on the basis of three separate bearings on a single object. Data that must be supplied includes the magnetic variation (V) and the three compass bearings in conjunction with their corresponding times of observation.

The procedure outlined below is used to determine the course made good.

First,

$$N = \frac{(t_3 - t_2)\sin(B_{c1} - B_{c2})}{(t_2 - t_1)\sin(B_{c2} - B_{c3})}$$

is evaluated.

Then, (x, y) is converted to the polar representation (r, θ) where

$$x = \cos B_{c1} - N\cos B_{c3} \qquad \text{and} \qquad y = \sin B_{c1} - N\sin B_{c3}.$$

Now, $CMG = \theta - V - De \qquad (0° \leqslant CMG < 360°).$

The additional variables used in the above equations are:

$t_{1,2,3}$ = the times of the observations and

$B_{c1,2,3}$ = the compass bearings of the object at the observation times.

REMARKS:

1. The vessel speed and course through the water must remain constant between the first and third observations for correct results.
2. The magnetic deviation may be disregarded.

Solid State Software				TI ©1977
CMG FROM 3 BEARINGS				NG-09
V; De	Bc1	Bc2	Bc3	
	t1	t2	t3	→CMG

USER INSTRUCTIONS

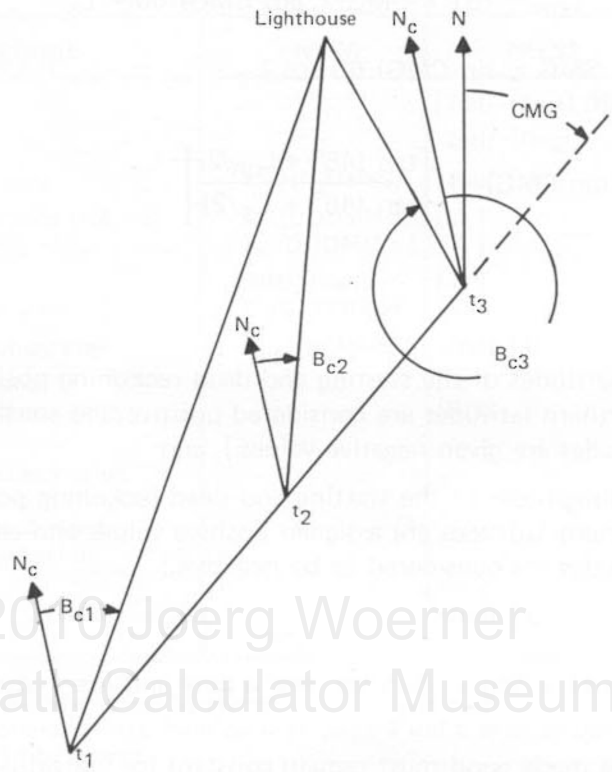
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 09	
2	Select degree mode.		[2nd] [Deg]	
3a	Enter magnetic variation (+W, −E).	V (DD.dd)	[2nd] [A′]	V (DD.dd)
3b	Enter magnetic deviation if desired (+W, −E).	De (D.dd)	[R/S]	De (D.dd)
4	Enter first time.	t_1 (HH.MMSS)	[B]	t_1 (HH.hh)
5	Enter first compass bearing.	B_{c1} (DDD.dd)	[2nd] [B′]	B_{c1} (DDD.dd)
6	Enter second time.	t_2 (HH.MMSS)	[C]	t_2 (HH.hh)
7	Enter second compass bearing.	B_{c2} (DDD.dd)	[2nd] [C′]	B_{c2} (DDD.dd)
8	Enter third time.	t_3 (HH.MMSS)	[D]	t_3 (HH.hh)
9	Enter third compass bearing.	B_{c3} (DDD.dd)	[2nd] [D′]	B_{c3} (DDD.dd)
10	Compute true course made good.		[E]	CMG (DDD.dd)

NOTES:
1. Data may be entered or corrected in any order (3b must follow 3a).
2. If De is to be corrected, V must be reentered first.
3. All times are entered on a 24-hour basis and must be in the same time zone (or GMT).
4. Printer may be used with this program.

Register Contents

R_{00}	R_{05}	R_{10}	R_{15} V + De	R_{20} N
R_{01} B_{c1}	R_{06}	R_{11}	R_{16} t_2	R_{26} Used
R_{02} B_{c2}	R_{07}	R_{12}	R_{17}	
R_{03} B_{c3}	R_{08}	R_{13} CMG	R_{18}	
R_{04}	R_{09}	R_{14} t_1	R_{19} t_3	

EXAMPLE: At 8:00 you sight a lighthouse bearing 031° (compass). At 8:19 the same lighthouse bears 016° (compass) and at 8:34 the bearing is 341°. Given that the magnetic variation is 13.75°W and the magnetic deviation is 3°E, determine your course made good between 8:00 and 8:34. Your speed and course through the water have remained constant during this time interval.



ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 09		Select Program
	[2nd] [Deg]		Select Degree Mode
13.75†	[2nd] [A′]	13.75	V
3†	[+/−] [R/S]	−3.	De
8†	[B]	8.	t_1
31†	[2nd] [B′]	31.	B_{c1}
8.19†	[C]	8.316666667	t_2
16†	[2nd] [C′]	16.	B_{c2}
8.34†	[D]	8.566666667	t_3
341†	[2nd] [D′]	341.	B_{c3}
	[E]	39.74111499†	CMG (DDD.dd)

† Printed if PC-100A is connected.

DEAD RECKONING

As is indicated by the title, this program determines the dead reckoning position after being given the starting position (L_S, λ_S) and time (t_S), the true course (CMG) and speed (SMG) made good, and the time of dead reckoning (t_{DR}).

$$L_{DR} = (\Delta t \times SMG \times \cos CMG)/60 + L_S.$$

$$\lambda_{DR} = \begin{cases} \lambda_S - (\Delta t \times SMG \times \sin CMG)/60 \cos L_S & \text{if CMG} = 90°, 270°, \\ \lambda_S - \dfrac{180}{\pi} (\tan CMG) \ln \left[\dfrac{\tan (45° + L_{DR}/2)}{\tan (45° + L_S/2)}\right] & \text{elsewhere.} \end{cases}$$

In the above equations,

$L_{S,DR}$ = the latitudes of the starting and dead reckoning positions (Northern latitudes are considered positive and southern latitudes are given negative values.), and

$\lambda_{S,DR}$ = the longitudes of the starting and dead reckoning positions. (Western latitudes are assigned positive values and eastern latitudes are considered to be negative.)

REMARKS:

1. This routine cannot follow a meridian over a pole and loses accuracy when within 0.5° of a pole.
2. Speed and course made good must remain constant for individual legs.

Solid State Software			TI ©1977	
DEAD RECKONING				NG-10
ts			UPDATE	t_{DR}
L_S, λ_S			SMG, CMG	→L_{DR}; λ_{DR}

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 10	
2	Select degree mode.		[2nd] [Deg]	
3	Enter starting time.	t_S (HH.MMSS)	[2nd] [A']	t_S (HH.hh)
4a	Enter starting latitude (+N, −S)	L_S (DDDMM.m)	[A]	Prev. L_S (DDD.dd)
4b	and longitude (+W, −E).	λ_S (DDDMM.m)	[A]	Prev. λ_S (DDD.dd)
5a	Enter speed and	SMG (knots)	[D]	Prev. SMG (knots)
5b	true course made good.	CMG (DDD.dd)	[D]	Prev. CMG (DDD.dd)
6	Enter dead reckoning time.	t_{DR} (HH.MMSS)	[2nd] [E']	t_{DR} (HH.hh)
7a	Display latitude and		[E]	L_{DR} (DDDMM.m)
7b	longitude of dead reckoning position.		[R/S]	λ_{DR} (DDDMM.m)
	To find new dead reckoning position, go to step 6. (If SMG or CMG has changed perform step 8 and return to step 5.)			
8			[2nd] [D']	0.0

NOTES:
1. Data entries and correction by reentry may be performed in any order (part b must follow part a). In correcting data, both parts of Steps 4 and 5 must be performed even if only one entry is to be altered.
2. All time entries are based on the 24-hour clock and should be in the same time zone (or GMT).

EXAMPLE: At 23:10 your position is 22°17.3′ N, 176°21.7′ E. You sail a true course of 120° at a speed of 20 knots until 5:25 the next day. At this time you alter your course to 150° and increase your speed to 22 knots. Find your dead reckoning positions at 5:25 and 14:25.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 10		Select Program
	[2nd] [Deg]		Select Degree Mode
23.1†	[2nd] [A′]	23.16666667	t_S
2217.3†	[A]	0.*	L_S
17621.7†	[+/−] [A]	0.*	λ_S
20†	[D]	0.*	SMG
120†	[D]	0.*	CMG
5.25†	[2nd] [E′]	5.416666667	t_{DR}
	[E]	2114.8†	L_{DR} (DDDMM.m)
	[R/S]	−17818.26686†	λ_{DR} (DDDMM.m)
	[2nd] [D′]	0.*	Update
22†	[D]	20.*	SMG
150†	[D]	120.*	CMG
14.25†	[2nd] [E′]	14.41666667	t_{DR}
	[E]	1823.333839†	L_{DR} (DDDMM.m)
	[R/S]	17956.48978†	λ_{DR} (DDDMM.m)

Register Contents

R_{00}	R_{05}	R_{10}	R_{15} DMG	R_{20}
R_{01} t_s	R_{06}	R_{11}	R_{16}	R_{21} L_{DR}
R_{02} L_s	R_{07}	R_{12}	R_{17} SMG	R_{22} λ_{DR}
R_{03} λ_s	R_{08}	R_{13}	R_{18} CMG	R_{26} Used
R_{04}	R_{09}	R_{14}	R_{19} t_{DR}	

*Previous entries will be displayed if another problem has been computed or if corrections are made.
†Printed if PC-100A is connected.

RHUMBLINE (MERCATOR) NAVIGATION

Given the position coordinates of the starting and destination points specified by the navigator, this program is designed to compute the rhumbline course from the start to the destination. The routine will also give the distance between the two points along the rhumbline and keep track of the cumulative distance if more than one leg is computed. Another computation possible is the speed over the bottom (SMG) necessary to complete the voyage in a time interval (Δt) established by the navigator.

$$\tan \text{CMG} = \frac{\pi (\lambda_S - \lambda_D)}{180} \Big/ \ln \left[\frac{\tan (45^\circ + L_D/2)}{\tan (45^\circ + L_S/2)} \right]$$

$$\text{Dist} = \begin{cases} 60 \mid (\lambda_D - \lambda_S) \cos L_S \mid & \text{if } L_D = L_S, \\ 60 \mid L_D - L_S)/\cos \text{CMG} \mid & \text{elsewhere.} \end{cases}$$

In the equations used above,

$L_{S,D}$ = the latitudes of the starting and destination positions (Northern latitudes are taken to be positive while southern latitudes are assigned negative values.), and

$\lambda_{S,D}$ = the longitudes of the starting and destination positions. (Western longitudes are given positive values and eastern longitudes are considered to be negative.)

REMARKS:

1. A rhumbline course should not pass through a pole.
2. This routine looses accuracy near the poles.
3. Accuracy diminishes for legs less than 2 or 3 miles long.

Solid State Software				TI ©1977
RHUMBLINE NAVIGATION				NG-11
INIT	UPDATE		→tD	Δt→SMG
Ls, λs	LD, λD	COMPUTE	→D	→CMG

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 11	
2	Select degree mode.		[2nd] [Deg]	
3	Initialize.		[2nd] [A′]	0.
4a	Enter starting latitude (+N, −S)	L_S (DDDMM.m)	[A]	Prev. L_S (DDD.dd)
4b	and longitude (+W, −E).	λ_S (DDDMM.m)	[A]	Prev. λ_S (DDD.dd)
5a	Enter destination latitude (+N, −S)	L_D (DDDMM.m)	[B]	Prev. L_D (DDD.dd)
5b	and longitude (+W, −E).	λ_D (DDDMM.m)	[B]	Prev. λ_D (DDD.dd)
6	Compute.		[C]	0.
7	Display distance.		[D]	D (nau. mi.)
8	Display true course to make good.		[E]	CMG (DDD.dd)
9	Display total distance.		[2nd] [D′]	tD (nau. mi.)
10	Enter time interval and display speed to make good.	Δt (HH.MMSS)	[2nd] [E′]	SMG (knots)
11	Perform this step to use the destination as a new starting position and go to step 5.		[2nd] [B′]	0.

NOTES:

1. Major data entry steps (4 and 5, not 4a and 4b) may be performed or corrected by reentry in either order; however, both parts of a step must be performed even if only one of the values entered by that step is to be corrected (Step 10 must follow 6).
2. Step 10 may be performed in succession for any number of time intervals.
3. Use of the print cradle is optional.
4. This program may not be run in engineering mode.

EXAMPLE: You wish to sail from 33°20.3'N, 171°00.0'W to 32°25.0'N, 178°13.9'W and then to 29°00.0'N, 176°12.7'E. Find the distance and course for each leg, as well as the total distance of the voyage. Compute the speeds required to complete each leg in 16 hours; in 20 hours.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 11		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [A']	0.	Initialize
3320.3†	[A]	0.*	L_S
17100†	[A]	0.*	λ_S
3225†	[B]	0.*	L_D
17813.9†	[B]	0.*	λ_D
	[C]	0.	Compute
	[D]	368.5685903†	D (nau. mi.)
	[E]	261.3707603†	CMG (dec. deg.)
16†	[2nd] [E']	23.03553689†	$\Delta t \rightarrow$ SMG (knots)
20†	[2nd] [E']	18.42842951†	$\Delta t \rightarrow$ SMG (knots)
	[2nd] [B']	0.	Update
2900†	[B]	32.41666667*	L_D
17612.7†	[+/–] [B]	178.2316667*	λ_D
	[C]	0.	Compute
	[D]	352.3516467†	D (nau. mi.)
	[E]	234.4223928†	CMG (dec. deg.)
	[2nd] [D']	720.920237†	tD (nau. mi.)
16†	[2nd] [E']	22.02197792†	$\Delta t \rightarrow$ SMG (knots)
20†	[2nd] [E']	17.61758234†	$\Delta t \rightarrow$ SMG (knots)

Register Contents

R_{00} Used	R_{05}	R_{10}	R_{15} D	R_{20} Used
R_{01} $\lambda_s - \lambda_D$	R_{06}	R_{11}	R_{16}	R_{21} L_D
R_{02} L_S	R_{07}	R_{12}	R_{17}	R_{22} λ_D
R_{03} λ_S	R_{08}	R_{13}	R_{18} CMG	R_{26} Used
R_{04}	R_{09}	R_{14}	R_{19} tD	

*Display will differ if corrections are made or if a previous example has been run.
† Printed if PC-100A is connected.

CHART INITIALIZATION (LAT/LON)

The constants listed below are necessary inputs to the short range **LAT/LON** programs described in the pages following this program. The function of this routine is to store these constants in the proper registers for use in the **LAT/LON** programs. These constants depend on location, and once the constants for a particular area have been entered, they may be recorded on a blank card. Thereafter, the navigator need only load the data card, select this program, and press [E] to properly store the constants.

The constants are:

V = magnetic variation, the difference between true and magnetic north in decimal (DDD.ddd) degrees (Western variation is taken to be positive and eastern is assigned a negative value.),

L_m = nautical miles in a given interval of latitude (e.g., nautical miles per degree times number of degrees),

λ_m = nautical miles in a given interval of longitude,

$L_{1,2}$ = latitudes of objects 1 and 2 on a map (Northern latitudes are given positive values while southern latitudes are considered to be negative.), and

$\lambda_{1,2}$ = longitudes of objects 1 and 2 on a map. (Western longitudes are assigned positive values and eastern longitudes are taken to be negative.)

Accurate values for L_m and λ_m are provided by tables found in *Bowditch* and elsewhere. These quantities vary, however one minute of latitude is approximately equal to one nautical mile ($1° \doteq 60$ nautical miles) and one minute of longitude may be estimated by taking the cosine of the latitude and expressing the result in nautical miles. If the navigator does not have access to the appropriate tables, he may enter the midpoint of the latitude interval he wishes to use and press [2nd] [C']. The calculator will then store the constants described above using latitude and longitude intervals of one minute. (The calculator simply enters an average value and does not restrict the user to computation within the above intervals.)

REMARK: The intervals used for determining L_m and λ_m must be equivalent (in degrees, not actual distance).

Solid State Software		TI ©1977		
CHART INITIALIZATION				NG-12
V	L_2, λ_2	L		
	L_1, λ_1	L_m, λ_m		STORE

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 12	
2	Select degree mode.		[2nd] [Deg]	
3	Enter magnetic variation (+W, −E).	V (DD.dd)	[2nd] [A′]	V (DD.dd)
4a	Enter latitude (+N, −S) and	L_1 (DDD.MMSS)	[B]	Prev. L_1 (DDD.dd)
4b	longitude (+W, −E) of object 1.	λ_1 (DDD.MMSS)	[B]	Prev. λ_1 (DDD.dd)
5a	Enter latitude (+N, −S) and	L_2 (DDD.MMSS)	[2nd] [B′]	Prev. L_2 (DDD.dd)
5b	longitude (+W, −E) of object 2.	λ_2 (DDD.MMSS)	[2nd] [B′]	Prev. λ_2 (DDD.dd)
	EITHER			
6a	Enter nautical miles in latitude interval,	L_m (nau. mi.)	[C]	Prev. L_m (nau. mi.)
6b	in longitude interval,	λ_m (nau. mi.)	[C]	Prev. λ_m (nau. mi.)
	OR			
7	Enter average latitude (+N, −S).	L(DDD.MMSS)	[2nd] [C′]	1.
8	Load the constants.		[E]	0.
9	Record the constants on a blank card for future use.	4	[2nd] [Write]	4.
	Feed card into card slot.			4.

NOTES:
1. Major data steps (4 and 5, not 4a and 4b) may be entered or corrected in any order; however, both parts of the step must be performed in correcting data even if only one value is to be changed.
2. Printer usage is optional with this program.
3. If the proper data has already been stored on a magnetic card, simply clear the calculator's display, feed the card into the card slot, and press [2nd] [Pgm] [1] [2] [E].

EXAMPLE: According to your chart, a beacon is located at 41°04′15″N, 71°51′27″W and a lighthouse is at 41°06′03″N, 71°46′17″W. You see from your tables that at 41°, 1° of latitude equals 59.964 nautical miles, and 1° of longitude equals 45.431 nautical miles. The magnetic variation is 13.75°. Enter this data and then prepare a customized card.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 12		Select Program
	[2nd] [Deg]		Select Degree Mode
13.75	[2nd] [A′]	13.75	V
41.0415	[B]	0.*	L_1
71.5127	[B]	0.*	λ_1
41.0603	[2nd] [B′]	0.*	L_2
71.4617	[2nd] [B′]	0.*	λ_2
59.964**	[C]	0.*	L_m
45.431**	[C]	0.*	λ_m
	[E]	0.	Load Constants††

You may now record this data on a blank magnetic card by entering 4, pressing [2nd] [Write], and feeding the card into the card slot.

Register Contents

R_{00}	R_{05} λ_m	R_{10} L_2	R_{15}	R_{20} V
R_{01}	R_{06}	R_{11} λ_2	R_{16} V	R_{21} L_1
R_{02}	R_{07}	R_{12} L_m	R_{17}	R_{22} λ_1
R_{03}	R_{08} L_1	R_{13} λ_m	R_{18}	R_{23} L_2
R_{04} L_m	R_{09} λ_1	R_{14}	R_{19}	R_{24} λ_2

*If an example has already been run or an entry is corrected, the previous entry is displayed
**If you do not have access to these values, enter 41 and press [2nd] [C′].
†Printed if PC-100A is connected.
††Constants are printed when print cradle is used.

RUNNING FIX FROM ONE OBJECT (LAT/LON)

Given two observations of a single object, the vessel speed through the water, the compass course, and the drift and set of the current, this program will determine the fix at the time of the second observation. (The **CHART INITIALIZATION** program must be used to enter the quantities V, L_m, λ_m, and L_1 and λ_1 or L_2 and λ_2.)

The velocity made good vector is the vector sum of the velocity and current vectors ($\overrightarrow{VMG} = \vec{V} + \overrightarrow{Cr}$)

where:

$\overrightarrow{VMG}$ has magnitude SMG and direction CMG,

$\vec{V}$ has magnitude S and direction C_t, and

$\overrightarrow{Cr}$ has magnitude Dr and direction St.

The distance made good is found as the product of the speed made good and the time interval between observations, then the distance off the object at the second observation is found by the equation:

$$D = DMG \sin (CMG - B_{t1})/\sin (B_{t1} - B_{t2}).$$

$B_{t1,2}$ = the true bearings of the object from the observation points.

The latitude (L) and longitude (λ) of the fix are now found as

$$L = L_i + (D/60) \cos (B_{t2} - 180°)$$

and

$$\lambda = \lambda_i - (D/60) \sin (B_{t2} - 180°) (L_m/\lambda_m) \qquad i = (1, 2).$$

L_m (λ_m) = nautical miles in some interval of latitude (longitude).

REMARKS:

1. If the navigator desires to omit the magnetic deviation, he must enter zero when it is called for.
2. There should be at least 10° of separation between the bearings for accurate results.

Solid State Software			TI ©1977	
RUNNING FIX FROM 1 OBJECT				NG-13
De(B)	Dr, St		OBJ 2	SAVE 1
S, Cc; De	Bc	t	OBJ 1	→L ; λ

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 13	
2	Select degree mode.		[2nd] [Deg]	
3	Enter magnetic deviation of compass used to find bearings (+W, −E).	De (B) (D.dd)	[2nd] [A′]	De (B) + V (DD.dd)
4a 4b 4c	Enter vessel speed, compass course, and magnetic deviation of the vessel's compass (+W, −E).	S (knots) C_c (DDD.dd) De (D.dd)	[A] [A] [R/S]	S (knots) C_c(DDD.dd) De + V (DD.dd)
5a 5b	Enter drift and set of current.	Dr (knots) St (DDD.dd)	[2nd] [B′] [2nd] [B′]	prev. Dr (knots) prev. St (DDD.dd)
6	Enter first compass bearing to object.	B_{c1} (DDD.dd)	[B]	prev. B_{t1} (DDD.dd)
7	Enter first time.	t_1 (HH.MMSS)	[C]	t_1 − prev. t_2 (HH.hh)
8	Enter second bearing.	B_{c2} (DDD.dd)	[B]	prev. B_{t2} (DDD.dd)
9	Enter second time.	t_2 (HH.MMSS)	[C]	Δt (HH.hh)
10	If using object 1. If using object 2.		[D] [2nd] [D′]	9. 11.
11	Compute fix (L = +N, −S; λ = +W, −E).		[E] [R/S]	L (DD.MMSS) λ (DD.MMSS)
	For two new observations, go to step 6.			
	To enter a new second observation and use the previous second observation as the first observation, go to step 8.			
	To enter a new second observation without altering the first observation, perform step 12 and go to step 8.			
12	Save first observation.		[2nd] [E′]	B_{t1} (DDD.dd)

NOTES:
1. In entering or correcting data by reentry, minor steps (a, b, and c) must be performed in sequence even if only one value is to be entered or reentered. Also, Step 8(9), must accompany and follow Step 6(7) and Step 3 must precede 6 and 8.
2. The option provided in Step 10 is designed to allow use of either object recorded on a customized card.
3. All time entries are on a 24-hour basis and should be in the same time zone (or GMT).
4. If the value of any entry is zero, enter zero.

EXAMPLE: At a speed of 6 knots through the water, you are steering a compass course of 317°. The current is estimated to set 220° at a drift of 0.4 knots. A lighthouse bears 345° (compass) at 8:00 and 100° at 8:17. The magnetic deviation of the hand-held compass you used to determine these bearings is 1.5°W. The magnetic variation is 13.75°W and the deviation of the ship's compass is 2°W. You know the coordinates of the lighthouse to be 41°08'27"N, 71°35'45"W. Also, at latitude 41°N, one degree of latitude is approximately 59.964 nautical miles and the same interval of longitude is about 45.431 nautical miles. Determine your fix at the time of the second observation.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 12		Select Program 12
	[2nd] [Deg]		Select Degree Mode
13.75	[2nd] [A']	13.75	V
41.0827	[B]	0.*	L_1
71.3545	[B]	0.*	λ_1
59.964	[C]	0.*	L_m
45.431	[C]	0.*	λ_m
	[E]	0.	Load Constants††
	[2nd] [Pgm] 13		Select Program 13
1.5†	[2nd] [A']	15.25	De (B) → De (B)+V
6†	[A]	6.	S
317†	[A]	317.	C_c
2†	[R/S]	15.75	De → De + V
.4†	[2nd] [B']	0.*	Dr
220†	[2nd] [B']	0.*	St
345†	[B]	0.*	B_{c1}
8†	[C]	8.*	t_1
100†	[B]	0.*	B_{c2}
8.17†	[C]	.2833333333	Δt (HH.hh)
	[D]	9.†	obj. 1
	[E]	41.08214401†	L (DD.MMSS)
	[R/S]	71.37048644†	λ (DD.MMSS)

Register Contents

R_{00}	R_{05} λ_m	R_{10} L_2	R_{15} V + De	R_{26} Used
R_{01} B_{t_1}	R_{06} Dr	R_{11} λ_2	R_{16} V	R_{27} Used
R_{02} B_{t_2}	R_{07} St	R_{12}	R_{17} S	R_{28} Pointer
R_{03} t_1	R_{08} L_1	R_{13}	R_{18} C_t	R_{29} Pointer
R_{04} L_m	R_{09} λ_1	R_{14} Δt	R_{19} t_2	

*Display will differ if a previous problem has been run or corrections are made.
†Printed if PC-100A is connected
††Constants are printed when print cradle is used.

FIX FROM TWO OBJECTS (LAT/LON)

By taking simultaneous bearings ($B_{c1,2}$) of two objects, this program may be used to compute the position of the vessel at the time of the observations (the **CHART INITIALIZATION** program must be used for entering V, L_1, λ_1, L_2, λ_2, L_m, and λ_m).

Calculation is begun by converting (x, y) to polar coordinates (r, θ) where x and y have been evaluated as:

$$x = L_2 - L_1$$

and

$$y = -\lambda_m\ (\lambda_2 - \lambda_1)/L_m$$

where:

$L_1, \lambda_1\ (L_2, \lambda_2)$ = latitude and longitude of object 1 (2), and
$L_m\ (\lambda_m)$ = number of nautical miles in a given interval of latitude (longitude).

The true bearing (B_t') from object 1 to object 2 is equal to θ and the distance (D) between the two is 60r.

After the observed compass bearings are converted to true bearings ($B_t = B_c - De - V$), the distance off object 1 is given by the formula:

$$D_1 = D \sin (B_t' - B_{t2})/\sin (B_{t2} - B_{t1}).$$

Then, the latitude (L) and longitude (λ) of the fix are computed from the equations:

$$L = L_1 - (D_1/60) \cos B_{t1}$$

and

$$\lambda = \lambda_1 + (D_1/60)\ (L_m/\lambda_m)\ \sin B_{t1}.$$

REMARK: If the navigator wishes to disregard the magnetic deviation, zero must be entered into the calculator.

Register Contents

R_{00}	R_{05} λ_m	R_{10} L_2	R_{15} De + V	R_{26} Used
R_{01} B_{t1}	R_{06}	R_{11} λ_2	R_{16} V	R_{28} L
R_{02} B_{t2}	R_{07}	R_{12}	R_{17}	R_{29} λ
R_{03}	R_{08} L_1	R_{13}	R_{18}	
R_{04} L_m	R_{09} λ_1	R_{14}	R_{19}	

Solid State Software				TI ©1977
FIX FROM 2 OBJECTS				NG-14
De				
	B_{c1}, B_{c2}			→L ; λ

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 14	
2	Select degree mode.		[2nd] [Deg]	
3	Enter magnetic deviation of compass used to take bearings (+W, −E).	De (D.dd)	[2nd] [A′]	De + V
	Enter compass bearing			
4a	to object 1,	B_{c1} (DDD.dd)	[B]	prev. B_{t1} (DDD.dd)
4b	to object 2.	B_{c2} (DDD.dd)	[B]	prev. B_{t2} (DDD.dd)
5	Compute fix (L = +N, −S; λ = +W, −E).		[E] [R/S]	L (DDD.MMSS) λ (DDD.MMSS)

NOTES:
1. Data must be entered in the above order.
2. Data may be corrected by reentry; however, both bearings must be reentered even if only one is incorrect.
3. Printing unit may be used with this program.
4. If the value of any data is zero, enter zero.

EXAMPLE: Simultaneous compass bearings of a lighthouse and a flag tower are 301° and 006°, respectively. You know the position of the lighthouse to be 41°08′58″N, 72°14′25″W and the flag tower is located at 41°09′48″N, 72°13′26″W. The magnetic variation is 13.75°W and the deviation is 4°E for the compass used to find the bearings. Also, at 41°N, one degree of latitude is about 59.964 nautical miles and 45.431 nautical miles is the approximate size of an equivalent interval of longitude. Determine the position of your vessel.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 12		Select Program 12
	[2nd] [Deg]		Select Degree Mode
13.75	[2nd] [A′]	13.75	V
41.0858	[B]	0.*	L_1
72.1425	[B]	0.*	λ_1
41.0948	[2nd] [B′]	0.*	L_2
72.1326	[2nd] [B′]	0.*	λ_2
59.964	[C]	0.*	L_m
45.431	[C]	0.*	λ_m
	[E]	0.	Load Constants††
	[2nd] [Pgm] 14		Select Program 14
4	[+/−] [2nd] [A′]	9.75†	De → De + V
301†	[B]	0.*	B_{c1}
6†	[B]	0.*	B_{c2}
	[E]	41.08388545†	L (DD.MMSS)
	[R/S]	72.13200182†	λ (DD.MMSS)

*Earlier entries will be displayed if a previous problem has been run or corrections are made.
†Printed if PC-100A is connected.
††Constants are printed when print cradle is used.

CELESTIAL NAVIGATION

The celestial programs are intended to conform to acceptable standards of accuracy for practical navigation at sea. For example, the **SEXTANT CORRECTION** program can be considered accurate to within plus or minus 0.1 nautical mile. This standard conforms to the accuracy of the altitude correction tables found in *The Nautical Almanac*.

However, the major error factor in celestial navigation is the accuracy of the observation which is related to the prevailing conditions and skill of the navigator. In general, celestial fixes yield results that should not be considered more accurate than plus or minus 2 miles.

The navigator can use these programs for all normal sailing latitudes. However, above 70°N or below 70°S the navigator is considered to be in the polar regions where conditions require specialized navigation skills.

Position coordinates are entered and displayed in the degree-minute-decimal minute format while celestial data may appear using either the above or the degree-minute-second form. Placement of the decimal point is explained in the user instructions. See page 9 for conversion instructions.

The Process of Celestial Navigation

Celestial navigation begins with a dead reckoning position (Program NG-10) would be useful here) which is the navigator's best estimate of his latitude and longitude based on courses steered, speed, and time. The navigator then observes a celestial body with his sextant, noting the exact Greenwich time and date of the observation.

The process then requires the navigator to correct the sextant angle for various errors and additional information extracted from *The Nautical Almanac* which is published jointly each year by the U.S. Naval Observatory in Washington, D.C. and Her Majesty's Nautical Almanac Office in London. This publication is for sale in the U.S. by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

The above information is entered into the calculator and used to solve a complex problem referred to as the celestial triangle. The results of a single observation will enable the navigator to start at his DR estimate and construct a single line of position. The navigator then knows he is somewhere along that line. By taking two or more observations the navigator is able to construct lines of position for each, the intersection of which provides a reasonably accurate fix.

Using the Sextant

The sextant is an instrument used for measuring angles. In celestial navigation the sextant measures the angle between the horizon and the celestial body.

Assuming the navigator has a properly adjusted instrument, the basic procedure for observing celestial bodies is to:

1. Aim the sextant in the direction of the body to be observed.
2. Adjust the instrument so that the body appears to rest just on the edge of the horizon (figure 1).
3. When observing the sun or moon, the procedure requires the navigator to bring either the upper or lower edge (limb) of the body into tangency with the horizon (figure 1).
4. At the instant of tangency, the navigator should record the GMT time/date and apply any known watch error to obtain correct GMT.
5. Record the sextant reading in degrees, minutes, and decimal minutes.

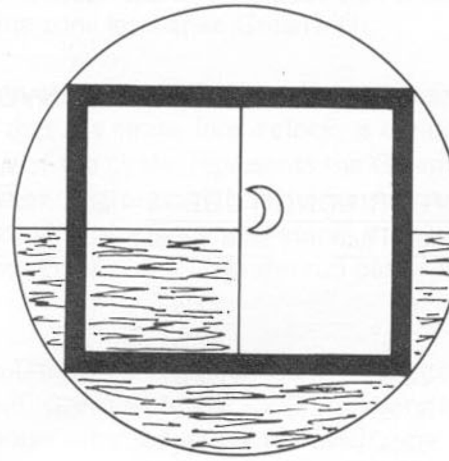


FIGURE 1.

Celestial Timekeeping

The development of the microelectronic quartz crystal watch has greatly simplified celestial timekeeping. With such accurate instruments, it is now possible for the navigator to carry on his wrist, not only a very accurate timepiece, but a timepiece that he can set to keep accurate time and date for any specific place on the earth.

Modern celestial navigation requires that the navigator know the Greenwich, England date and time of his observations. Time should be accurate to the nearest second as an error of 2 seconds will mean that your position will be in doubt by 1/2 mile.

The Texas Instruments quartz crystal watch is ninety times more accurate than most electronic tuning fork watches and immensely more accurate than even the best of the expensive, jeweled movement chronometers of a few years ago. With a quartz crystal watch set to the local date and time of the Greenwich meridian, the navigator can use his watch anywhere in the world to time his celestial sights.

Greenwich time is called either Greenwich Mean Time (GMT) or Coordinated Universal Time. This time system uses six digits to record hours, minutes, and seconds. The first two digits record the hours (0–23), the second two the minutes (0–59), and the last two record the seconds (0–59). Thus, for 6:04:12 p.m., you would add the 12 hours that elapsed before noon and record the time as 18 hours 04 minutes and 12 seconds GMT. Be careful in handling minutes and seconds when you record a watch time with a one digit expression. The reason this is important is the program requires the GMT minutes and seconds to be entered as a decimal expression. There is quite a difference between 0.412 (41 minutes 20 seconds) and 0.0412 (04 minutes and 12 seconds).

The following table, adapted from *Bowditch*, H.O. Publication No. 9, can be used to convert local (zone) time to Greenwich. (In the U.S. when converting from zone time to Greenwich, if the area you are in is keeping daylight savings time, you *subtract one hour* from the hours you would add according to the table.)

TABLE FOR CONVERSION OF ZONE TIME TO GMT

IF YOUR LONGITUDE IS		WEST LONGITUDE FROM ZONE TIME TO GMT ADD	EAST LONGITUDE FROM ZONE TIME TO GMT SUBTRACT
Greater Than	Less Than		
0°	7½°	0	0
7½°	22½°	+ 1 hr.	– 1 hr.
22½°	37½°	+ 2 hrs.	– 2 hrs.
37½°	52½°	+ 3 hrs.	– 3 hrs.
52½°	67½°	+ 4 hrs.	– 4 hrs.
67½°	82½°	+ 5 hrs.	– 5 hrs.
82½°	97½°	+ 6 hrs.	– 6 hrs.
97½°	112½°	+ 7 hrs.	– 7 hrs.
112½°	127½°	+ 8 hrs.	– 8 hrs.
127½°	142½°	+ 9 hrs.	– 9 hrs.
142½°	157½°	+10 hrs.	–10 hrs.
157½°	172½°	+11 hrs.	–11 hrs.
172½°	180°	+12 hrs.	–12 hrs.

EXAMPLE

You live in San Francisco, California and plan to sail to Hawaii. You are not on daylight savings time and want to know how many hours you should add or subtract from your local time to obtain GMT.

Solution

Longitude of San Francisco:	122° 25′ West.
Hours added or subtracted according to the table:	+8 hours.

Now that you have the time function of the watch set to Greenwich, you have to make sure the date on your watch is correct for Greenwich.

Depending on where you are in the world, it can be a day earlier, the same day, or one day later at Greenwich, England.

A time diagram is a sketch which indicates the relationship of time to longitude and helps the navigator set the Greenwich date on his timepiece.

The distance on the earth that the sun covers in 1 hour as it moves from east to west is equal to 15 degrees of longitude. In a 24 hour day, the sun moves all the way around the world covering 360° of longitude. Thus, you can determine how many hours (as the sun flies) you are ahead of or behind Greenwich by dividing your local longitude by 15°. If you are east of Greenwich, the sun will obviously reach you first, and you are time wise ahead of Greenwich; if you are west of Greenwich, the sun reaches you later and you are in a time zone later than Greenwich.

To graphically show these relationships, you draw a diagram like figure 2. The circle represents the path the sun makes around the world in a day. Note that the circle, like a clock, is divided into equal 24 hour time increments. G, located at the top of the circle, represents the Greenwich meridian. The arrows W⇆E at the top indicate east and west longitudes. When the sun is overhead at G, it is noon at Greenwich. Little g, located at the bottom of the circle, represents the place in the sun's daily travels when midnight at Greenwich occurs. Obviously, when the sun passes little g, a new day starts at Greenwich, England.

In this diagram, M represents your own time-longitude relationship to Greenwich. To locate the position of M, mark off how many hours ahead, or behind, Greenwich you are. For example, if you were in San Francisco where the sun is overhead 8 hours after it passes Greenwich, you would mark the location of M as shown in figure 2.

When the sun is overhead at M, it is noon in San Francisco at the longitude where you are.

Now, on the other side of the world from M, you mark a little m to indicate where the sun will be when it is midnight at San Francisco. When the sun flies past m on that side of the world, the new day starts for you at M.

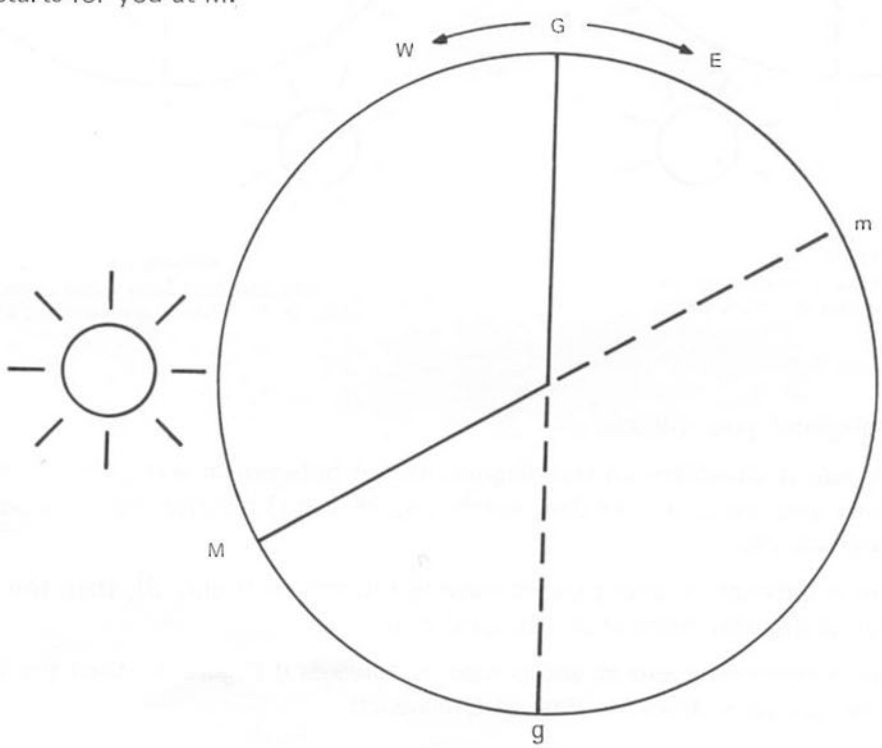


FIGURE 2.

To continue with our example, let's assume it is 10:00 a.m. California time, and the date in San Francisco when you want to set your watch to Greenwich is March 1. Remember, the sun always moves in a westerly direction, and it must still travel 2 more hours (on the 24 hour clock) before it will be noon at M. Figure 2 shows how to draw the sun's position in the diagram.

In this case, the completed time diagram shows that the Greenwich date is the same as the San Francisco date. The date at Greenwich will not change until the sun moves all the way around to g.

Figures 3 and 4 illustrate the other two possibilities.

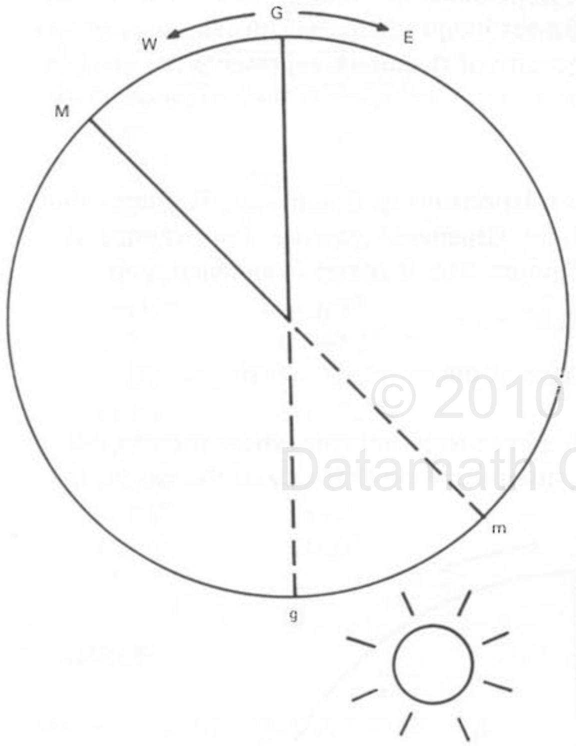


FIGURE 3.
TIME DIAGRAM WITH GREENWICH ONE DAY AHEAD OF LOCAL DATE.

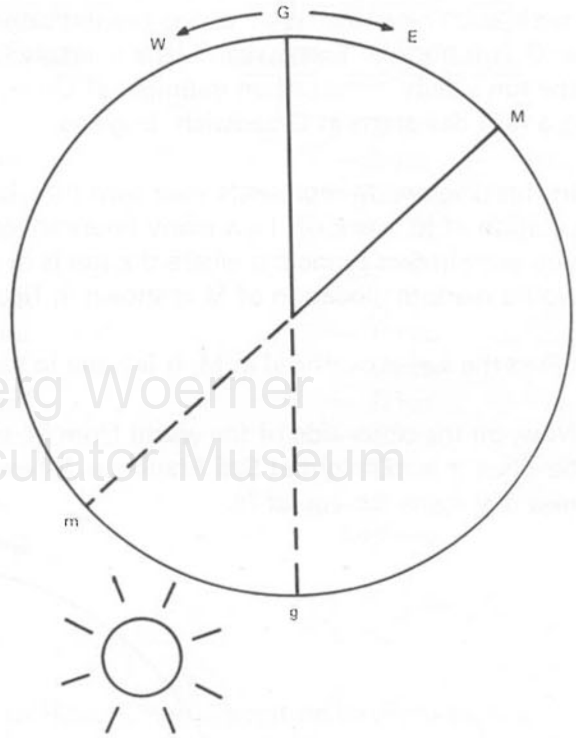


FIGURE 4.
TIME DIAGRAM WITH LOCAL DATE ONE DAY AHEAD OF GREENWICH DATE.

As you study the diagrams you will see:

1. When the sun is anywhere on the diagram except between m and g, the date is the same where you are as it is at Greenwich (i.e., M and G occupy the same portion of the circle as the sun).
2. If the sun is between m and g and is moving towards m (figure 3), then the date at Greenwich is one day more than the local date.
3. If the sun is between g and m and is moving towards g (figure 4), then the local date is one day more than the date at Greenwich.

Accuracy

Navigators use the very accurate time signals from Radio Station WWV, Fort Collins, Colorado (broadcast continuously on 2.5, 5, 10, 15, and 25 megahertz) to set their watches and obtain any subsequent watch error.

Watch error is simply the few seconds difference between your watch and the reference time given by the station. To obtain the correct time, you subtract errors that are fast and add errors that are slow on GMT.

TABLE 1.

1975 JUNE 24, 25, 26 (TUES., WED., THURS.)

	G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
	d h	° ′	° ′	° ′	′	° ′	′	′
	24 00	179 28.0	N23 25.7	355 44.5	9.3	S20 21.9	3.8	56.4
	01	194 27.9	25.6	10 12.8	9.3	20 18.1	3.8	56.3
	02	209 27.8	25.6	24 41.1	9.4	20 14.3	4.0	56.3
	03	224 27.6 ··	25.6	39 09.5	9.4	20 10.3	4.0	56.3
	04	239 27.5	25.5	53 37.9	9.6	20 06.3	4.2	56.3
	05	254 27.4	25.5	68 06.5	9.5	20 02.1	4.3	56.3
	06	269 27.2	N23 25.4	82 35.0	9.7	S19 57.8	4.4	56.2
	07	284 27.1	25.4	97 03.7	9.6	19 53.4	4.5	56.2
	08	299 27.0	25.4	111 32.3	9.8	19 48.9	4.5	56.2
T	09	314 26.8 ··	25.3	126 01.1	9.8	19 44.4	4.7	56.2
U	10	329 26.7	25.3	140 29.9	9.9	19 39.7	4.8	56.1
E	11	344 26.6	25.2	154 58.8	9.9	19 34.9	4.9	56.1
S	12	359 26.4	N23 25.2	169 27.7	10.0	S19 30.0	5.0	56.1
D	13	14 26.3	25.2	183 56.7	10.1	19 25.0	5.1	56.1
A	14	29 26.2	25.1	198 25.8	10.1	19 19.9	5.1	56.0
Y	15	44 26.0 ··	25.1	212 54.9	10.2	19 14.8	5.3	56.0
	16	59 25.9	25.0	227 24.1	10.2	19 09.5	5.4	56.0
	17	74 25.8	25.0	241 53.3	10.3	19 04.1	5.4	56.0
	18	89 25.6	N23 24.9	256 22.6	10.4	S18 58.7	5.6	56.0
	19	104 25.5	24.9	270 52.0	10.5	18 53.1	5.6	55.9
	20	119 25.4	24.8	285 21.5	10.5	18 47.5	5.8	55.9
	21	134 25.2 ··	24.8	299 51.0	10.5	18 41.7	5.8	55.9
	22	149 25.1	24.7	314 20.5	10.7	18 35.9	5.9	55.9
	23	164 25.0	24.7	328 50.2	10.7	18 30.0	6.0	55.8
	25 00	179 24.8	N23 24.6	343 19.9	10.7	S18 24.0	6.1	55.8
	01	194 24.7	24.6	357 49.6	10.9	18 17.9	6.2	55.8
	02	209 24.6	24.5	12 19.5	10.9	18 11.7	6.3	55.8
	03	224 24.4 ··	24.5	26 49.4	11.0	18 05.4	6.3	55.8
	04	239 24.3	24.4	41 19.4	11.0	17 59.1	6.5	55.7
	05	254 24.2	24.4	55 49.4	11.1	17 52.6	6.5	55.7
	06	269 24.0	N23 24.3	70 19.5	11.2	S17 46.1	6.6	55.7
W	07	284 23.9	24.3	84 49.7	11.2	17 39.5	6.7	55.7
E	08	299 23.8	24.2	99 19.9	11.3	17 32.8	6.8	55.6
D	09	314 23.6 ··	24.1	113 50.2	11.4	17 26.0	6.8	55.6
N	10	329 23.5	24.1	128 20.6	11.4	17 19.2	6.9	55.6
E	11	344 23.4	24.0	142 51.0	11.5	17 12.3	7.0	55.6
S	12	359 23.2	N23 24.0	157 21.5	11.6	S17 05.3	7.1	55.6
D	13	14 23.1	23.9	171 52.1	11.6	16 58.2	7.2	55.5
A	14	29 23.0	23.9	186 22.7	11.7	16 51.0	7.2	55.5
Y	15	44 22.8 ··	23.8	200 53.4	11.8	16 43.8	7.3	55.5
	16	59 22.7	23.7	215 24.2	11.8	16 36.5	7.4	55.5
	17	74 22.6	23.7	229 55.0	11.9	16 29.1	7.5	55.5
	18	89 22.4	N23 23.6	244 25.9	12.0	S16 21.6	7.5	55.4
	19	104 22.3	23.5	258 56.9	12.0	16 14.1	7.6	55.4
	20	119 22.2	23.5	273 27.9	12.1	16 06.5	7.6	55.4
	21	134 22.1 ··	23.4	287 59.0	12.2	15 58.9	7.8	55.4
	22	149 21.9	23.3	302 30.2	12.2	15 51.1	7.8	55.3
	23	164 21.8	23.3	317 01.4	12.3	15 43.3	7.9	55.3
	26 00	179 21.7	N23 23.2	331 32.7	12.4	S15 35.4	7.9	55.3
	01	194 21.5	23.1	346 04.1	12.4	15 27.5	8.0	55.3
	02	209 21.4	23.1	0 35.5	12.5	15 19.5	8.1	55.3
	03	224 21.3 ··	23.0	15 07.0	12.5	15 11.4	8.1	55.2
	04	239 21.1	22.9	29 38.5	12.7	15 03.3	8.2	55.2
	05	254 21.0	22.9	44 10.2	12.6	14 55.1	8.3	55.2
	06	269 20.9	N23 22.8	58 41.8	12.8	S14 46.8	8.3	55.2
	07	284 20.7	22.7	73 13.6	12.8	14 38.5	8.4	55.2
T	08	299 20.6	22.6	87 45.4	12.9	14 30.1	8.4	55.1
H	09	314 20.5 ··	22.6	102 17.3	12.9	14 21.7	8.5	55.1
U	10	329 20.3	22.5	116 49.2	13.0	14 13.2	8.5	55.1
R	11	344 20.2	22.4	131 21.2	13.0	14 04.7	8.7	55.1
S	12	359 20.1	N23 22.3	145 53.2	13.1	S13 56.0	8.6	55.1
D	13	14 19.9	22.3	160 25.3	13.2	13 47.4	8.7	55.1
A	14	29 19.8	22.2	174 57.5	13.3	13 38.7	8.8	55.0
Y	15	44 19.7 ··	22.1	189 29.8	13.2	13 29.9	8.8	55.0
	16	59 19.6	22.0	204 02.0	13.4	13 21.1	8.9	55.0
	17	74 19.4	21.9	218 34.4	13.4	13 12.2	9.0	55.0
	18	89 19.3	N23 21.9	233 06.8	13.5	S13 03.2	9.0	55.0
	19	104 19.2	21.8	247 39.3	13.5	12 54.2	9.0	54.9
	20	119 19.0	21.7	262 11.8	13.6	12 45.2	9.1	54.9
	21	134 18.9 ··	21.6	276 44.4	13.6	12 36.1	9.1	54.9
	22	149 18.8	21.5	291 17.0	13.7	12 27.0	9.2	54.9
	23	164 18.6	21.4	305 49.7	13.8	12 17.8	9.2	54.9
		S.D. 15.8	*d* 0.1	S.D. 15.3		15.1		15.0

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 24	Moonrise 25	Moonrise 26	Moonrise 27
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	■	23 53	23 27	23 09
N 70	□	□	□	23 35	23 16	23 05	22 57
68	□	□	□	22 51	22 50	22 49	22 46
66	□	□	□	22 21	22 30	22 35	22 38
64	////	////	01 32	21 59	22 14	22 24	22 31
62	////	////	02 10	21 41	22 00	22 14	22 25
60	////	00 51	02 37	21 26	21 49	22 06	22 19
N 58	////	01 41	02 57	21 13	21 39	21 58	22 14
56	////	02 11	03 14	21 02	21 30	21 52	22 10
54	00 47	02 34	03 28	20 52	21 22	21 46	22 06
52	01 33	02 52	03 41	20 44	21 15	21 41	22 03
50	02 01	03 07	03 51	20 36	21 09	21 36	22 00
45	02 47	03 37	04 14	20 19	20 55	21 26	21 53
N 40	03 17	03 59	04 32	20 06	20 44	21 17	21 47
35	03 41	04 17	04 47	19 54	20 34	21 10	21 42
30	03 59	04 33	05 00	19 44	20 26	21 03	21 38
20	04 28	04 58	05 22	19 26	20 11	20 52	21 30
N 10	04 51	05 18	05 41	19 11	19 58	20 42	21 23
0	05 10	05 36	05 59	18 57	19 46	20 33	21 17
S 10	05 27	05 53	06 16	18 43	19 34	20 23	21 10
20	05 43	06 11	06 35	18 27	19 21	20 13	21 04
30	06 00	06 30	06 56	18 10	19 06	20 02	20 56
35	06 08	06 40	07 08	17 59	18 58	19 55	20 51
40	06 18	06 52	07 22	17 48	18 48	19 47	20 46
45	06 28	07 05	07 39	17 34	18 36	19 39	20 40
S 50	06 40	07 21	08 00	17 17	18 22	19 28	20 33
52	06 45	07 29	08 10	17 09	18 15	19 23	20 30
54	06 51	07 37	08 21	17 00	18 08	19 17	20 26
56	06 57	07 46	08 34	16 50	18 00	19 11	20 22
58	07 04	07 57	08 48	16 38	17 51	19 04	20 17
S 60	07 11	08 08	09 06	16 25	17 40	18 57	20 12

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 24	Moonset 25	Moonset 26	Moonset 27
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	■	■	04 17	06 19
N 70	□	□	□	■	02 54	04 53	06 39
68	□	□	□	01 54	03 37	05 18	06 54
66	□	□	□	02 38	04 06	05 37	07 06
64	22 32	////	////	03 06	04 28	05 53	07 17
62	21 54	////	////	03 28	04 45	06 05	07 25
60	21 28	23 13	////	03 46	05 00	06 16	07 33
N 58	21 07	22 23	////	04 01	05 12	06 26	07 39
56	20 51	21 53	////	04 14	05 23	06 34	07 45
54	20 36	21 31	23 17	04 25	05 32	06 41	07 50
52	20 24	21 13	22 31	04 34	05 40	06 48	07 55
50	20 13	20 58	22 03	04 43	05 48	06 54	07 59
45	19 51	20 28	21 18	05 01	06 03	07 06	08 08
N 40	19 33	20 06	20 47	05 16	06 16	07 17	08 16
35	19 18	19 47	20 24	05 29	06 27	07 25	08 22
30	19 05	19 32	20 05	05 40	06 37	07 33	08 28
20	18 43	19 07	19 36	05 59	06 53	07 46	08 38
N 10	18 24	18 47	19 14	06 15	07 08	07 58	08 46
0	18 06	18 29	18 55	06 30	07 21	08 09	08 54
S 10	17 49	18 11	18 38	06 45	07 34	08 20	09 02
20	17 30	17 54	18 22	07 02	07 48	08 31	09 10
30	17 09	17 35	18 05	07 20	08 04	08 44	09 20
35	16 57	17 25	17 56	07 31	08 14	08 51	09 25
40	16 42	17 13	17 47	07 43	08 24	09 00	09 31
45	16 26	16 59	17 37	07 58	08 37	09 10	09 39
S 50	16 05	16 43	17 25	08 15	08 52	09 22	09 47
52	15 55	16 36	17 20	08 23	08 59	09 27	09 51
54	15 44	16 28	17 14	08 33	09 06	09 33	09 55
56	15 31	16 19	17 08	08 43	09 15	09 40	10 00
58	15 17	16 08	17 01	08 55	09 25	09 47	10 05
S 60	14 59	15 57	16 53	09 09	09 36	09 56	10 11

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	Age	Phase
	m s	m s	h m	h m	h m	d	
24	02 08	02 14	12 02	00 18	12 44	15	○
25	02 20	02 27	12 02	01 09	13 34	16	
26	02 33	02 39	12 03	01 58	14 21	17	

TABLE 2

1975 JUNE 24, 25, 26 (TUES., WED., THURS.)

G.M.T. d h	ARIES G.H.A.	VENUS −4.0 G.H.A.	VENUS Dec.	MARS +0.8 G.H.A.	MARS Dec.	JUPITER −1.9 G.H.A.	JUPITER Dec.	SATURN +0.3 G.H.A.	SATURN Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
24 00	271 31.7	131 25.4	N17 11.8	247 52.7	N 8 04.6	252 00.2	N 6 54.0	160 11.5	N21 55.3
01	286 34.1	146 25.6	10.9	262 53.5	05.3	267 02.3	54.1	175 13.6	55.3
02	301 36.6	161 25.9	10.0	277 54.2	06.0	282 04.4	54.3	190 15.8	55.2
03	316 39.1	176 26.1	·· 09.1	292 55.0	·· 06.6	297 06.6	·· 54.4	205 17.9	·· 55.2
04	331 41.5	191 26.4	08.3	307 55.8	07.3	312 08.7	54.5	220 20.0	55.2
05	346 44.0	206 26.6	07.4	322 56.6	07.9	327 10.8	54.7	235 22.2	55.1
06	1 46.5	221 26.9	N17 06.5	337 57.3	N 8 08.6	342 12.9	N 6 54.8	250 24.3	N21 55.1
07	16 48.9	236 27.1	05.6	352 58.1	09.3	357 15.0	54.9	265 26.4	55.0
T 08	31 51.4	251 27.4	04.8	7 58.9	09.9	12 17.2	55.0	280 28.5	55.0
U 09	46 53.9	266 27.7	·· 03.9	22 59.6	·· 10.6	27 19.3	·· 55.2	295 30.7	·· 55.0
E 10	61 56.3	281 27.9	03.0	38 00.4	11.2	42 21.4	55.3	310 32.8	54.9
S 11	76 58.8	296 28.2	02.1	53 01.2	11.9	57 23.5	55.4	325 34.9	54.9
D 12	92 01.2	311 28.5	N17 01.3	68 01.9	N 8 12.6	72 25.6	N 6 55.6	340 37.1	N21 54.8
A 13	107 03.7	326 28.7	17 00.4	83 02.7	13.2	87 27.8	55.7	355 39.2	54.8
Y 14	122 06.2	341 29.0	16 59.5	98 03.5	13.9	102 29.9	55.8	10 41.3	54.7
15	137 08.6	356 29.3	·· 58.6	113 04.2	·· 14.5	117 32.0	·· 55.9	25 43.4	·· 54.7
16	152 11.1	11 29.5	57.7	128 05.0	15.2	132 34.1	56.1	40 45.6	54.7
17	167 13.6	26 29.8	56.9	143 05.8	15.8	147 36.3	56.2	55 47.7	54.6
18	182 16.0	41 30.1	N16 56.0	158 06.6	N 8 16.5	162 38.4	N 6 56.3	70 49.8	N21 54.6
19	197 18.5	56 30.4	55.1	173 07.3	17.2	177 40.5	56.5	85 52.0	54.5
20	212 21.0	71 30.6	54.2	188 08.1	17.8	192 42.6	56.6	100 54.1	54.5
21	227 23.4	86 30.9	·· 53.3	203 08.9	·· 18.5	207 44.7	·· 56.7	115 56.2	·· 54.5
22	242 25.9	101 31.2	52.5	218 09.6	19.1	222 46.9	56.8	130 58.3	54.4
23	257 28.4	116 31.5	51.6	233 10.4	19.8	237 49.0	57.0	146 00.5	54.4
25 00	272 30.8	131 31.7	N16 50.7	248 11.2	N 8 20.5	252 51.1	N 6 57.1	161 02.6	N21 54.3
01	287 33.3	146 32.0	49.8	263 11.9	21.1	267 53.2	57.2	176 04.7	54.3
02	302 35.7	161 32.3	48.9	278 12.7	21.8	282 55.4	57.3	191 06.8	54.2
03	317 38.2	176 32.6	·· 48.1	293 13.5	·· 22.4	297 57.5	·· 57.5	206 09.0	·· 54.2
04	332 40.7	191 32.9	47.2	308 14.3	23.1	312 59.6	57.6	221 11.1	54.2
05	347 43.1	206 33.2	46.3	323 15.0	23.7	328 01.7	57.7	236 13.2	54.1
06	2 45.6	221 33.5	N16 45.4	338 15.8	N 8 24.4	343 03.9	N 6 57.9	251 15.4	N21 54.1
W 07	17 48.1	236 33.8	44.5	353 16.6	25.0	358 06.0	58.0	266 17.5	54.0
E 08	32 50.5	251 34.1	43.6	8 17.3	25.7	13 08.1	58.1	281 19.6	54.0
D 09	47 53.0	266 34.3	·· 42.7	23 18.1	·· 26.4	28 10.2	·· 58.2	296 21.7	·· 53.9
N 10	62 55.5	281 34.6	41.9	38 18.9	27.0	43 12.4	58.4	311 23.9	53.9
E 11	77 57.9	296 34.9	41.0	53 19.6	27.7	58 14.5	58.5	326 26.0	53.9
S 12	93 00.4	311 35.2	N16 40.1	68 20.4	N 8 28.3	73 16.6	N 6 58.6	341 28.1	N21 53.8
D 13	108 02.9	326 35.5	39.2	83 21.2	29.0	88 18.7	58.7	356 30.2	53.8
A 14	123 05.3	341 35.8	38.3	98 22.0	29.6	103 20.9	58.9	11 32.4	53.7
Y 15	138 07.8	356 36.1	·· 37.4	113 22.7	·· 30.3	118 23.0	·· 59.0	26 34.5	·· 53.7
16	153 10.2	11 36.4	36.5	128 23.5	30.9	133 25.1	59.1	41 36.6	53.6
17	168 12.7	26 36.7	35.7	143 24.3	31.6	148 27.2	59.2	56 38.8	53.6
18	183 15.2	41 37.1	N16 34.8	158 25.0	N 8 32.3	163 29.4	N 6 59.4	71 40.9	N21 53.6
19	198 17.6	56 37.4	33.9	173 25.8	32.9	178 31.5	59.5	86 43.0	53.5
20	213 20.1	71 37.7	33.0	188 26.6	33.6	193 33.6	59.6	101 45.1	53.5
21	228 22.6	86 38.0	·· 32.1	203 27.3	·· 34.2	208 35.8	·· 59.7	116 47.3	·· 53.4
22	243 25.0	101 38.3	31.2	218 28.1	34.9	223 37.9	6 59.9	131 49.4	53.4
23	258 27.5	116 38.6	30.3	233 28.9	35.5	238 40.0	7 00.0	146 51.5	53.3
26 00	273 30.0	131 38.9	N16 29.4	248 29.7	N 8 36.2	253 42.1	N 7 00.1	161 53.6	N21 53.3
01	288 32.4	146 39.2	28.5	263 30.4	36.8	268 44.3	00.2	176 55.8	53.3
02	303 34.9	161 39.6	27.7	278 31.2	37.5	283 46.4	00.4	191 57.9	53.2
03	318 37.4	176 39.9	·· 26.8	293 32.0	·· 38.1	298 48.5	·· 00.5	207 00.0	·· 53.2
04	333 39.8	191 40.2	25.9	308 32.7	38.8	313 50.7	00.6	222 02.1	53.1
05	348 42.3	206 40.5	25.0	323 33.5	39.4	328 52.8	00.7	237 04.3	53.1
06	3 44.7	221 40.8	N16 24.1	338 34.3	N 8 40.1	343 54.9	N 7 00.9	252 06.4	N21 53.1
07	18 47.2	236 41.2	23.2	353 35.1	40.7	358 57.0	01.0	267 08.5	53.0
T 08	33 49.7	251 41.5	22.3	8 35.8	41.4	13 59.2	01.1	282 10.7	53.0
H 09	48 52.1	266 41.8	·· 21.4	23 36.6	·· 42.0	29 01.3	·· 01.2	297 12.8	·· 52.9
U 10	63 54.6	281 42.1	20.5	38 37.4	42.7	44 03.4	01.4	312 14.9	52.9
R 11	78 57.1	296 42.5	19.6	53 38.1	43.3	59 05.6	01.5	327 17.0	52.8
S 12	93 59.5	311 42.8	N16 18.7	68 38.9	N 8 44.0	74 07.7	N 7 01.6	342 19.2	N21 52.8
D 13	109 02.0	326 43.1	17.8	83 39.7	44.6	89 09.8	01.7	357 21.3	52.8
A 14	124 04.5	341 43.5	16.9	98 40.4	45.3	104 12.0	01.9	12 23.4	52.7
Y 15	139 06.9	356 43.8	·· 16.0	113 41.2	·· 46.0	119 14.1	·· 02.0	27 25.5	·· 52.7
16	154 09.4	11 44.1	15.1	128 42.0	46.6	134 16.2	02.1	42 27.7	52.6
17	169 11.9	26 44.5	14.3	143 42.8	47.3	149 18.4	02.2	57 29.8	52.6
18	184 14.3	41 44.8	N16 13.4	158 43.5	N 8 47.9	164 20.5	N 7 02.3	72 31.9	N21 52.5
19	199 16.8	56 45.2	12.5	173 44.3	48.6	179 22.6	02.5	87 34.0	52.5
20	214 19.2	71 45.5	11.6	188 45.1	49.2	194 24.8	02.6	102 36.2	52.5
21	229 21.7	86 45.9	·· 10.7	203 45.8	·· 49.8	209 26.9	·· 02.7	117 38.3	·· 52.4
22	244 24.2	101 46.2	09.8	218 46.6	50.5	224 29.0	02.8	132 40.4	52.4
23	259 26.6	116 46.5	08.9	233 47.4	51.1	239 31.2	03.0	147 42.5	52.3
Mer. Pass.	h m 5 49.0	v 0.3	d 0.9	v 0.8	d 0.7	v 2.1	d 0.1	v 2.1	d 0.0

STARS Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 40.2	S40 24.0
Achernar	335 48.1	S57 21.3
Acrux	173 41.1	S62 58.2
Adhara	255 35.3	S28 56.4
Aldebaran	291 22.4	N16 27.6
Alioth	166 45.5	N56 05.8
Alkaid	153 21.1	N49 26.3
Al Na'ir	28 19.1	S47 04.5
Alnilam	276 15.6	S 1 13.1
Alphard	218 24.3	S 8 33.3
Alphecca	126 34.8	N26 47.9
Alpheratz	358 13.0	N28 57.3
Altair	62 35.7	N 8 48.3
Ankaa	353 43.8	S42 26.0
Antares	113 00.9	S26 22.8
Arcturus	146 21.5	N19 18.6
Atria	108 27.7	S68 59.2
Avior	234 30.2	S59 26.1
Bellatrix	279 02.9	N 6 19.6
Betelgeuse	271 32.4	N 7 24.1
Canopus	264 09.3	S52 41.0
Capella	281 17.0	N45 58.4
Deneb	49 50.5	N45 11.5
Denebola	183 02.7	N14 42.5
Diphda	349 24.5	S18 07.1
Dubhe	194 26.7	N61 53.2
Elnath	278 49.0	N28 35.2
Eltanin	90 58.8	N51 29.6
Enif	34 14.8	N 9 45.8
Fomalhaut	15 55.2	S29 44.9
Gacrux	172 32.6	S56 58.9
Gienah	176 21.6	S17 24.5
Hadar	149 28.0	S60 15.6
Hamal	328 33.1	N23 20.8
Kaus Aust.	84 21.1	S34 23.8
Kochab	137 18.0	N74 15.6
Markab	14 06.6	N15 04.4
Menkar	314 45.1	N 3 59.7
Menkent	148 41.0	S36 15.2
Miaplacidus	221 46.4	S69 37.3
Mirfak	309 21.5	N49 46.3
Nunki	76 33.2	S26 19.6
Peacock	54 03.4	S56 48.6
Pollux	244 02.8	N28 05.1
Procyon	245 29.8	N 5 17.2
Rasalhague	96 32.5	N12 34.7
Regulus	208 13.9	N12 05.2
Rigel	281 39.7	S 8 13.8
Rigil Kent.	140 30.2	S60 44.3
Sabik	102 44.9	S15 41.7
Schedar	350 13.1	N56 24.0
Shaula	97 00.1	S37 05.2
Sirius	258 59.2	S16 41.0
Spica	159 01.2	S11 02.1
Suhail	223 13.7	S43 20.3
Vega	80 57.8	N38 45.7
Zuben'ubi	137 36.7	S15 56.5

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	219 00.9	15 14
Mars	335 40.4	7 27
Jupiter	340 20.3	7 08
Saturn	248 31.8	13 14

TABLE 3

A2 ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

SUN

OCT.—MAR. App. Alt.	Lower Limb	Upper Limb	APR.—SEPT. App. Alt.	Lower Limb	Upper Limb
° ′	′	′	° ′	′	′
9 34			9 39		
	+10·8	−21·5		+10·6	−21·2
9 45			9 51		
	+10·9	−21·4		+10·7	−21·1
9 56			10 03		
	+11·0	−21·3		+10·8	−21·0
10 08			10 15		
	+11·1	−21·2		+10·9	−20·9
10 21			10 27		
	+11·2	−21·1		+11·0	−20·8
10 34			10 40		
	+11·3	−21·0		+11·1	−20·7
10 47			10 54		
	+11·4	−20·9		+11·2	−20·6
11 01			11 08		
	+11·5	−20·8		+11·3	−20·5
11 15			11 23		
	+11·6	−20·7		+11·4	−20·4
11 30			11 38		
	+11·7	−20·6		+11·5	−20·3
11 46			11 54		
	+11·8	−20·5		+11·6	−20·2
12 02			12 10		
	+11·9	−20·4		+11·7	−20·1
12 19			12 28		
	+12·0	−20·3		+11·8	−20·0
12 37			12 46		
	+12·1	−20·2		+11·9	−19·9
12 55			13 05		
	+12·2	−20·1		+12·0	−19·8
13 14			13 24		
	+12·3	−20·0		+12·1	−19·7
13 35			13 45		
	+12·4	−19·9		+12·2	−19·6
13 56			14 07		
	+12·5	−19·8		+12·3	−19·5
14 18			14 30		
	+12·6	−19·7		+12·4	−19·4
14 42			14 54		
	+12·7	−19·6		+12·5	−19·3
15 06			15 19		
	+12·8	−19·5		+12·6	−19·2
15 32			15 46		
	+12·9	−19·4		+12·7	−19·1
15 59			16 14		
	+13·0	−19·3		+12·8	−19·0
16 28			16 44		
	+13·1	−19·2		+12·9	−18·9
16 59			17 15		
	+13·2	−19·1		+13·0	−18·8
17 32			17 48		
	+13·3	−19·0		+13·1	−18·7
18 06			18 24		
	+13·4	−18·9		+13·2	−18·6
18 42			19 01		
	+13·5	−18·8		+13·3	−18·5
19 21			19 42		
	+13·6	−18·7		+13·4	−18·4
20 03			20 25		
	+13·7	−18·6		+13·5	−18·3
20 48			21 11		
	+13·8	−18·5		+13·6	−18·2
21 35			22 00		
	+13·9	−18·4		+13·7	−18·1
22 26			22 54		
	+14·0	−18·3		+13·8	−18·0
23 22			23 51		
	+14·1	−18·2		+13·9	−17·9
24 21			24 53		
	+14·2	−18·1		+14·0	−17·8
25 26			26 00		
	+14·3	−18·0		+14·1	−17·7
26 36			27 13		
	+14·4	−17·9		+14·2	−17·6
27 52			28 33		
	+14·5	−17·8		+14·3	−17·5
29 15			30 00		
	+14·6	−17·7		+14·4	−17·4
30 46			31 35		
	+14·7	−17·6		+14·5	−17·3
32 26			33 20		
	+14·8	−17·5		+14·6	−17·2
34 17			35 17		
	+14·9	−17·4		+14·7	−17·1
36 20			37 26		
	+15·0	−17·3		+14·8	−17·0
38 36			39 50		
	+15·1	−17·2		+14·9	−16·9
41 08			42 31		
	+15·2	−17·1		+15·0	−16·8
43 59			45 31		
	+15·3	−17·0		+15·1	−16·7
47 10			48 55		
	+15·4	−16·9		+15·2	−16·6
50 46			52 44		
	+15·5	−16·8		+15·3	−16·5
54 49			57 02		
	+15·6	−16·7		+15·4	−16·4
59 23			61 51		
	+15·7	−16·6		+15·5	−16·3
64 30			67 17		
	+15·8	−16·5		+15·6	−16·2
70 12			73 16		
	+15·9	−16·4		+15·7	−16·1
76 26			79 43		
	+16·0	−16·3		+15·8	−16·0
83 05			86 32		
	+16·1	−16·2		+15·9	−15·9
90 00			90 00		

STARS AND PLANETS

App. Alt.	Corr^n
° ′	′
9 56	
	−5·3
10 08	
	−5·2
10 20	
	−5·1
10 33	
	−5·0
10 46	
	−4·9
11 00	
	−4·8
11 14	
	−4·7
11 29	
	−4·6
11 45	
	−4·5
12 01	
	−4·4
12 18	
	−4·3
12 35	
	−4·2
12 54	
	−4·1
13 13	
	−4·0
13 33	
	−3·9
13 54	
	−3·8
14 16	
	−3·7
14 40	
	−3·6
15 04	
	−3·5
15 30	
	−3·4
15 57	
	−3·3
16 26	
	−3·2
16 56	
	−3·1
17 28	
	−3·0
18 02	
	−2·9
18 38	
	−2·8
19 17	
	−2·7
19 58	
	−2·6
20 42	
	−2·5
21 28	
	−2·4
22 19	
	−2·3
23 13	
	−2·2
24 11	
	−2·1
25 14	
	−2·0
26 22	
	−1·9
27 36	
	−1·8
28 56	
	−1·7
30 24	
	−1·6
32 00	
	−1·5
33 45	
	−1·4
35 40	
	−1·3
37 48	
	−1·2
40 08	
	−1·1
42 44	
	−1·0
45 36	
	−0·9
48 47	
	−0·8
52 18	
	−0·7
56 11	
	−0·6
60 28	
	−0·5
65 08	
	−0·4
70 11	
	−0·3
75 34	
	−0·2
81 13	
	−0·1
87 03	
	0·0
90 00	

App. Alt.	Additional Corr^n
1975	
VENUS	
Jan. 1 – June 7	
0°	
	+0′·1
42	
June 8 – July 21	
0°	
	+0′·3
46	
July 22 – Aug. 6	
0°	
	+0′·4
11	
	+0·5
41	
Aug. 7 – Aug. 15	
0°	
	+0′·5
6	
	+0·6
20	
	+0·7
31	
Aug. 16 – Sept. 10	
0°	
	+0′·6
4	
	+0·7
12	
	+0·8
22	
Sept. 11 – Sept. 19	
0°	
	+0′·5
6	
	+0·6
20	
	+0·7
31	
Sept. 20 – Oct. 5	
0°	
	+0′·4
11	
	+0·5
41	
Oct. 6 – Nov. 22	
0°	
	+0′·3
46	
Nov. 23 – Dec. 31	
0°	
	+0′·1
42	
MARS	
Jan. 1 – Sept. 8	
0°	
	+0′·1
60	
Sept. 9 – Nov. 22	
0°	
	+0′·2
41	
	+0·1
75	
Nov. 23 – Dec. 31	
0°	
	+0′·3
34	
	+0·2
60	
	+0·1
80	

DIP

Ht. of Eye (m)	Corr^n	Ht. of Eye (ft.)
2·4		8·0
	−2′·8	
2·6		8·6
	−2·9	
2·8		9·2
	−3·0	
3·0		9·8
	−3·1	
3·2		10·5
	−3·2	
3·4		11·2
	−3·3	
3·6		11·9
	−3·4	
3·8		12·6
	−3·5	
4·0		13·3
	−3·6	
4·3		14·1
	−3·7	
4·5		14·9
	−3·8	
4·7		15·7
	−3·9	
5·0		16·5
	−4·0	
5·2		17·4
	−4·1	
5·5		18·3
	−4·2	
5·8		19·1
	−4·3	
6·1		20·1
	−4·4	
6·3		21·0
	−4·5	
6·6		22·0
	−4·6	
6·9		22·9
	−4·7	
7·2		23·9
	−4·8	
7·5		24·9
	−4·9	
7·9		26·0
	−5·0	
8·2		27·1
	−5·1	
8·5		28·1
	−5·2	
8·8		29·2
	−5·3	
9·2		30·4
	−5·4	
9·5		31·5
	−5·5	
9·9		32·7
	−5·6	
10·3		33·9
	−5·7	
10·6		35·1
	−5·8	
11·0		36·3
	−5·9	
11·4		37·6
	−6·0	
11·8		38·9
	−6·1	
12·2		40·1
	−6·2	
12·6		41·5
	−6·3	
13·0		42·8
	−6·4	
13·4		44·2
	−6·5	
13·8		45·5
	−6·6	
14·2		46·9
	−6·7	
14·7		48·4
	−6·8	
15·1		49·8
	−6·9	
15·5		51·3
	−7·0	
16·0		52·8
	−7·1	
16·5		54·3
	−7·2	
16·9		55·8
	−7·3	
17·4		57·4
	−7·4	
17·9		58·9
	−7·5	
18·4		60·5
	−7·6	
18·8		62·1
	−7·7	
19·3		63·8
	−7·8	
19·8		65·4
	−7·9	
20·4		67·1
	−8·0	
20·9		68·8
	−8·1	
21·4		70·5

Ht. of Eye	Corr^n
m	′
1·0	−1·8
1·5	−2·2
2·0	−2·5
2·5	−2·8
3·0	−3·0
See table ←	
m	′
20	−7·9
22	−8·3
24	−8·6
26	−9·0
28	−9·3
30	−9·6
32	−10·0
34	−10·3
36	−10·6
38	−10·8
40	−11·1
42	−11·4
44	−11·7
46	−11·9
48	−12·2
ft.	′
2	−1·4
4	−1·9
6	−2·4
8	−2·7
10	−3·1
See table ←	
ft.	′
70	−8·1
75	−8·4
80	−8·7
85	−8·9
90	−9·2
95	−9·5
100	−9·7
105	−9·9
110	−10·2
115	−10·4
120	−10·6
125	−10·8
130	−11·1
135	−11·3
140	−11·5
145	−11·7
150	−11·9
155	−12·1

App. Alt. = Apparent altitude = Sextant altitude corrected for index error and dip.
For daylight observations of Venus, see page 260.

TIME OF SUNRISE/SUNSET/TWILIGHT

The navigator observes planets and stars during that part of the day when the bodies and the horizon are both visible. These periods of time occurring right around the time the sun rises or sets are called twilight. Because it is important for the navigator to be on deck and ready to observe celestial bodies during this time and because the times of these events are constantly changing, he needs a reasonably accurate way to predict their occurence.

Given a reasonably accurate dead reckoning (DR) track, these programs should enable the navigator to predict the times of sunrise, sunset, and a.m. and p.m. twilight within several minutes. If the DR track is in doubt, the navigator should plan to be on deck ready to observe celestial bodies several minutes earlier than the programs might otherwise indicate.

When using this program, the navigator should use his DR position to estimate where he expects to be about the time of the desired event. Then, consulting the appropriate daily page of the *Almanac,* he should take the following data from the twilight/sunrise (sunset) tables:

1. The tabulated latitude (whole degrees) which is at or above the projected DR latitude.
2. The tabulated latitude (whole degrees) which is below the projected DR latitude.

In other words, the two tabulated latitudes should bracket the DR latitude where the navigator expects to be when the desired event occurs. While in this table, the navigator should also take out the times (GMT) corresponding to the desired event for the two tabulated latitudes. The navigator should use the twilight/sunrise data from the top half of the page if he desires an a.m. event, and the sunset/twilight data from the bottom half if he desires a p.m. event. The navigator should also note that the twilight/sunrise and sunset/twilight data is given once for the 3-day period covered by each daily page.

After completing the program for the GMT of one a.m. or p.m. event, the navigator can obtain the GMT for the other a.m. or p.m. event by simply taking out the times listed for the other event and entering them in steps 7 and 8.

This program is designed to be used by itself or in conjunction with the **PLANET LOCATION** program. When used with this program, the DR latitude, longitude and GMT are stored automatically and, therefore, need not be reentered. To use these programs together as a system, the navigator first calculates the GMT for either a.m. or p.m. twilight and then uses the planet location program to identify the approximate azimuth (true direction) and altitude (sextant reading).

The projected time is calculated by the following equation:

$$\text{GMT} = \left[0.558\left(\frac{L_1 - L_{DR}}{L_1 - L_2}\right)^2 + 0.337\left(\frac{L_1 - L_{DR}}{L_1 - L_2}\right) + 0.024\right](t_2 - t_1) + t_1 + (\lambda_{DR}/15).$$

The variables used in the above equation are:

λ_{DR} = dead reckoning longitude,

L_{DR} = dead reckoning latitude,

L_1 = tabular value of latitude at or above L_{DR},

L_2 = tabular value of latitude below L_{DR},

t_1 = time of event at L_1, and

t_2 = time of event at L_2.

Solid State Software			TI ©1977	
SUNRISE, SUNSET, TWILIGHT			NG-15	
t_2	→GMT			
L_{DR}	λ_{DR}	L_1	L_2	t_1

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 15	
2	Select degree mode.		[2nd] [Deg]	
3	Enter dead reckoning latitude (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR}
4	Enter dead reckoning longitude (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR}
5	Enter tabulated latitude at or above L_{DR} (+N, −S).	L_1 (DD)	[C]	L_1
6	Enter tabulated latitude below L_{DR} (+N, −S).	L_2 (DD)	[D]	L_2
7	Enter tabulated time for L_1.	t_1 (HH.MM)	[E]	t_1 (HH.hh)
8	Enter tabulated time for L_2.	t_2 (HH.MM)	[2nd] [A′]	t_2 (HH.hh)
9	Compute time of event at DR position		[2nd] [B′]	GMT (HH.MMSSs)

NOTES:
1. Data may be corrected by reentry.
2. Steps 7–9 may be repeated as necessary.
3. If GMT ⩾ 24, subtract 24 for the proper result.
4. Printer usage is optional.

EXAMPLE: Determine the GMT of a.m. civil twilight and sunrise for June 24, 1975 assuming a dead reckoning position of 34° 40′ N, 71° 15′ W.

From table 1:

L_1 = 35°N, t_1 (sunrise) = 4:47, t_1 (a.m. civil twilight) = 4:17,
L_2 = 30°N, t_2 (sunrise) = 5:00, t_2 (a.m. civil twilight) = 4:33.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 15		
	[2nd] [Deg]		
3440†	[A]	34.66666667	L_{DR}
7115†	[B]	71.25	λ_{DR}
35†	[C]	35.	L_1
30†	[D]	30.	L_2
4.47†	[E]	4.783333333	t_1 (sunrise)
5†	[2nd] [A′]	5.	t_2 (sunrise)
	[2nd] [B′]	9.33462256†	GMT (HH.MMSSs)
4.17†	[E]	4.283333333	t_1 (civil twilight)
4.33†	[2nd] [A′]	4.55	t_2 (civil twilight)
	[2nd] [B′]	9.04107392†	GMT (HH.MMSSs)

Register Contents

R_{00} GMT	R_{05} t_2	R_{10} Used	R_{15}
R_{01} L_{DR}	R_{06} λ_{DR}	R_{11}	R_{16}
R_{02} L_1	R_{07} MS	R_{12}	R_{17}
R_{03} L_2	R_{08} Used	R_{13}	R_{18}
R_{04} t_1	R_{09} Used	R_{14}	R_{19}

† Printed if PC-100A is connected.

PLANET LOCATION

The four navigational planets (Venus, Mars, Jupiter, and Saturn) are very helpful to the navigator when they are visible during either a.m. or p.m. twilight. The planets generally appear among the brighter objects in the sky emitting a warm, brilliant, steady light that distinguishes them from stars which emit a bluish, twinkling light.

The planet location program is important for three reasons:

1. It tells the navigator which planets he will have available (i.e., above the horizon).
2. It enables the navigator to distinguish the navigational planets from stars.
3. It tells the navigator approximately where to look, and how to initially adjust his sextant to find the planets.

This program is designed to be used by itself or in conjunction with the **TIME OF SUNSET/ SUNRISE/TWILIGHT** program. When used with NG-15, the navigator does not need to reenter the coordinates and time of his dead reckoning position.

The Greenwich hour angle (GHA) of the desired planet should be extracted for the whole hours of GMT for a.m. or p.m. twilight of the day of observation. Information on how to extract data for planets from the *Nautical Almanac* is found on pages 79-80. Usually, the navigator of slower yachts will obtain sufficient accuracy if he uses the GMT of the previous day's a.m. or p.m. twilight for his entry. The increments (minutes and seconds) of the previous day's GMT are entered in step 5. However, the navigator of faster vessels, particularly those steaming on east-west courses, would be advised to use NG-15 to obtain a more accurate estimate of GMT. Navigators on vessels of this type should also estimate the location of the planets every day. Since the location of the planets changes relatively slowly, particularly for smaller vessels such as yachts under sail, navigators on these vessels need only predict the location of planets every several days.

The skipper of a yacht may want to estimate the location of the planets for the duration of a voyage. The best way to do this is to obtain planet location data for the mid-week of each expected week of a voyage. The navigator, of course, will have to project his vessel's progress (when sailing the great circle route, program NG-26 may be of use here) and assume a DR position for the mid-week of each week of the trip. As long as the vessel's actual progress is within several hundred miles of the planning DR, the planet data will be sufficiently accurate to help the navigator locate the bodies.

The outputs of this program are the approximate altitude (sextant angle) and the azimuth or true direction of the planet. With this data, the navigator can pre-set his sextant to the indicated altitude, and sweep the horizon at twilight in the general azimuth (true) direction indicated to easily find the planet.

The print cradle can be useful, particularly when forecasting the positions of the planets for an extended trip.

The calculations performed by this program are:

$$LHA = GHA - \lambda_{DR} + (\nu + 15)\ MS,$$

$$Dec' = Dec + (d \times MS),$$

$$HC = \sin^{-1}\ [\sin(L_{DR})\sin(Dec') + \cos(L_{DR})\cos(Dec')\cos(LHA)],$$

$$Zn = \cos^{-1}\left[\frac{\sin(Dec') - \sin(L_{DR})\sin(Hc)}{\cos(Hc)\cos(L_{DR})}\right].$$

In the above equations:

L_{DR} = latitude of dead reckoning position,

λ_{DR} = longitude of dead reckoning position,

MS = minutes and seconds of GMT at DR position,

ν, d = corrections taken from tables,

GHA = Greenwich hour angle,

LHA = local hour angle,

Dec = declination of planet,

Hc = estimated altitude, and

Zn = estimated azimuth.

REMARKS

1. If the navigator obtains a negative altitude, that means that the particular planet at that time is below the visible horizon and obviously will not be available for use.
2. The navigator using a vessel's compass to locate planets should be aware of any significant variation and/or deviation in these instruments.

Solid State Software			TI ©1977	
PLANET LOCATION				NG-16
d	Dec→Hc	→Zn		
L_{DR}	λ_{DR}	GMT(MS)	ν	GHA

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 16	
2	Select degree mode.		[2nd] [Deg]	
3	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR}
4	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR}
5	Enter minutes and seconds of estimated GMT at DR position.	MS (.MMSS)	[C]	MS (.hh)
6	Enter ν correction.	ν (M.m)	[D]	intermediate calculation
7	Enter GHS of desired planet at twilight.	GHA (DDDMM.m)	[E]	sin LHA
8	Enter *d* correction.	*d* (M.m)	[2nd] [A′]	MS (.hh)
9	Enter declination of desired planet (+N, −S) and compute estimated altitude.	Dec (DDMM.m)	[2nd] [B′]	Hc (DDMM.m)
10	Compute estimated azimuth.		[2nd] [C′]	Zn (DDD.ddd)

NOTES:
1. If GHA is entered incorrectly, press [INV] [2nd] [St Flg] [0] and reenter. Remaining data may be corrected by reentry.
2. If data for more than one planet for same time and DR position is desired, after completing the work for the first planet, repeat Steps 6 through 10.
3. Use of printer is optional.

Register Contents

R_{00} GMT	R_{05} Used	R_{10}	R_{15}
R_{01} L_{DR}	R_{06} λ_{DR}	R_{11} LHA	R_{16}
R_{02} d · MS	R_{07} MS	R_{12} Dec	R_{17}
R_{03} Used	R_{08}	R_{13}	R_{18}
R_{04} Hc	R_{09}	R_{14}	R_{19}

EXAMPLE: Having used NG1-18 to find the GMT of a.m. civil twilight on June 24, 1975 at a DR position of 34° 40′ N, 71° 15′ W, determine which planets will be visible at the above time by finding the approximate altitude (Hc) and azimuth (Zn) of each.

The following data must first be extracted from table 2. (See page 80 for instructions.)

	GHA	Dec	v	d
Venus	266° 27.7′	17° 03.9′ N (decreasing)	0.3′	−0.9′
Mars	22° 59.6′	8° 10.6′ N (increasing)	0.8′	0.7′
Jupiter	27° 19.3′	6° 55.2′ N (increasing)	2.1′	0.1′
Saturn	295° 30.7′	21° 55.0′ N (decreasing)	2.1′	0.0′

Table 4.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 16		
	[2nd] [Deg]		
3440*†	[A]	34.66666667	L_{DR}
7115*†	[B]	71.25	λ_{DR}
.04107392*†	[C]	.0696497778	MS
			Venus
.3†	[D]	1.045094916	v
26627.7†	[E]	−.2799423094	GHA
.9†	[+/−] [2nd] [A′]	.0696497778	d → MS
1703.9†	[2nd] [B′]	−3600.590947†	Dec → Hc (DDMM.m)
	[2nd] [C′]	19.3194929†	Zn (DDD.dd)
			Mars
.8†	[D]	1.04567533	v
2259.6†	[E]	−.7338601916	GHA
.7†	[2nd] [A′]	.0696497778	d → MS
810.6†	[2nd] [B′]	3920.457025†	Dec → Hc (DDMM.m)
	[2nd] [C′]	110.0753272†	Zn (DDD.dd)
			Jupiter
2.1†	[D]	1.047184409	v
2719.3†	[E]	−.6804798157	GHA
.1†	[2nd] [A′]	.0696497778	d → MS
655.2†	[2nd] [B′]	4149.353708†	Dec → Hc (DDMM.m)
	[2nd] [C′]	114.9766342†	Zn (DDD.dd)
			Saturn
2.1†	[D]	1.047184409	v
29530.7†	[E]	−.7109081261	GHA
0†	[2nd] [A′]	.0696497778	d → MS
2155.0†	[2nd] [B′]	−1855.472556†	Dec → Hc (DDMM.m)
	[2nd] [C′]	44.20402805†	Zn (DDD.dd)

*Does nto need to be entered if memory registers were left undisturbed following calculation by NG-15. Note that the GMT of twilight must be calculated last.

†Printed if PC-100A is connected.

STAR IDENTIFICATION

One of the more troublesome areas of celestial navigation involves proper identification of stars once they have been observed during a.m. or p.m. twilight.

As a practical matter, there will usually only be a limited number of stars observable each morning or evening. As a rule, these tend to be the most significant or major stars. The editors of the *Nautical Almanac* have alphabetically listed 57 selected navigational stars at the right hand of the stars-planets section of the daily pages. The *Almanac* also contains similar data for 173 other stars in the back of the book.

When working with the start identification program, the navigator should follow this procedure:

1. Observe a star with the sextant.
2. Record the GMT date/time, DR latitude and longitude, GMT minutes/seconds, the GHA of Aries (for the whole hours of GMT), and the uncorrected sextant reading (Hs) on a standard sight reduction workform.
3. The approximate azimuth (true compass direction) of the star should also be recorded by using a hand bearing compass. The reading should be corrected for local variation.
4. The data from the worksheet is then entered into the calculator as indicated. The program calculates the *approximate* SHA of the star you observed. To find out which star you have observed, consult the SHA-declination values (table 2) listed for the 57 selected stars on the appropriate daily page to find a star whose tabulated SHA and declination closely matches the *approximate* values. If a match cannot be found from the stars listed on the daily pages, consult the more detailed listing at the back of the *Almanac*.
5. Record the tabulated Declination and SHA on the workform and proceed with the normal sextant correction and star sight reduction programs.

The following formulas are used in computing the program outputs:

$$LHA = \lambda_{DR} - 15.042\ (MS) - GHA\ \Upsilon,$$

$$Dec = \sin^{-1}\ [\sin(L_{DR})\sin(Hs) + \cos(L_{DR})\cos(Hs)\cos(Zn)],$$

$$SHA = \cos^{-1}\left(\frac{\sin(Hs) - \sin(L_{DR})\sin(Dec)}{\cos(L_{DR})\cos(Dec)}\right) + LHA.$$

The variables in the above equations are defined as:

L_{DR} = latitude of dead reckoning position,
λ_{DR} = longitude of dead reckoning position,
Hs = sextant altitude,
Zn = observed azimuth,
GHA Υ = Greenwich hour angle of Aires,
LHA = local hour angle, and
MS = minutes and seconds of GMT at DR position.

Solid State Software			TI ©1977	
STAR IDENTIFICATION				NG-17
GMT (MS)	→Dec	→SHA	INIT	
L_{DR}	λ_{DR}	Hs	Obs Zn	GHA ♈

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 17	
2	Select degree mode.		[2nd] [Deg]	
3	Initialize.		[2nd] [D']	0.
4	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR} (DD.dd)
5	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDMM.m)	[B]	λ_{DR} (DD.dd)
6	Enter sextant reading.	Hs (DDMM.m)	[C]	Hs (DD.dd)
7	Enter observed azimuth.	Zn (DDD)	[D]	Zn
8	Enter Greenwich hour angle of Aries.	GHA ♈(DDDMM.m)	[E]	GHA ♈ (DDD.dd)
9	Enter minutes and seconds of GMT at DR position.	MS (.MMSSs)	[2nd] [A']	MS (.hh)
10	Compute estimated declination (+N, −S).		[2nd] [B']	Dec (DDMM.m)
11	Compute sidereal hour angle of star.		[2nd] [C']	SHA (DDDMM.m)

NOTES:
1. If Zn is entered incorrectly, press [INV] [2nd] [St Flg] [0] and reenter. Remaining data may be corrected by reentry.
2. The print cradle may be used with this program.

EXAMPLE: At 9:19:21 GMT on June 24, 1975 you observed a star from a DR position of 34° 40′ N, 71° 15′ W. The uncorrected sextant altitude was 41° 25′ and the approximate azimuth (true direction) of the star was 290°. Identify the star. (The GHA of Aries may be found in table 2.)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 17		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [D′]	0.	Initialize
3440†	[A]	34.66666667	L_{DR}
7115†	[B]	71.25	λ_{DR}
4125†	[C]	41.41666667	Hs
290†	[D]	290	Zn
4653.9†	[E]	46.89833333	GHA ♈
.1921†	[2nd] [A′]	0.3225	MS
	[2nd] [B′]	3557.659592†	Dec (DDMM.m)
	[2nd] [C′]	8001.874919†	SHA (DDMM.m)

Vega, with a SHA of 80° 57.8′ and a declination of 38° 45.7′ N is closest to the above approximation. (See table 2.)

Register Contents

R_{00}		R_{05}	Dec	R_{10}		R_{15}	
R_{01}	L_{DR}	R_{06}	λ_{DR}	R_{11}		R_{16}	
R_{02}	Hs	R_{07}	Used	R_{12}		R_{17}	
R_{03}	Zn	R_{08}	MS	R_{13}		R_{18}	
R_{04}	GHA ♈	R_{09}	-LHA	R_{14}		R_{19}	

† Printed if PC-100A is connected.

SEXTANT CORRECTION

After the navigator has observed a celestial body and recorded the time and sextant reading, the reading must be corrected and adjusted for a number of factors. This program is designed to apply these corrections and adjustments to the reading in computing the observed altitude (Ho) which is then stored in the calculator and may be used later with a sight reduction program or NG-25.

The sextant correction workform may be used to organize the data for entry into the calculator. First, you fill out the general information at the top of the workform. This indicates the name or kind of body you observed, the date (Greenwich), the upper or lower limb if the body was the sun or moon, and the watch time, corrected for watch errors to produce GMT.

The form's input data is organized according to its chronological entry into the program. The step reference numbers at the left of the workform correspond to the step-procedure instructions of the program.

The workform is organized to help the navigator handle the decimal point when entering data. There is also space at the bottom of the form to record the program output, your corrected sextant reading (Ho).

To record the input data, you begin by entering the sextant reading (Hs) from the instrument.

The uncorrectible instrument error of your particular sextant for that reading will be noted on the certificate, usually found inside the lid of the sextant case.

The index correction, which can be positive or negative, adjusts the reading for the fact that the index mirror and horizon glass may not be parallel. You find the index error by:

1. Setting the instrument to zero.
2. Looking at the horizon to determine if it appears as a single or broken line.
3. Adjusting the sextant to form a single horizon line if the "zero setting" produced a broken line.
4. Noting how many minutes/tenths must be added or subtracted to return the setting to zero.

The additional sextant corrections for Venus and Mars are given in the middle column of page A-2, Altitude Corrections for Sun, Stars and Planets of the *Nautical Almanac.* You will find these corrections on the inside cover at the front of each year's *Almanac.* Table 3, reprinted from the 1975 *Nautical Almanac*, shows how this table is organized.

The Semi-Diameter (SD) of the sun or moon is found on the right hand side of the white (daily) pages of the *Nautical Almanac*. The information will be found at the bottom of the page. One entry is given for the sun for the three-day period covered by each page, and three entries, one for each day, are given for the moon. Table 2 is an extract of the 1975 *Almanac* for June 24, 25 and 26 which shows that the SD for the sun for any of those three days is 15.8′. The SD for the moon for June 24 is 15.3′, for June 25, 15.1′ and for June 26, 15.0′.

The height of the navigator's eye above the water at the time of observation is recorded in feet. This information will be entered into the calculator to correct the sextant reading for the fact that the observer's eye was above sea level.

The horizontal parallax (HP) adjusts the reading for the special characteristics of the moon. HP is given in the daily pages of the *Almanac* for each whole hour of GMT of the moon as illustrated by table 1.

Non-Standard Conditions

Extreme conditions are defined as very high (above 90° F) or very low (below 30° F) temperature; very high (above 30.5 inches) or very low (below 29.5 inches) barometric pressure.

Since such conditions affect the sextant reading, the sextant correction program can adjust the reading for these extremes.

If you find your observations involve extreme temperatures or barometric conditions, enter the air temperature (in degrees Fahrenheit) and barometric pressure (in inches) in steps 12 and 13. If conditions are standard, ignore these steps and proceed with the program.

Very low altitude sightings (e.g., below 10°) are considered by many navigators as inherently unreliable. If, however, you are forced to use a low altitude sight, it is a good idea to use the prevailing temperature and barometric pressure components of the program even if conditions appear normal as low altitude sights are more sensitive to variations of pressure and temperature.

Once you have taken a sight, recorded the data, and completed the sextant correction program according to the instructions, the corrected sextant reading (Ho) will be automatically stored in your calculator's data memory. The navigator should jot down the corrected sextant reading Ho (DD.MMSS0 in the program output space on the workform in case Ho must be entered manually due to a data entry error in the sight reduction program which required clearing the calculator memories. You are then ready to proceed with the appropriate sun, moon, star, planet sight or noon sight reduction program.

The following formula is used to determine the observed altitude:

$$Ho = Hs + IE + IC - D + SD - Rm + T' - P' + HP\,[\cos(ha - Rm)].$$

The variables are defined as:

Ho = observed altitude,

Hs = sextant reading,

IE = instrument error,

IC = index correction,

D = dip = $0.01617\sqrt{\text{height of eye in feet}}$,

SD = semi-diameter of sun or moon,

$$Rm = \text{mean refraction} = \begin{cases} 0.00117 + 0.0154/\tan ha & \text{if } ha \geqslant 8^\circ, \\ 0.0236 + 0.0119/\tan ha & \text{if } ha < 8^\circ, \end{cases}$$

T' = air temperature correction = $Rm\,[1 - 510/(460 + T)]$,

T = temperature of air, °F,

P' = barometric pressure correction = $Rm\,(1 - P/29.83)$,

P = barometric pressure,

$ha = Hs + IE + IC - D + SD$, and

HP = horizontal parallax.

REMARK

This program may be used to compute and store up to six sights for use in programs NG-19 through 22.

Solid State Software				TI ©1977
SEXTANT CORRECTION				NG-18
T	P	→Ho	STORE Ho	INIT
Hs, SC	LL	SD	EYE	HP

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 18	
2	Select degree mode.		[2nd] [Deg]	
3	Initialize. (Perform 4-15 for each sight.)		[2nd] [E′]	0.
4	Enter sextant reading.	Hs (DDMM.m)	[A]	Hs (DD.dd)
5	Enter instrument error.	IE (MM.m)	[A]	IE (.dd)
6	Enter index correction.	IC (MM.m)	[A]	IC).dd)
7	Enter additional correction for Venus or Mars.	♂, ♀ (MM.m)	[A]	♂, ♀ (.dd)
8	Perform this step only if you observed the lower limb of the sun or moon.		[B]	♂, ♀ (.dd)
9	Enter semi-diameter of the sun or moon.	SD (MM.m)	[C]	±SD (.dd)
10	Enter height of eye above water.	EYE (ft)	[D]	Rm (.dd)
11	Enter horizontal parallax (moon only).	HP (MM.m)	[E]	HP [cos (ha - RM)]
12	Enter air temperature.	T (°F)	[2nd] [A′]	T′
13	Enter barometric pressure.	P (inches)	[2nd] [B′]	P′
14	Compute observed altitude.		[2nd] [C′]	Ho (DD.MMSSs)
15	Store Ho.		[2nd] [D′]	sight no.

NOTES:

1. If [B] is erroneously pressed, correct by pressing [INV] [2nd] [St flg] [0].
2. If [2nd] [D′] is pressed at the wrong time, press [INV] [2nd] [St flg] [0] [2] [INV] [SUM] [0] [0] [1] [INV] [SUM] [0] [3] and return to Step 4. (If the error is made on the first sight, simply initialize and begin again.)
3. Program space will not allow simple corrections, therefore, for any data entry error, press [INV] [2nd] [St flg] [0] [0] [STO] [0] [4] and return to Step 4. Do not initialize the program again as the altitudes will then be improperly stored.
4. Do not initialize the program between sights as this will cause improper storage of the observed altitudes when stacking.
5. The print cradle may be used with this program.

Register Contents

R_{00} Pointer	R_{05}	R_{10} Ho_2	R_{15}	R_{20} Pointer
R_{01}	R_{06}	R_{11}	R_{16} Ho_5	R_{21} Pointer
R_{02} Rm	R_{07}	R_{12} Ho_3	R_{17}	
R_{03} Sight no.	R_{08} Ho_1	R_{13}	R_{18} Ho_6	
R_{04} Used	R_{09}	R_{14} Ho_4	R_{19}	

SEXTANT CORRECTION WORKFORM FOR SUN, MOON, STAR AND PLANET SIGHTS

(For Use With Sextant Correction Program NG-18)

SIGHT # ____________ WATCH TIME ______ Hrs. . ______ Mins. ______ Secs.

BODY ____________ DATE ____________ (Greenwich) WATCH ERROR (− fast +slow) ______ Mins. ______ Secs.

LIMB Upper ________ Lower ____________ GMT ______ Hrs. . ______ Mins. ______ Secs.

Program Step Reference		Program Input Data
4	Sextant Reading (Hs)	______ Deg. ______ Mins. . ______ Tenths
5	Instrument Error (+ or −)	______ Mins. . ______ Tenths
6	Index Correction (+ or −)	______ Mins. . ______ Tenths
7	Additional Correction for Venus/Mars	______ Mins. . ______ Tenths
9	Semi-Diameter (SD) of Sun or Moon	______ Mins. . ______ Tenths
10	Height of Eye Above Water	______ Feet
11	Horizontal Parallax (HP) (Moon)	______ Mins. . ______ Tenths
*12	Temperature of Air (°F)	______ Deg.
*13	Barometric Pressure	______ Inches . ______ Tenths
14	Program Output — Automatically Stored for Later Use (Corrected Sextant Reading — [Ho])	______ Deg. ______ Mins. . ______ Secs.

*(For Non-Standard Conditions Only)

EXAMPLE: The sights listed below were taken June 24, 1975. Correct the sextant altitudes to find the observed altitudes.

	GMT	Hs	IC	IE	EYE	T(°F)	P	SD	HP	♂, ♀
MOON	9:20:05	11°07.2′	+.4′	+.2′	20 ft.	80°	29.5″	15.3′	56.2′	–
MARS	9:23:15	42°52.8′	+.4′	+.2′	20 ft.	80°	29.5″	–	–	+.1′
KOCHAB	9:19:21	26°37.6′	+.6′	0	25 ft.	80°	29.5″	–	–	–
SUN (LL)	16:47:14	78°54.8′	–.2′	0	27 ft.	87°	29.5″	15.8′	–	–

Table 5.

The data to the right of the double line was taken from tables 1 and 3.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 18		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [E′]	0.	Initialize
			Moon
1107.2†	[A]	11.12	Hs
.4†	[A]	.0066666667	IC
.2†	[A]	.0033333333	IE
15.3†	[C]	–.0042166667	SD
20†	[D]	.0818790742	EYE
56.2†	[E]	.9203174389	HP
80†*	[2nd] [A′]	.0045488375	T
29.5†*	[2nd] [B′]	.0009058027	P
	[2nd] [C′]	11.38476829†	Ho (DD.MMSSs)
	[2nd] [D′]	1.†	store Ho → sight no.
			Mars
4252.8†	[A]	42.88	Hs
.4†	[A]	.0066666667	IC
.2†	[A]	.0033333333	IE
.1†	[A]	.0016666667	♂
20†	[D]	.0177892239	EYE
	[2nd] [C′]	42.48056268†	Ho (DD.MMSSs)
	[2nd] [D′]	2.†	store Ho → sight no.
			Kochab
2637.6†	[A]	26.62666667	Hs
.6†	[A]	0.01	IC
25†	[D]	.0319824143	EYE
	[2nd] [C′]	26.31258033†	Ho (DD.MMSSs)
	[2nd] [D′]	3.†	store Ho → sight no.

ENTER	PRESS	DISPLAY	COMMENTS
			Sun
7854.8†	[A]	78.91333333	Hs
.2†	[+/–] [A]	–.0033333333	IC
	[B]	–.0033333333	LL
15.8†	[C]	0.0043	SD
27†	[D]	.0041385521	EYE
	[2nd] [C']	79.05066228†	Ho (DD.MMSSs)
	[2nd] [D']	4.†	store Ho → sight no.

Note that these sights have been loaded into calculator memory for use in later programs.

*Even though the temperature and pressure are within normal limits they should be entered due to the low altitude of the moon.

†Printed if PC-100A is connected.

Entering the Corrected Sextant Reading (Ho) Manually

Some navigators may wish to correct their sextant readings by means of arithmetic and the altitude correction tables found in the *Nautical Almanac.* Whenever the **SEXTANT CORRECTION** program is not used, the navigator may correct his sextant reading and enter Ho for use in the **SIGHT REDUCTION** programs (following step 2) and the **NOON SIGHT FIX** program (following step 3) according to the procedure outlined below.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Store register counters.	8	[STO] [2] [0]	8.
		9	[STO] [2] [1]	9.
2	If H_0 is in the form DDMM.m perform Steps 2-5.	H_0 (DDMM.m)	[INV] [2nd] [D.MS]	H_0 (DDMM.SS)
3	If H_0 is in the form DDMM.SS perform Steps 3-5.	H_0 (DDMM.SS)	[÷]	H_0 (DDMM.SS)
		100	[=]	H_0 (DD.MMSS)
4	If H_0 is in the form DD.MMSS perform Steps 4-5.	H_0 (DD.MMSS)	[2nd] [D.MS]	H_0 (DD.dd)
5	Store H_0 in the register indicated below – perform this step only when H_0 is in the form (DD.dd)	H_0 (DD.dd)	[STO] [n] [n]	H_0 (DD.dd)

Sight No.	Register
1	R_{08}
2	R_{10}
3	R_{12}
4	R_{14}
5	R_{16}
6	R_{18}

SIGHT REDUCTION

The following programs (NG-19 through NG-22) are designed to be used alone or in conjunction with the **SEXTANT CORRECTION** and **FIX BY TWO OBSERVATIONS** programs. A common workform is suggested to help the navigator organize his work and provide a record of the data necessary to check his results.

"Reducing a sight" is the mathematical process by which an accurately timed celestial observation is converted into information the navigator can use to construct a line of position on a plotting sheet or chart.

Each program requires the time of the observation and the dead reckoning position at that time to be entered. The remaining data must be extracted from the daily pages of the *Nautical Almanac* as explained in the following.

Daily Page Information for the Sun

The sun's Greenwich Hour Angle or GHA (table 1) is tabulated in degrees, minutes, and tenths for each GMT whole hour of each day. The program requires you to take out the sun's GHA which corresponds to the GMT *whole hours* and date of observation.

The sun's declination (Dec) like GHA is tabulated for each whole hour of each day. The declination is found just to the right of the GHA, as indicated in table 1. Note that the declination is given in whole degrees, minutes, and tenths and contains a prefix "N" for North and "S" for South. Note also that the whole degrees and the prefix are listed intermittently down the column. Be sure that every declination you extract contains *whole degrees* and a *prefix notation*.

The *d* correction for the sun is listed once for the 3-day period covered by each page. It is found at the bottom of the sun column just to the right of the semi-diameter (SD).

REMARKS:

For northern declinations:
The *d* correction takes on a positive value if the declination increases as the day progresses and is negative if the declination decreases.

For southern declinations:
When the declination decreases through the day, the *d* correction is considered to be positive and is taken as negative if the declination is increasing.

Daily Page Information for the Moon

The GHA of the moon (table 1) is taken from the *Almanac* for the GMT whole hours and date of observation, using the same procedure outlined for the sun.

The ν correction for each hour of GMT is found in the daily pages of the moon column just to the right of the GHA. The ν correction is always a positive value.

The declination of the moon is found to the right of the ν correction, for each GMT whole hour and date. It is extracted for the whole hours according to the same instructions given for the sun.

The *d* corrections for the moon are also listed for each GMT whole hour and date and are assigned positive or negative values according to the procedure established for the sun.

Daily Page Information for the Planets

On the left hand side of each daily page you will find *Almanac* data for the four navigational planets: Venus, Mars, Jupiter, and Saturn. Table 2, extracted from the 1975 *Almanac*, shows how this information is presented.

The GHA of a planet is given for each whole hour of GMT for each day. It is taken from the *Almanac* in the same manner described for the sun and moon.

At the bottom of the GHA column for each planet, you will find the ν correction for planets which is always positive unless otherwise listed.

The declination for each planet is found just to the right of the GHA column. The declination, as for other bodies, is given for each whole hour of GMT for each day.

The *d* correction for each planet is found at the bottom of the page underneath the declination column. This correction is given once on each page for each planet and covers the 3-day period of the page. Again, the sign of the declination follows the same pattern established for the sun.

Daily Page Information for the Stars

The information you need for stars is given in the first and the last columns of the left hand daily pages as shown in table 2. The first column is labeled "Aries" and the last column, appropriately, is labeled "Stars".

For each star sight you will need to take out the GHA of Aries for the GMT whole hour and date of observation. In the calculator program, the GHA of Aries (really an imaginary fixed point in the sky) will be combined with the value of the star's sideral hour angle (SHA).

The SHA of each of the 57 selected navigational stars listed in the daily pages is given once for each 3-day period.

Right next to the SHA column of each star is the declination. Like SHA the declination for each listed star is given once and is good for the 3-day period covered by each page. Stars have no ν or *d* corrections.

These programs calculate the computed altitude (Hc), the intercept or altitude difference (a), and the true azimuth (Zn) according to the following equations:

$$Hc = \sin^{-1}\ [\sin(Dec')\sin(L_{DR}) + \cos(Dec')\cos(L_{DR})\cos(LHA),$$

$$a = Ho - Hc,$$

$$\cos(Z) = [\sin(Dec') - \sin(L_{DR})\sin(Hc)]/[\cos(Hc)\cos(L_{DR})],$$

$$Zn = \begin{cases} Z & \text{if } \sin LHA < 0. \\ 360 - Z & \text{if } \sin LHA \geq 0. \end{cases}$$

The local hour angle (LHA) and corrected declination (Dec') are found according to individual program requirements.

REMARKS

1. When stacking sights they must be reduced in the same order used in NG-18 (or in manual storage).
2. The print cradle may be used with any of the **SIGHT REDUCTION** programs.

Error Corrections (NG-19 through NG-22)

Step	Data Entered Incorrectly	Procedure for Correction
3	DR latitude	Reenter Step 3.
4	DR longitude	Reenter Step 4.
5	minutes and seconds of GMT	Reenter Step 5.
6 (omit for sun)	ν correction (or SHA)	Repeat Step 5, then reenter Step 6.
7	GHA	Press [INV] [2nd] [St Flg] [0], repeat Steps 5 and 6, then reenter Step 7.
8a (omit for start)	*d* correction	Repeat Step 5, then reenter Step 8a.
8b (step 8 for star)	declination	For stars: reenter Step 8. For remaining bodies: repeat Steps 5 and 8a, then reenter Step 8b.
9		Store Ho_i (i = 1 – 6) in the register listed on page 78 and continue. Do not enter register counters.
10		If display following Step 7 was negative, press [2nd] [st flg] [0] and continue. If not, ignore display and continue.
11		Press [2] [INV] [SUM] [2] [0] [INV] [SUM] [2] [1] [1] [INV] [SUM] [0] [7] and continue

Solid State Software			TI ©1977	
SIGHT REDUCTION (SUN)				NG-19
Dec → Hc	→ a	→ Zn	STORE Zn	
L_{DR}	λ_{DR}	GMT (MS)	GHA	*d*

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 19	
2	Select degree mode.		[2nd] [Deg]	
3	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR} (DD.dd)
4	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR} (DD.dd)
5	Enter minutes and seconds of GMT at DR position.	MS (.MMSS)	[C]	Intermediate calculation
6	(Omit for sun.)			
7	Enter GHA of sun for whole hours of GMT	GHA (DDDMM.m)	[D]	sin LHA
8a	Enter *d* correction	*d* (M.m)	[E]	*d* (.dd)
8b	Enter declination (+N, −S) of sun for whole hours of GMT to find computed altitude.	Dec (DDMM.m)	[2nd] [A']	Hc (DD.MMSS)
9	Compute intercept.		[2nd] [B']	a (nau. mi.)
10	Compute azimuth.		[2nd] [C']	Zn (DDD.dd)
11	Store azimuth.		[2nd] [D']	sight number

Register Contents

R_{00}		R_{05}	Used	R_{10}	a_2	R_{15}	Zn_4	R_{20}	Pointer
R_{01}	L_{DR}	R_{06}	λ_{DR}	R_{11}	Zn_2	R_{16}	a_5	R_{21}	Pointer
R_{02}	Dec	R_{07}	Sight no.	R_{12}	a_3	R_{17}	Zn_5		
R_{03}	LHA	R_{08}	a_1	R_{13}	Zn_3	R_{18}	a_6		
R_{04}	Hc	R_{09}	Zn_1	R_{14}	a_4	R_{19}	Zn_6		

Solid State Software				TI ©1977
SIGHT REDUCTION (MOON)				NG-20
d	Dec→Hc	→a	→Zn	STORE Zn
L_{DR}	λ_{DR}	GMT (MS)	ν	GHA

Solid State Software				TI ©1977
SIGHT REDUCTION (PLANET)				NG-21
d	Dec→Hc	→a	→Zn	STORE Zn
L_{DR}	λ_{DR}	GMT (MS)	ν	GHA

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.[1]		[2nd] [Pgm] mm	
2	Select degree mode.		[2nd] [Deg]	
3	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR} (DD.dd)
4	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR} (DD.dd)
5	Enter minutes and seconds of GMT at DR position.	MS (.MMSS)	[C]	Intermediate calculation
6	Enter ν correction.	ν (MM.m)	[D]	Intermediate calculation
7	Enter GHA (for whole hours of GMT) for moon or planet.	GHA (DDDMM.m)	[E]	sin LHA
8a	Enter *d* correction.	*d* (M.m)	[2nd] [A′]	*d* (.dd)
8b	Enter declination (+N, −S) for whole hours of GMT of moon or planet to find computed altitude.	Dec (DDMM.m)	[2nd] [B′]	Hc (DD.MMSS)
9	Compute intercept.		[2nd] [C′]	a (nau. mi.)
10	Compute azimuth.		[2nd] [D′]	Zn (DDD.dd)
11	Store azimuth.		[2nd] [E′]	sight number

NOTE: 1. For the moon, use [2nd] [Pgm] 20; for a planet, use [2nd] [Pgm] 21.

Register Contents

R_{00}		R_{05}		R_{10}	a_2	R_{15}	Zn_4	R_{20}	Pointer
R_{01}	L_{DR}	R_{06}	λ_{DR}	R_{11}	Zn_2	R_{16}	a_5	R_{21}	Pointer
R_{02}	Dec	R_{07}	Sight no.	R_{12}	a_3	R_{17}	Zn_5		
R_{03}	LHA	R_{08}	a_1	R_{13}	Zn_3	R_{18}	a_6		
R_{04}	Hc	R_{09}	Zn_1	R_{14}	a_4	R_{19}	Zn_6		

Solid State Software				TI ©1977
SIGHT REDUCTION (STAR)				NG-22
Dec → Hc	→ a	→ Zn	STORE Zn	
L_{DR}	λ_{DR}	GMT (MS)	SHA	GHA ♈

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 22	
2	Select degree mode.		[2nd] [Deg]	
3	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR} (DD.dd)
4	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR} (DDD.dd)
5	Enter minutes and seconds of GMT at DR position.	MS (.MMSS)	[C]	Intermediate calculation
6	Enter SHA of star for whole hours of GMT.	SHA (DDDMM.m)	[D]	SHA (DDD.dd)
7	Enter GHA of Aires for whole hours of GMT.	GHA ♈ (DDDMM.m)	[E]	sin LHA
8	Enter declination (+N, −S) of star for whole hours of GMT to find computed altitude.	Dec (DDMM.m)	[2nd] [A′]	Hc (DD.MMSS)
9	Compute intercept.		[2nd] [B′]	a (nau. mi.)
10	Compute azimuth.		[2nd] [C′]	Zn (DDD.dd)
11	Store azimuth.		[2nd] [D′]	sight no.

Register Contents

R_{00}	R_{05} Used	R_{10} a_2	R_{15} Zn_4	R_{20} Pointer
R_{01} L_{DR}	R_{06} λ_{DR}	R_{11} Zn_2	R_{16} a_5	R_{21} Pointer
R_{02} Dec	R_{07} Sight no.	R_{12} a_3	R_{17} Zn_5	
R_{03} LHA	R_{08} a_1	R_{13} Zn_3	R_{18} a_6	
R_{04} Hc	R_{09} Zn_1	R_{14} a_4	R_{19} Zn_6	

SIGHT REDUCTION FORM

(For Use In Connection With Sextant Correction Program And Star Identification Program)*

SIGHT # ____________

NAME OF STAR ____________

Program Inputs

Program Step Reference				
3	DR Latitude (+N, −S)	____ Degs.	____ Mins.	. ____ Tenths
4	DR Longitude (+W, −E)	____ Degs.	____ Mins.	. ____ Tenths
5	MS (Minutes/Seconds of GMT)	.	____ Mins.	____ Secs.
6	ν correction for moon or planet or SHA of star (omit for sun)	____ Degs.	____ Mins.	. ____ Tenths
7	GHA of observed body (use Aires for all stars)	____ Degs.	____ Mins.	. ____ Tenths
8a	*d* correction (omit for star)	____ Degs.	____ Mins.	. ____ Tenths
8b (8 for star)	Declination (+N, −S)	____ Degs.	____ Mins.	. ____ Tenths

Program Outputs

Program Step Reference				
7	Check if display was negative			☐
8b (8 for star)	Hc	____ Degs.	. ____ Mins.	____ Tenths
9	Intercept (+ toward) (− away)		____ Miles	. ____ Tenths
10	Azimuth	____ Degs.		. ____ Tenths

*(If Sextant Correction Program Was Not Used, See Page 78 for Procedure to Manually Enter H_0.)

For Use With **Star Identification Program Only**.

Sextant Reading (Hs) (Uncorrected) ____ Degs. ____ Mins. . ____ Tenths   Azimith (Approx.) ____ Degs. ____ Times

Estimated SHA ____ Degs. ____ Mins. . ____ Tenths   Estimated Dec. ____ Degs. ____ Mins. . ____ Tenths

EXAMPLE: Reduce the sights found in the example on page 77. Use a dead reckoning position of 34° 25′ N, 71° 15′ W for the sun and 34° 40′ N, 71° 15′ W for the remaining.

First, extract the following information from the appropriate tables.

	MS	*ν*	SHA	GHA	Dec	*d*
MOON	.2005	9.8′	—	126° 01.1′	19° 44.4′ S (decreasing)	4.7′
MARS	.2315	0.8′	—	22° 59.6′	8° 10.6′ N (increasing)	0.7′
KOCHAB	.1921	—	137° 18′	46° 53.9′	74° 15.6′ N	—
SUN	.4714	—	—	59° 25.9′	23° 25.0′ N (decreasing)	−0.1′

Table 6.

Now, perform the example on page 77 or enter the corrected sextant readings manually according to the instructions found on page 78. (Note that the output of NG-18 is in the form DD.MMSSs, not DDMM.SSs.)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 20		Select Program
	[2nd] [Deg]		Select Degree Mode
			Moon
3440†	[A]	34.66666667	L_{DR}
7115†	[B]	71.25	λ_{DR}
.2005†	[C]	4.792218056	MS
9.8†	[D]	.0546712963	*ν*
12601.1†	[E]	.8626480848	GHA
4.7†	[2nd] [A′]	.0783333333	*d*
1944.4†	[+/−] [2nd] [B′]	11.31225401†	Dec → Hc (DD.MMSSs)
	[2nd] [C′]	7.419046164†	a
	[2nd] [D′]	235.9748706†	Zn (DDD.dd)
	[2nd] [E′]	1.†	store Zn → sight no.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 21		Select Program
			Mars
.2315†	[C]	5.8125	MS
.8†	[D]	.0051666667	*ν*
2259.6†	[E]	−.6748048819	GHA
.7†	[2nd] [A′]	.0116666667	*d*
810.6†	[2nd] [B′]	42.58496444†	Dec → Hc (DD.MMSSs)
	[2nd] [C′]	−10.73362728†	a
	[2nd] [D′]	114.0768904†	Zn (DDD.dd)
	[2nd] [E′]	2.†	store Zn → sight no.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 22		Select Program *Kochab*
.1921†	[C]	4.85094825	MS
13718†	[D]	137.3	SHA
4653.9†	[E]	0.884586823	GHA ϒ
7415.6†	[2nd] [A′]	26.19196291†	Dec → Hc (DD.MMSSs)
	[2nd] [B′]	12.10290281†	a
	[2nd] [C′]	344.4711948†	Zn (DDD.dd)
	[2nd] [D′]	3.†	store Zn → sight no.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 19		Select Program *Sun*
3425†	[A]	34.41666667	L_{DR}
.4714†	[C]	11.80833333	MS
5925.9†	[D]	–.0001745329	GHA
.1†	[+/–] [E]	–.0016666667	*d*
2325†	[2nd] [A′]	78.59552642†	Dec → Hc (DD.MMSSs)
	[2nd] [B′]	5.189309942†	a
	[2nd] [C′]	179.9519115†	Zn (DDD.dd)
	[2nd] [D′]	4.†	store Zn → sight no.

† Printed if PC-100A is connected.

Note that the latitude and longitude need only be entered for the first sight unless the sights were taken at different positions. In the above example, only the sun requires such a correction.

These examples are now stored in calculator memory for use in the **FIX BY TWO OBSERVATIONS** program.

Plotting Results Manually

If you choose, you may plot the results of the **SIGHT REDUCTION** programs manually to produce:

1. a single line of position.
2. a fix from simultaneous observations, or
3. a running fix.

The following examples are shown as they would be plotted directly on nautical charts. These same instructions, however, would also apply if you were using a plotting sheet.

Manual plotting is as easy as constructing a line of position (LOP) from visual bearings.

The azimuth (in degrees) is the true bearing or direction of the line you will construct.

The intercept is the length (in nautical miles) of the line. If the intercept is positive, the line is drawn toward the direction of the azimuth. If it is negative, the line is drawn away from the azimuth.

The dead reckoning (DR) position you used for the sight is the point from which the line will be constructed.

A fix is the longitude and latitude indicated by the intersection of 2 or more lines of position.

In the following diagrams, the length of the line drawn for the intercept is found using the latitude scale opposite the DR position where one degree is equivalent to 60 nautical miles.

In figure 1 the solid lines indicate the LOP resulting from a positive intercept, the dotted lines represent a negative intercept. Remember, the intercept is from the dead reckoning position and in the direction of the azimuth for positive values and away from the azimuth when negative. A perpendicular line drawn at the end of the intercept represents the line of position.

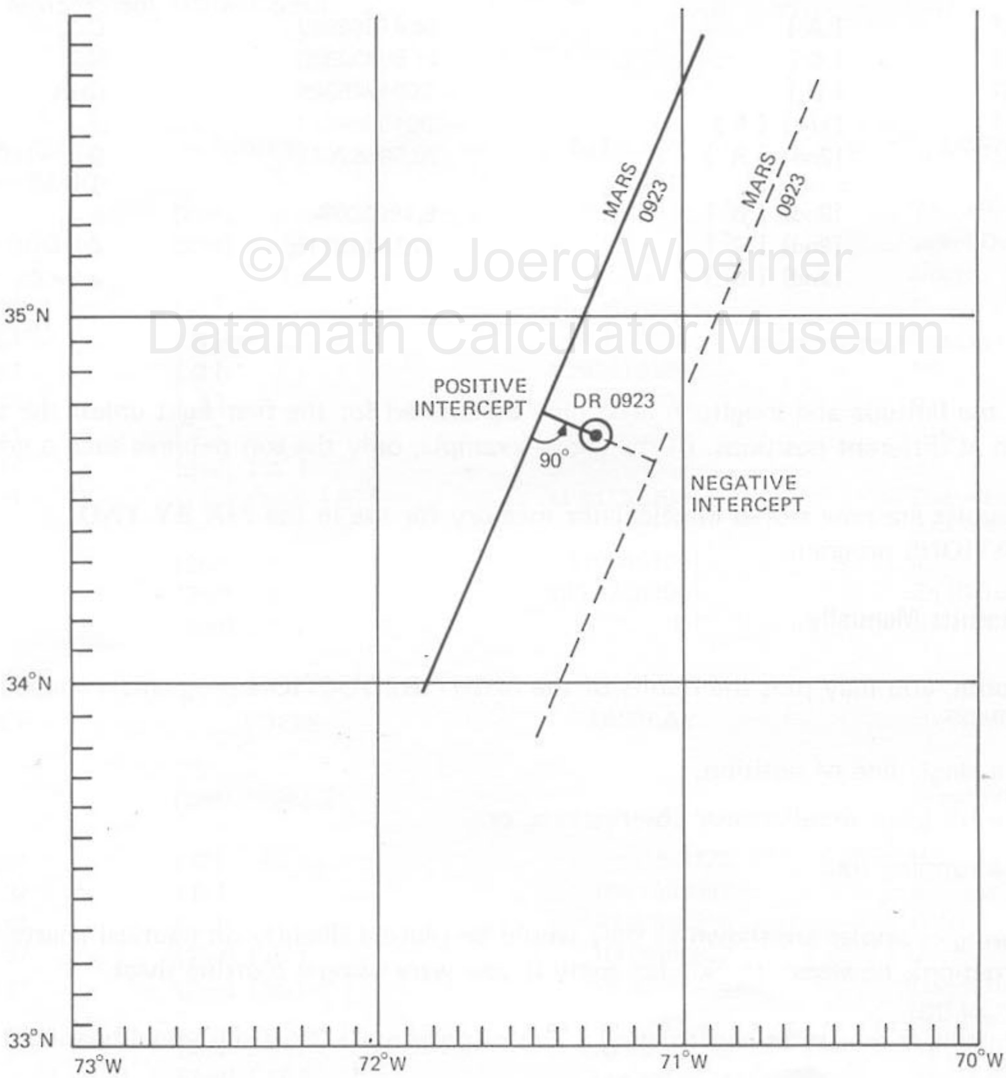


FIGURE 1.

Figure 2 shows how a fix may be estimated from the three simultaneous observations reduced in the last example. The intersection of any two lines of position represents the fix resulting from the appropriate sights.

Only two observations are necessary for such a fix; however, when three observations are combined such that they create a tightly drawn triangle as in figure 2, the navigator has taken sights in which he can place a lot of confidence.

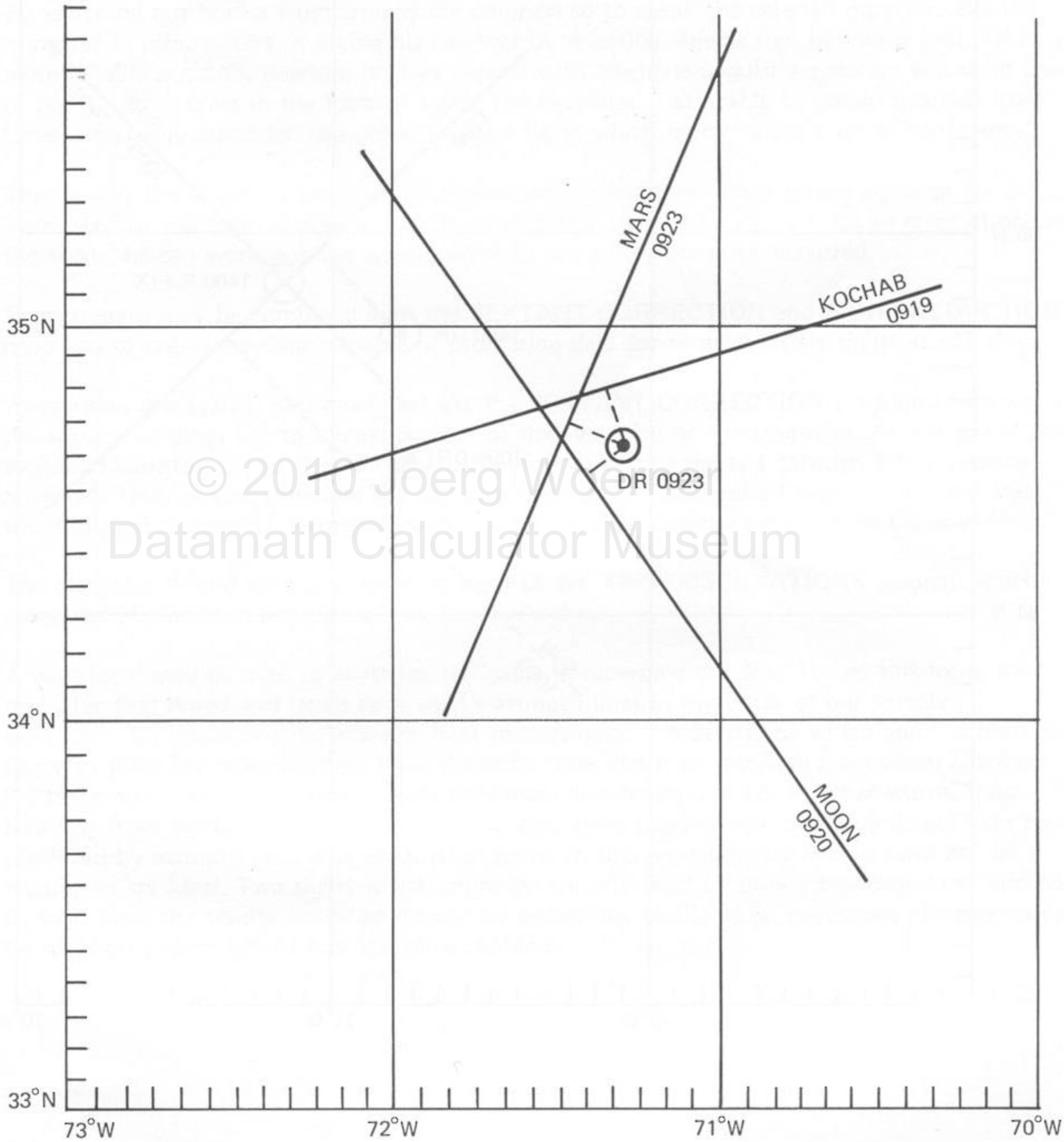


FIGURE 2.

Two different sights of the sun are combined in figure 3 to produce a running fix. The procedure here simply requires the navigator to reconstruct the 10:00 LOP using the 14:00 DR position. The labeling indicates this is a running rather than simultaneous fix.

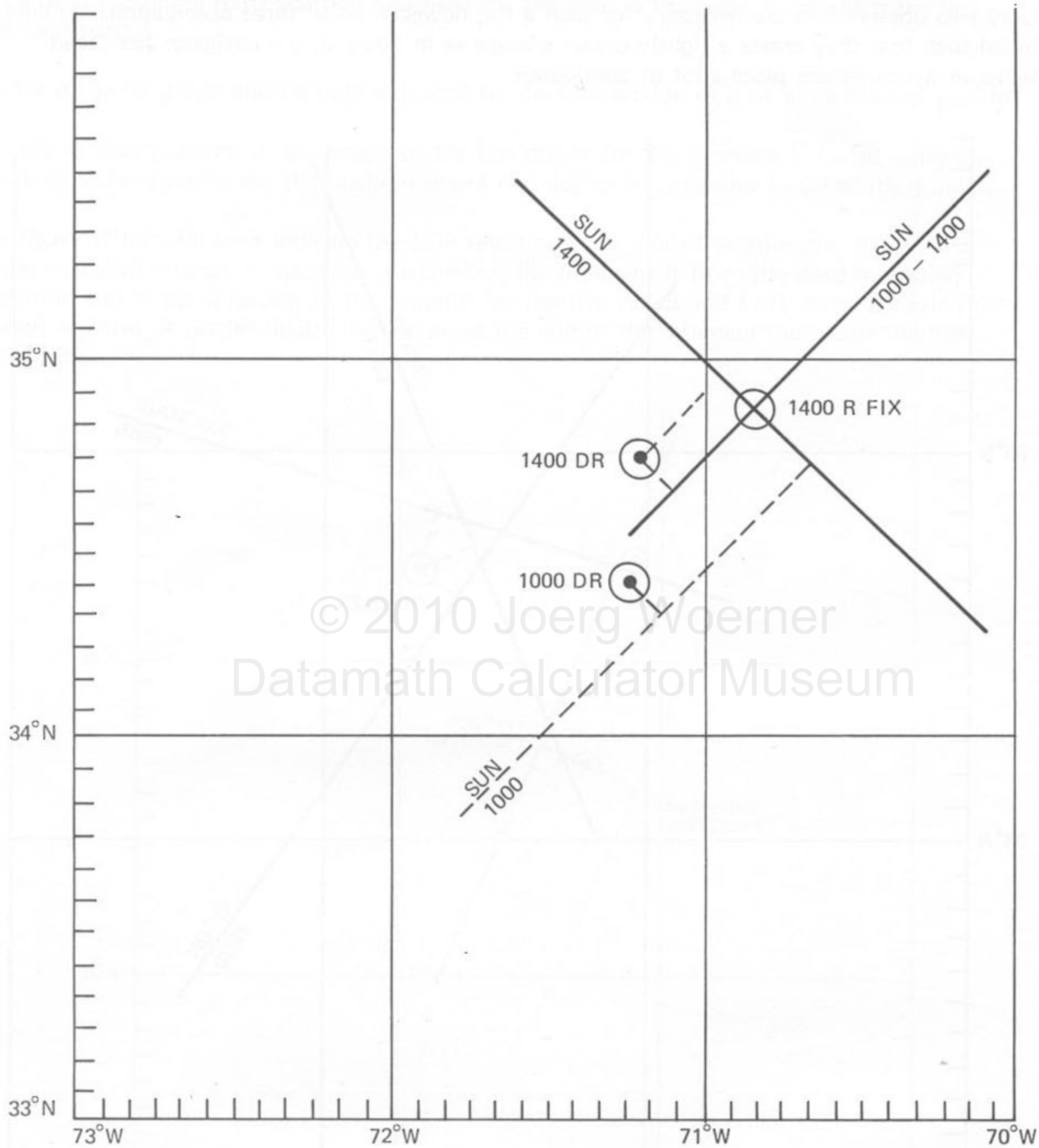


FIGURE 3.

FIX BY TWO OBSERVATIONS

To obtain a reliable fix from visual bearings, navigators select objects that have adequate angular separation. This same principal also applies to celestial observations. When selecting celestial bodies for observation, the navigator should try to obtain sights from general different directions. Try to get a star or planet that is astern, another star off the starbeam beam. Look to port and see if you can find yet another body that is visible before twilight ends.

By searching out bodies from around the compass so to speak the celestial observer, like the navigator in pilot waters, is taking his bearings by selecting objects that he knows will yield a more reliable position. Bearings on two objects with adequate angular separation will yield lines of position that cross in the form of a fix. The navigator that is able to obtain bearings from three adequately separated objects will have a fix in which he can place a lot of confidence.

That is why the 3-star fix has been so popular with navigators. When taking sightings for a 3-star fix, the navigator should try to shoot each star twice. Then if he finds an error in one of the sights, he can work out the second sights to see where the error occurred.

This program may be combined with the **SEXTANT CORRECTION** and **SIGHT REDUCTION** programs to create a system capable of processing data for as many as six sights at one time.

When using this system you must first use the **SEXTANT CORRECTION** program to correct all the sextant readings (up to a maximum of 6) that you will be working with. At the top of the suggested workform, you should consecutively number your sights 1 through 6 in the space provided. Then as you complete the last step (storing the observed altitude), make sure that the displayed number (1 through 6) agrees with the sight number recorded on the workform.

The navigator should then proceed with the **FIX BY TWO OBSERVATIONS** program which computes his fix from any two of the selected sights.

A workform may be used to assist the navigator in recording the data To use this form, the navigator first draws and labels each sight's azimuth lines in the circle of our sample workform. By inspecting the azimuth lines the navigator can determine which combinations are likely to yield the most accurate fixes. Celestial fixes like fixes resulting from visual bearings are more accurate if the objects have a significant angular separation. In other words, fixes resulting from sights whose azimuth lines are very close together will be less accurate than those produced by azimuth lines that are further apart. In this regard, sights with around 60° of separation are ideal. Two sights whose azimuths are separated by only a few degrees should not be used since the results would be inherently unreliable. Incidentally, navigators plotting results by hand on a chart would face the same problem.

Simplified Data Entries

If the navigator is working out a simultaneous (e.g., 3-star) fix in which all the sights were taken at the same DR position, the DR latitude and longitude is entered only once in the first sight reduction program. These items, then, are stored in the calculator, used with the other sight reduction programs and are automatically retained for use with the **FIX BY TWO OBSERVATIONS** program.

If the navigator working with this system wants to compute a running fix based on observations with different dead reckoning positions, he should make sure he enters the data from his sights in the order the sights were taken. This ensures that the DR which is retained for use with NG-23 will be the correct, e.g., the most recent DR.

Assuming the navigator is working out a 3-star fix, and that he has completed and stored the results of two observations of each of the stars in his calculator, he initially records the longitude-latitude of the first round of observations. If they closely agree with one another, he plots his fix. If there is a problem with one of the combinations, the navigator should try various combinations including pairing the back up observations with various sights from the first round to see which sight is in error.

Each fix is computed according to the following equations:

$$L = L_{DR} - \Delta L_1 + \tan Zn_1 \left[\frac{\Delta L_2 - \Delta L_1 - \Delta\lambda_1 \tan Zn_1 + \Delta\lambda_2 \tan Zn_2}{\tan Zn_2 - \tan Zn_1} - \Delta\lambda_1 \right],$$

$$\lambda = \lambda_{DR} + \frac{\Delta L_2 - \Delta L_1 - \Delta\lambda_1 \tan Zn_1 + \Delta\lambda_2 \tan Zn_2}{(\tan Zn_2 - \tan Zn_1) \cos L_{DR}}.$$

The variables used in computation are defined as:

L_{DR} = dead reckoning latitude,

λ_{DR} = dead reckoning longitude,

$\Delta L_i = a_i \cos Zn_i$,

$\Delta\lambda_i = a_i \sin Zn_i$,

a_i = intercept of sight i, and

Zn_i = observed azimuth of sight i.

(i = 1, 2 denotes either the first or second sight chosen for the fix, not the number of the sight as it is stacked.)

REMARK

This program cannot compute a fix using a sight with an azimuth of 90° or 270°.

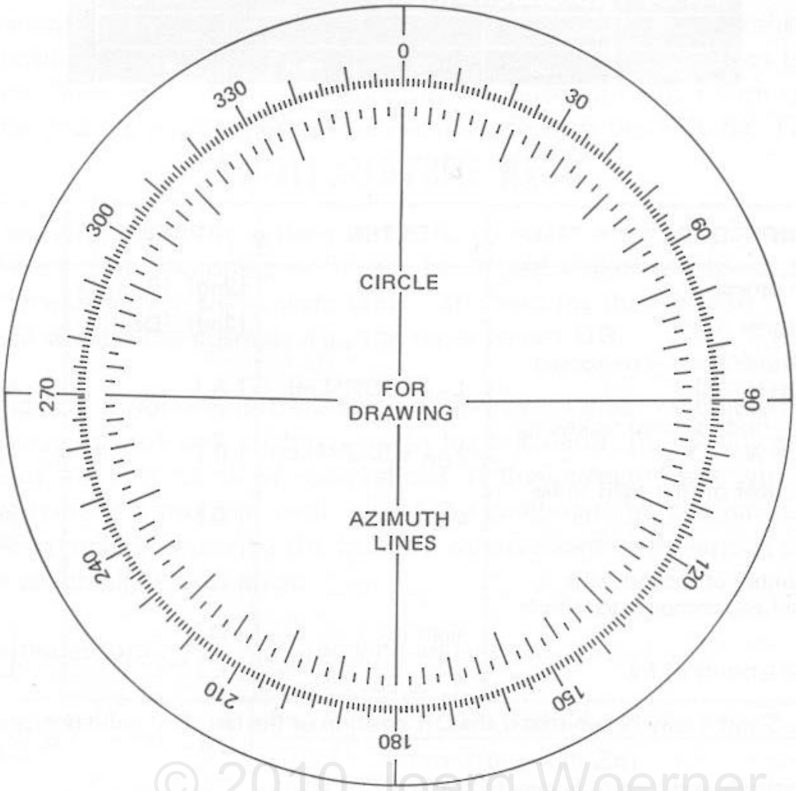
Solid State Software			TI ©1977	
FIX BY TWO OBSERVATIONS				NG-23
L_{DR}	λ_{DR}	#	# → λ	→ L

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 23	
2	Select degree mode.		[2nd] [Deg]	
3	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR} (DD.dd)
4	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR} (DDD.dd)
5	Enter number of first sight to be used.	sight no.	[C]	intermediate calculation
6	Enter number of second sight to be used and compute longitude of fix.	sight no.	[D]	λ (DDDMM.m)
7	Compute latitude of fix		[E]	L (DDMM.m)

NOTES:
1. Steps 3 and 4 may be omitted if the DR position of the last sight reduction program is to be used.
2. DR latitude and longitude may be corrected by reentry.
3. Steps 5-7 may be repeated as needed.
4. Printer usage is optional.

Fix By Two Observations Workform



Combination

Sight #	Sight #	Latitude (DDMM.m)	Longitude (DDDMM.m)

EXAMPLE: Use the sights of the Moon, Mars, and Kochab found on page 77 to determine a 3-star fix.

First perform the example on page 86. (Omit the sun sight.)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 23		Select Program
1†	[C]	4.151375195	sight no.
2†	[D]	7127.935853†	sight no. → λ
	[E]	3442.499872†	L
1†	[C]	4.151375195	sight no.
3†	[D]	7132.847011†	sight no. → λ
	[E]	3448.482728†	L
2†	[C]	−4.378914695	sight no.
3†	[D]	7123.528461†	sight no. → λ
	[E]	3450.612369†	L

Summary

Sight Combination #	#	Latitude (DDMM.m)	Longitude (DDDMM.m)
1	2	34° 42.5′ N	71° 27.9′ W
1	3	34° 48.5′ N	71° 32.8° W
2	3	34° 50.6′ N	71° 23.5′ W

The latitude and longitude were entered in the last example and do not need to be reentered here.

Register Contents

R_{00}	Used	R_{05}	Used	R_{10}	a_2	R_{15}	Zn_4
R_{01}	L_{DR}	R_{06}	λ_{DR}	R_{11}	Zn_2	R_{16}	a_5
R_{02}	Used	R_{07}	Used	R_{12}	a_3	R_{17}	Zn_5
R_{03}	Used	R_{08}	a_1	R_{13}	Zn_3	R_{18}	a_6
R_{04}	Used	R_{09}	Zn_1	R_{14}	a_4	R_{19}	Zn_6

† Printed if PC-100A is connected.

TIME OF LOCAL APPARENT NOON AND SUN LINES

On days when the sun and the horizon are visible, it is possible to obtain a running fix by combining an a.m. and p.m. sun line and a fix from observing the sun at local apparent noon (LAN). LAN is the GMT of the sun's passage over your meridian of longitude. By careful observation and timing of the sun at LAN, the navigator can calculate both latitude and longitude.

The a.m. and p.m. sun lines in this program refer to those times when, because of the sun's travels around the heavens, the most accurate running fixes from morning and afternoon observations will occur. With the a.m. and p.m. sun lines, however, the navigator can make the observations several minutes earlier or later than the indicated times without noticeably affecting the accuracy of the resulting lines of position.

When using this program to predict the approximate time for a.m. and p.m. lines and LAN, the navigator should use as his dead reckoning (DR) longitude and latitude the position he expects to be around LAN. The declination, since it changes very little during a day, should be the declination for the whole hour nearest LAN. If the DR position (particularly the longitude) is uncertain, the navigator should compensate by beginning his LAN observation several minutes early. In any case, it is a good idea to begin observing LAN a little before the indicated time, since the sun must be observed and timed during its actual meridian passage.

This program requires the navigator to obtain the equation of time (EQ) for the sun for 12 hours from the bottom of the sun-moon page of the *Almanac* (table 1) for the appropriate day. The navigator must also check the time of the sun's meridian passage (Mer) to see if the sun on that day arrived at Greenwich a little before or after noon (1200 hours).

Be careful when handling this data to remember (a) to copy down any zeroes in the minutes or seconds; and (b) to place the indicated decimal point in front of the equation of time when it is entered.

The equations used by this program are:

$$LAN = (\lambda_{DR}/15) + 12 - EQ,$$

$$\text{p.m. sun sight} = LAN + | L_{DR} - EQ | /15,$$

$$\text{a.m. sun sight} = LAN - | L_{DR} - EQ | /15.$$

In the above:

L_{DR} = latitude of dead reckoning position,

λ_{DR} = longitude of dead reckoning position,

EQ = equation of time for sun for 12 hours, and

LAN = local apparent noon.

REMARK

Step 7 is completed only if the meridian passage occurred after 12 hours 00 minutes GMT.

Solid State Software			TI ©1977	
TIME (GMT) FOR SUN SHOTS				NG-24
→LAN	→PM	→AM	INIT	
L_{DR}	λ_{DR}	EQ (12 hrs)	Mer (PM)	Dec

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 24	
2	Select degree mode.		[2nd] [Deg]	
3	Initialize.		[2nd] [D']	0.
4	Enter latitude of dead reckoning position (+N, −S).	L_{DR} (DDMM.m)	[A]	L_{DR} (DD.dd)
5	Enter longitude of dead reckoning position (+W, −E).	λ_{DR} (DDDMM.m)	[B]	λ_{DR} (DDD.dd)
6	Enter equation of time for sun for 12 hours.	EQ (.MMSS)	[C]	EQ (.ddd)
7	Perform this step only if the meridian passage at Greenwich is after 12:00 GMT.		[D]	±EQ
8	Enter declination (+N, −S)	Dec (DDMM.m)	[E]	Dec (DD.dd)
9	Compute GMT of local apparent noon.		[2nd] [A']	LAN (HH.MMSS)
10	Compute GMT of p.m. sun line.		[2nd] [B']	p.m. sight
11	Compute GMT of a.m. sun line.		[2nd] [C']	a.m. sight

NOTES:
1. If [D] is erroneously pressed, correct by pressing again.
2. Data may be corrected by reentry.
3. Printer usage is optional with this program.
4. Outputs are in GMT.

EXAMPLE: You are expecting to be at 34° 25′ N, 71° 15′ W around the time of local apparent noon on June 24, 1975. Find the optimum times to take your a.m. and p.m. sun lines and the approximate time of LAN.

Table 1 indicates that the equation of time for the sun for 12 hours on this date is 2 minutes and 14 seconds (.0214). Also note from the table that meridian passage at Greenwich occurs after 12:00 GMT.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 24		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [D′]	0.	Initialize
3425†	[A]	34.41666667	L_{DR}
7115†	[B]	71.25	λ_{DR}
.0214†	[C]	.0372222222	EQ
	[D]*	−1.†	Mer (p.m.)
2325.0†	[E]	23.41666667	Dec
	[2nd] [A′]	16.4714†	LAN (HH.MMSS)
	[2nd] [B′]	17.3114†	p.m. sun line (GMT)
	[2nd] [C′]	16.0314†	a.m. sun line (GMT)

Register Contents

R_{00} L_{DR}	R_{05} Used	R_{10}	R_{15}
R_{01} λ_{DR}	R_{06}	R_{11}	R_{16}
R_{02} EQ	R_{07}	R_{12}	R_{17}
R_{03} Dec	R_{08}	R_{13}	R_{18}
R_{04} LAN	R_{09}	R_{14}	R_{19}

*[D] is pressed only when meridian passage at Greenwich follows 12:00 GMT.
†Printed if PC-100A is connected.

NOON SIGHT FIX

When the navigator obtains an accurately timed sight of the sun as it crosses his local meridian, he can use this program to calculate, not just a line of position, but a longitude, latitude fix.

As the sun approaches your meridian at local apparent noon (LAN), its rate of climb in the sky slows down. During meridian passage, the sun appears to hover in the sky for a minute or two at the same altitude and then slowly begins to descend. To make sure he has observed LAN, the navigator should begin observing the sun several minutes before he expects the meridian passage. By recording his observations every few seconds, the navigator can follow the sun's progress as it gains altitude, reaches the meridian passage, and then starts loosing altitude. The navigator should select a sight which was obtained when the sun reached its highest altitude as his LAN observation.

The noon sight workform will help you organize the data for entry into the calculator program. The sun's equation of time for 12 hours and information with respect to whether the meridian passage of the sun is before or after 12 hours 00 minutes GMT for that day is found at the bottom of the sun/moon pages of the *Almanac* (table 1).

The navigator should be aware that the GMT of local apparent noon observations, unlike all other sight reduction programs, requires you to enter the whole hours of GMT followed by a decimal point and the minutes/seconds. The declination and *d* corrections for the noon sight are taken from the *Almanac* the same as for regular sun sights.

The LAN program should be used after the sextant correction program (single sight mode) NG-18 in order that the observed altitude (Ho) will be stored in calculator memory. If the **SEXTANT CORRECTION** program was not used, enter Ho manually after step 3 according to the instructions on page 78.

This program calculates the observer's latitude (L) and longitude (λ) by using the following formulas:

$$\lambda = 15\,(\text{GMT} - 12 + \text{EQ}), \qquad \text{Dec}' = \text{Dec} + (d \times \text{MS}).$$

taking the signs of L_{DR} and Dec' into consideration:

$$L = \begin{cases} \text{Dec}' - \text{Ho} + 90^\circ & \text{if } L_{DR} \geq \text{Dec}', \\ \text{Dec}' + \text{Ho} - 90^\circ & \text{if } L_{DR} < \text{Dec}'. \end{cases}$$

Solid State Software			TI ©1977	
NOON SIGHT FIX (LAN)			NG-25	
Dec	L_{DR}→L			
LAN	EQ (12 hrs)	Mer (PM)	→λ	*d*

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 25	
2	Select degree mode.		[2nd] [Deg]	
3	Enter GMT of local apparent noon.	LAN (HH.MMSS)	[A]	LAN-12
4	Enter equation of time for sun for 12 hours.	EQ (.MMSS)	[B]	EQ (.ddd)
5	Perform this step only if meridian passage at Greenwich occurs after 12:00 GMT.		[C]	− EQ
6	Compute longitude of observer.		[D]	λ (DDDMM.m)
7	Enter *d* correction for sun.	*d* (M.m)	[E]	*d* (.ddd)
8	Enter declination of sun (+N, −S).	Dec (DDMM.m)	[2nd] [A′]	Dec (DD.ddd)
9	Enter dead reckoning latitude and compute actual latitude.	L_{DR}	[2nd] [B′]	L (DDDMM.m)

NOTES:
1. If LAN or EQ is entered incorrectly or if [C] is pressed by mistake, correct by immediately repeating the step. For any other error begin the program again.
2. The order of the steps may not be altered.
3. Printer usage is optional.
4. Do not press [CLR] or perform keyboard calculations while running this program.
5. Do not run this program in engineering mode.

Register Contents

R_{00} LAN	R_{05}	R_{10}	R_{15}	R_{20} Used
R_{01}	R_{06}	R_{11}	R_{16}	R_{21} Used
R_{02} Dec	R_{07}	R_{12}	R_{17}	
R_{03} L_{DR}	R_{08} Ho	R_{13}	R_{18}	
R_{04}	R_{09}	R_{14}	R_{19}	

LAN FORM – (NG-25)
(For Use In Connection With Sextant Correction Program NG-18)*

Program Step Reference				
4	GMT of LAN	______ Hrs. •	______ Mins.	______ Secs.
5	Eq. of time for sun at 12 hours	•	______ Mins.	______ Secs.
6	Time of meridian passage of sun (Is meridian passage before or after 12 hours 00 minutes GMT?)	______ Hrs. •	______ Mins.	
7**	Computed longitude	______ Degs.	______ Mins. •	______ Tenths
8	*d* correction for sun		______ Mins. •	______ Tenths
9	Declination of sun	______ Degs.	______ Mins. •	______ Tenths
10**	Observer's latitude	______ Degs.	______ Mins. •	______ Tenths

*If sextant correction program was not used, enter Ho manually after step 3 according to instructions on page 78.

**Outputs: Observer's longitude and latitude.

EXAMPLE: On June 24, 1975 you observed local apparent noon at 16:47:14 GMT from a DR position of 34°25'N, 71°15'W. Your sextant reading of 78°54.8' for a lower limb shot requires an index correction of −.2'. Determine the position you took the sight from given an eye height of 27 feet above the water.

Extract the following information from table 1:

EQ = 2 minutes and 14 seconds,
Mer = 12:02,
Dec = 23° 25.0' N (decreasing), and
d = −.1'.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 18*		Select Program
	[2nd] [Deg]		Select Degree Mode
	[2nd] [E']	0.	Initialize
7854.8†	[A]	78.91333333	Hs
.2†	[+/−] [A]	−.0033333333	IC
	[B]	−.0033333333	LL
15.8†	[C]	.0043	SD
27†	[D]	.0041385521	EYE
	[2nd] [C']	79.05066228†	Ho (DD.MMSS)
	[2nd] [D']	1.†	store Ho → sight no.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 25		Select Program
16.4714†	[A]	4.787222222	LAN
.0214†	[B]	.0372222222	EQ
	[C]	−.0372222222†	Mer (p.m.)
	[D]	7115.†	λ (DDDMM.m)
.1†	[+/−] [E]	−.0016666667	*d*
2325.0†	[2nd] [A']	23.41666667	Dec
3425†	[2nd] [B']	3419.818164†	L (DDMM.m)

*The sextant altitude may be manually corrected and entered following the instructions on page 78. Remember, Ho = Ho_1.
†Printed if PC-100A is connected.

GREAT CIRCLE SAILING

When the navigator is planning a long passage, it is advisable to consider the advantages of great circle sailing. By following a great circle route, rather than a rhumbline, appreciable distance and time can be saved. Figure 1 illustrates the difference between a great circle (curved) route and a straight line (or rhumbline) between Norfolk, Virginia, and Bishop Rock, England.

Given your initial and destination latitudes and longitudes this program will calculate the initial great circle distance and the intermediate points of latitude for any desired meridian of longitude along your great circle route.

By providing the points of latitude which correspond to intermediate points of longitude, the program enables the navigator to plot in advance any desired number of coordinates along his route. By connecting the charted coordinates with rhumblines (figure 1) the navigator is able to sail a series of convenient rhumbline courses that closely approximate a great circle course. He is also able to determine, in advance, if the great circle course will take him near any intervening land masses, or into an area where he might encounter a hazard such as pack ice. Only two intermediate points are plotted in figure 1, however, for courses which lie generally in an east-west direction standard navigational practice is to compute intermediate latitudes for every 5 degrees of longitude.

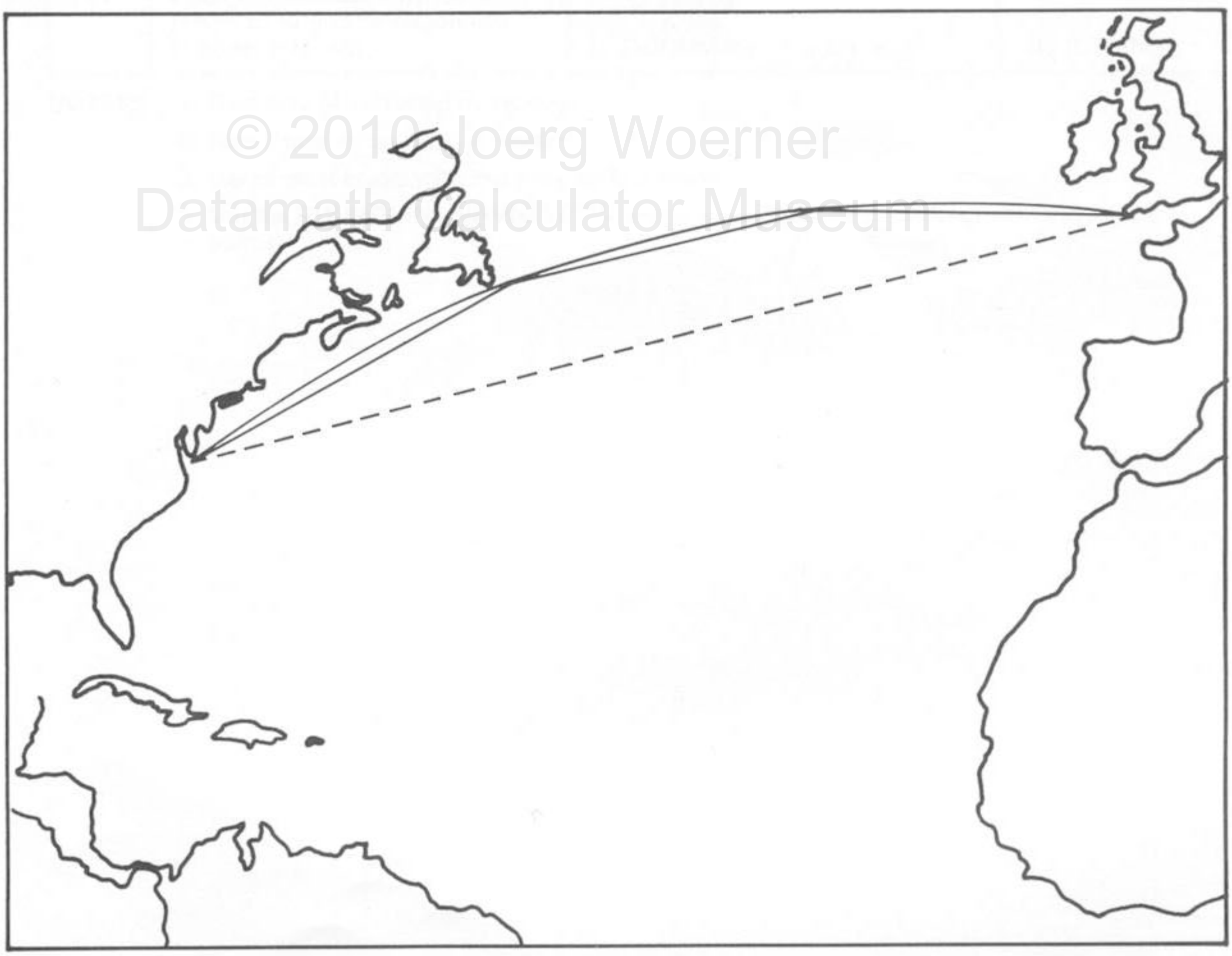


Figure 1

The rhumbline appears to be shorter because of chart distortion. The great circle route, however, traverses meridians at higher latitudes where the distance between them are less.

This program is computed according to the following formulas:

$$\text{hav } D = \text{hav } (\lambda_S - \lambda_D) \cos (L_S) \cos (L_D) + \text{hav } (L_S - L_D),$$

$$L_i = \tan^{-1}\left\{[\tan (L_D) \sin (\lambda_i - \lambda_S) - \tan (L_S) \sin (\lambda_i - \lambda_D)]/\sin (\lambda_D - \lambda_S)\right\}.$$

The variables used above are:

- D = great circle distance,
- $L_{S,D}$ = starting and destination latitudes,
- $\lambda_{S,D}$ = starting and destination longitudes,
- L_i = latitude of intermediate point i, and
- λ_i = longitude of intermediate point i.

Remarks: This program may not be used if $L_S = L_D$ or $L_S - L_D = \pm 180°$.

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GREAT CIRCLE SAILING				NG-26
L_S	λ_S	L_D	λ_D→DIST	λ'→L'

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 26	
2	Select degree mode.		[2nd] [Deg]	
3	Enter latitude of starting position (+N, −S).	L_S (DDMM.m)	[A]	L_S (DD.dd)
4	Enter longitude of starting position (+W, −E).	λ_S (DDDMM.m)	[B]	λ_S (DDD.dd)
5	Enter latitude of destination (+N, −S).	L_D (DDMM.m)	[C]	ΔL (DD.dd)
6	Enter longitude of destination (+W, −E) to compute great circle distance.	λ_D (DDDMM.m)	[D]	Dist (nau. mi.)
7	Enter intermediate longitudes (+W, −E) to find corresponding latitudes (+N, −S).	λ_i (DDDMM.m)	[E]	L_i (DDMM.m)

NOTES:
1. Data may be corrected by reentry.
2. Step 8 may be repeated as needed.
3. Use of print cradle with this program is optional.
4. Use the **RHUMBLINE NAVIGATION** program to determine courses between intermediate points.

EXAMPLE: You are planning a passage from Norfolk, Virginia, latitude 36°51.1'N longitude 76°18.1'W to Bishop Rock England, latitude 49°45.1'N longitude 6°35.1'W. Find the initial great circle distance and the intermediate points of longitude for 5 degree intervals of latitude along your route.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 26		Select Program
	[2nd] [Deg]		Select Degree Mode
3651.1†	[A]	36.85166667	L_S
7618.1†	[B]	76.30166667	λ_S
4945.1†	[C]	−12.9	$L_D \rightarrow \Delta L$
635.1†	[D]	3025.968098	$\lambda_D \rightarrow$ Dist
7000†	[E]	4027.477686†	$\lambda_1 \rightarrow L_1$ (DDMM.m)
6500†	[E]	4250.750167†	$\lambda_2 \rightarrow L_2$
6000†	[E]	4451.610381†	$\lambda_3 \rightarrow L_3$
5500†	[E]	4632.293056†	$\lambda_4 \rightarrow L_4$
5000†	[E]	4754.766136†	$\lambda_5 \rightarrow L_5$
4500†	[E]	4900.666247†	$\lambda_6 \rightarrow L_6$
4000†	[E]	4951.323211†	$\lambda_7 \rightarrow L_7$
3500†	[E]	5027.749011†	$\lambda_8 \rightarrow L_8$
3000†	[E]	5050.687747†	$\lambda_9 \rightarrow L_9$
2500†	[E]	5100.584875†	$\lambda_{10} \rightarrow L_{10}$
2000†	[E]	5057.66025†	$\lambda_{11} \rightarrow L_{11}$
1500†	[E]	5041.838292†	$\lambda_{12} \rightarrow L_{12}$
1000†	[E]	5012.812281†	$\lambda_{13} \rightarrow L_{13}$

Register Contents

R_{00} L_1	R_{05} Δ_λ	R_{10}	R_{15}
R_{01} λ_1	R_{06} λ_i	R_{11}	R_{16}
R_{02} L_2	R_{07} hav Δ L	R_{12}	R_{17}
R_{03} λ_2	R_{08}	R_{13}	R_{18}
R_{04} ΔL	R_{09}	R_{14}	R_{19}

† Printed if PC-100A is connected.

SAILING AND TACTICS

When it is necessary to tack in order to reach the desired destination, the skipper must choose a tacking angle. Having chosen his tacking angle, the skipper may then use the first two programs of this section to determine how to reach the mark. The **DISTANCE AND BEARING TO THE MARK** program is necessary only when the skipper desires to recompute his course due to changes in sailing conditions. (See the flow chart diagram on page 116.)

The skipper must have devices on his boat that measure the following quantities:

1. The boat speed through the water measured with a knotmeter.
2. The wind speed as measured on deck by an anemometer. (This will be referred to as the apparent wind speed.)
3. The angle between the direction the bow is pointing and the direction from which the apparent wind is arriving measured by a windvane. (This angle is always positive and less than or equal to 180°. It will be referred to as the apparent wind angle.)

The above quantities are used to determine a variable described as the modified wind for use in program calculations. The modified wind is defined as the true wind vector minus the current vector, or, the wind relative to a point moving with the current.

All angles are entered and displayed in decimal degrees. Time is found in the hour-minute-second (HH.MMSS) format.

Heel Angle

Wind, as measured onboard a sailboat by means of an anemometer, is affected by the angle of heel of the vessel. For example, if the vessel were lying on its side (a heel angle of 90°) and the wind was coming from the direction of the boat's side, then the anemometer would register zero wind speed as the wind would be blowing through its blades without exerting any pressure on them. If, at the same heel angle, the wind was blowing from the direction of the bow, the anemometer would register the correct apparent wind speed as it would be striking the blades in the usual perpendicular fashion.

The skipper may disregard the heel angle (HA = 0° is assumed by the program); however, if he chooses to enter this value and AW_m is the apparent wind speed indicated by his anemometer, then the actual apparent wind speed (AW) is calculated as outlined below.

First, x and y are evaluated as

$$x = \cos W_a^\circ \quad \text{and} \quad y = \sin W_a^\circ \cos HA.$$

Converting (x, y) to its polar representation (r, θ), AW_x and AW_y are calculated by the following equations:

$$AW_x = AW_m \cos\theta, \qquad AW_y = AW_m \sin\theta/\cos HA.$$

Next, (AW_x, AW_y) is transformed to the polar representation (ρ, ϕ) and AW is set equal to ρ for use in the program calculations.

Given AW and HA, AW_m is found by reversing the above.

Leeway Corrections

The bow of a sailboat does not point exactly in the direction of the boat's progress, but a few degrees into the wind. This is known as the phenomenon of leeway and may be corrected according to the angle between the direction of the bow and the direction of actual progress through the water. No provision is made for this correction in the programs; however, the skipper may make the proper adjustments according to the following procedure.

For inputs:

1. If on port tack, add the leeway correction to the course steered.
2. If on starboard tack, subtract the leeway correction from the course steered.
3. Add the correction to the apparent wind angle.

If the above is performed, then the program outputs will be the actual direction of the boat's progress through the water. The skipper should determine the course to steer as outlined below:

1. If on the port tack, subtract the leeway correction from the computed course.
2. If on the starboard tack, add the leeway correction to the computed course.

The apparent wind angle should be observed as calculated by the program.

MODIFIED WIND

This program is designed to compute and store values necessary to the operation of the programs in this section. The current tacking angle (Tk) sailed and the modified wind speed (MW) are determined when the vessel speed through the water (S), the apparent wind speed (AW), and the apparent wind angle ($W_a°$) are entered into the calculator. When the compass course (C_c), the magnetic variation (V), and the magnetic deviation (De) are supplied, the program will find the modified wind direction ($W_m°$). Aside from the computed values discussed above, the initial distance (D) and true bearing (B_t) to the mark and the drift (Dr) and set (St) of the current may be stored for use in other programs.

MW and Tk are set equal to r and θ after (x, y) is converted to its polar representation (r, θ) where x and y are evaluated as

$$x = AW \cos W_a° - S \quad \text{and} \quad y = AW \sin W_a°.$$

The true course is computed by: $C_t = C_c - De - V \quad (0° \leqslant C_t < 360°)$.

If the wind is arriving on the port side, then $W_m° = C_t - Tk$.

If the wind is arriving on the starboard side, then $W_m° = C_t + Tk$.

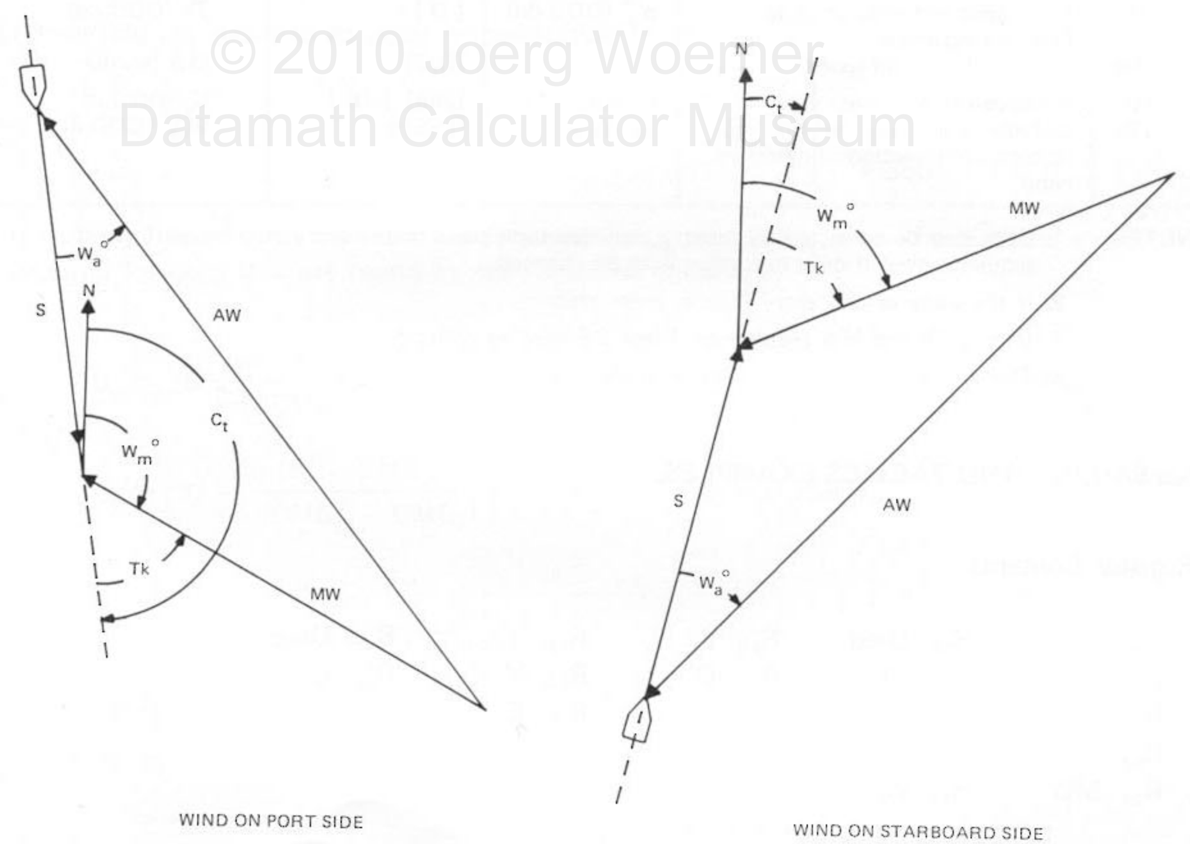

FIGURE 1

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MODIFIED WIND				NG-27
V	Dr, St		C_c; De → $W_m°$	D, Bt
PORT	S	AW; HA	$W_a°$ → Tk; MW	STBD

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 27	
2	Select degree mode.		[2nd] [Deg]	
3	If on port tack. If on starboard tack.		[A] [E]	−1.0 1.0
4	Enter magnetic variation (+W,−E)	V (DD.dd)	[2nd] [A′]	V (DD.d)
5a 5b	Enter drift and set of current.	Dr (knots) St (DDD.dd)	[2nd] [B′] [2nd] [B′]	prev. Dr (knots) prev. St (DDD.d)
6a 6b	Enter distance and true bearing to mark.	D (nau. mi.) B_t (DDD.dd)	[2nd] [E′] [2nd] [E′]	prev. D (nau. mi.) prev. B_t (DDD.d)
7	Enter speed through water.	S (knots)	[B]	S (knots)
8a 8b	Enter apparent wind speed. and heel angle if desired. (If no heel angle is entered, the program uses HA = 0°.)	AW (knots) HA (DD.dd)	[C] [R/S]	AW (knots) HA (DD.d)
9a 9b	Enter apparent wind angle to find tacking angle and modified wind speed.	$W_a°$ (DDD.dd)	[D] [R/S]	Tk (DDD.dd) MW (knots)
10a 19b	Enter compass course and magnetic deviation (+W,−E) to compute direction of modified wind.	C_c (DDD.dd) De (D.dd)	[2nd] [D′] [R/S]	C_c (DDD.d) $W_m°$ (DDD.d)

NOTES:
1. Data may be corrected by reentry provided both parts of the entry step are performed in sequence even if only one value is to be changed.
2. If the value of any entry is zero, enter zero.
3. If only Tk and MW are desired, Steps 3-6 may be omitted.
4. The printing unit may be used with this program.

See **SAILING AND TACTICS EXAMPLES.**

Register Contents

R_{00}	R_{05} Used	R_{10} B_t	R_{15}	R_{20} Used
R_{01} S	R_{06} Dr	R_{11} D	R_{16} V	R_{26} Used
R_{02} AW	R_{07} St	R_{12}	R_{17} C_c	
R_{03}	R_{08} Tk	R_{13}	R_{18}	
R_{04} MW	R_{09} $W_m°$	R_{14}	R_{19} HA	

SMG, CMG, AND TIME TO LAY-LINE

Given the tack being sailed (port or starboard) and the course steered on that tack, this program will compute the course to steer on the opposite tack and the amount of time to spend on each in order to reach the mark. In either case, the initial tacking angle sailed (Tk) and the modified wind speed (MW) and direction ($W_m°$) must first be determined by the **MODIFIED WIND** program. The distance (D) and true bearing (B_t) to the mark may be entered through either program. Further calculations that may be obtained from this program are the speed to make good (SMG) and distance to be sailed on each tack as well as the total time required to reach the mark.

The following calculations are carried out for each tack as required. The true and compass courses are found by the equations:

$$C_t = W_m° + Tk \qquad \text{(for port tack)},$$
$$C_t = W_m° - Tk \qquad \text{(for starboard tack)},$$
$$C_c = C_t + V + De \qquad (0° \leqslant C_t,\ C_c < 360°).$$

The velocity made good vector is the sum of the vessel velocity and current vectors. The cartesian coordinates of $\overrightarrow{VMG}$ are:

$$x = S \cos C_t + Dr \cos St, \qquad y = S \sin C_t + Dr \sin St.$$

Converting the above to its polar representation (r, θ):

$$SMG = r, \qquad CMG = \begin{cases} \theta & \text{if } \theta \geqslant 0°, \\ \theta + 360° & \text{if } \theta < 0°. \end{cases}$$

If the initial bearing to the mark lies between CMG_p and CMG_s, then the distance and time required for each tack are found by the following equations:

$$D_p = \left| D \frac{\sin (B_t - CMG_s)}{\sin (CMG_p - CMG_s)} \right|, \qquad t_p = D_p/SMG_p,$$

$$D_s = \left| D \frac{\sin (B_t - CMG_p)}{\sin (CMG_p - CMG_s)} \right|, \qquad t_s = D_s/SMG_s.$$

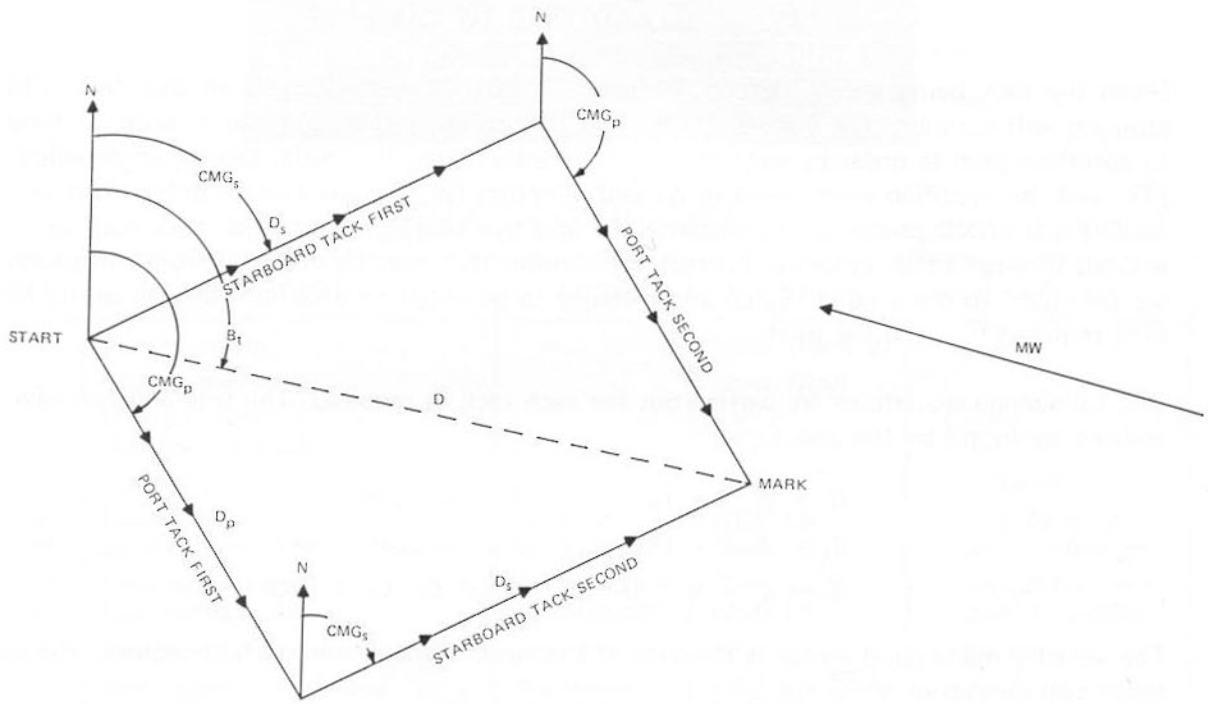


FIGURE 2

REMARKS:

1. In running the program, if the port tack is taken first (step 8), then t_p is the time to the lay-line and t_s is the time needed to reach the mark after changing tacks. If the starboard tack is taken first, these values are reversed.
2. The skipper may choose to disregard the magnetic deviation.

Register Contents

R_{00}	R_{05}	R_{10} B_t	R_{15} CMG_s	R_{20} Used
R_{01} S	R_{06} Dr	R_{11} D	R_{16} V	R_{21} Used
R_{02}	R_{07} St	R_{12} SMG_p	R_{17} Used	
R_{03}	R_{08} Tk	R_{13} CMG_p	R_{18} Used	
R_{04}	R_{09} W_m°	R_{14} SMG_s	R_{19}	

Solid State Software TI ©1977				
SMG, CMG, TIME TO LAY-LINE				NG-28
	→Δt_p; D_p	→Δt	→Δt_s; D_s	D, B_t
→C_{tp};De→C_c	→SMG_p;CMG		→SMG_s;CMG	→C_{ts}; De→C_c

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 28	
2	Select degree mode.		[2nd] [Deg]	
3a	Enter distance and	D (nau. mi.)	[2nd] [E′]	prev. D (nau. mi.)
3b	true bearing to mark unless stored by an earlier program.	B_t (DDD.dd)	[2nd] [E′]	prev. B_t (DDD.d)
4a	Compute true course to steer on port tack		[A]	C_{tp} (DDD.d)
4b	and enter magnetic deviation (+W, −E) to find compass course.	De (D.dd)	[R/S]	C_{cp} (DDD.d)
5a	Compute SMG_p		[B]	SMG_p (knots)
5b	and CMG_p.		[R/S]	CMG_p (DDD.d)
6a	Compute true course to steer on starboard tack		[E]	C_{ts} (DDD.d)
6b	and enter magnetic deviation (+W, −E) to find compass course.	De (D.dd)	[R/S]	C_{cs} (DDD.d)
7a	Compute SMG_s		[D]	SMG_s (knots)
7b	and CMG_s.		[R/S]	CMG_s (DDD.d)
8a	Calculate time and		[2nd] [B′]	Δt_p (HH.MMSS)
8b	length of port tack.		[R/S]	D_p (nau. mi.)
9a	Calculate time and		[2nd] [D′]	Δt_s (HH.MMSS)
9b	length of starboard tack.		[R/S]	D_s (nau. mi.)
10	Compute total time to the mark.		[2nd] [C′]	Δt (HH.MMSS)

NOTES:

1. D and B_t may be corrected by reentry provided both are reentered in the proper sequence.
2. If an erroneous value is entered for De and [R/S] is pressed, perform part a of the step again before reentering.
3. Steps 8 and 9 may be performed in either order. The order 6, 7, 4, 5 is also possible.
4. Steps 4b, 5b, 8b, and 9b are optional.
5. If the value of any data is zero, enter zero.
6. The printing unit may be used with this program.
7. When the print cradle is used, pressing [2nd] [C′] will cause the time for each tack and the total time to be printed.

See **SAILING AND TACTICS EXAMPLES.**

DISTANCE AND BEARING TO THE MARK

Regardless of which tack is taken first, this program will yield the distance made good (DMG) during the time (Δt) spent on the initial tack. It also computes the distance (D′) and true bearing (B_t') to the mark at the new position. An additional feature of this routine is its capability to update, or use the calculated position as a new start. The speed (SMG) and course (CMG) made good for the tack may be entered directly by the user if they are known. Otherwise, these values must first be found by using the **SMG, CMG, AND TIME TO LAY-LINE** program. The original distance (D) and true bearing (B_t) to the mark are required inputs.

The distance made good is calculated by: $DMG = SMG \times \Delta t$.

The distance and course to the mark at the end of the specified time interval are determined after converting (x, y) to the polar coordinates (r, θ) where

$$x = DMG \cos CMG - D \cos B_t \quad \text{and} \quad y = DMG \sin CMG - D \sin B_t.$$

Now,

$$D' = r \quad \text{and} \quad B_t' = \begin{cases} \theta & \text{if } \theta \geqslant 0^\circ, \\ \theta + 360^\circ & \text{if } \theta < 0^\circ. \end{cases}$$

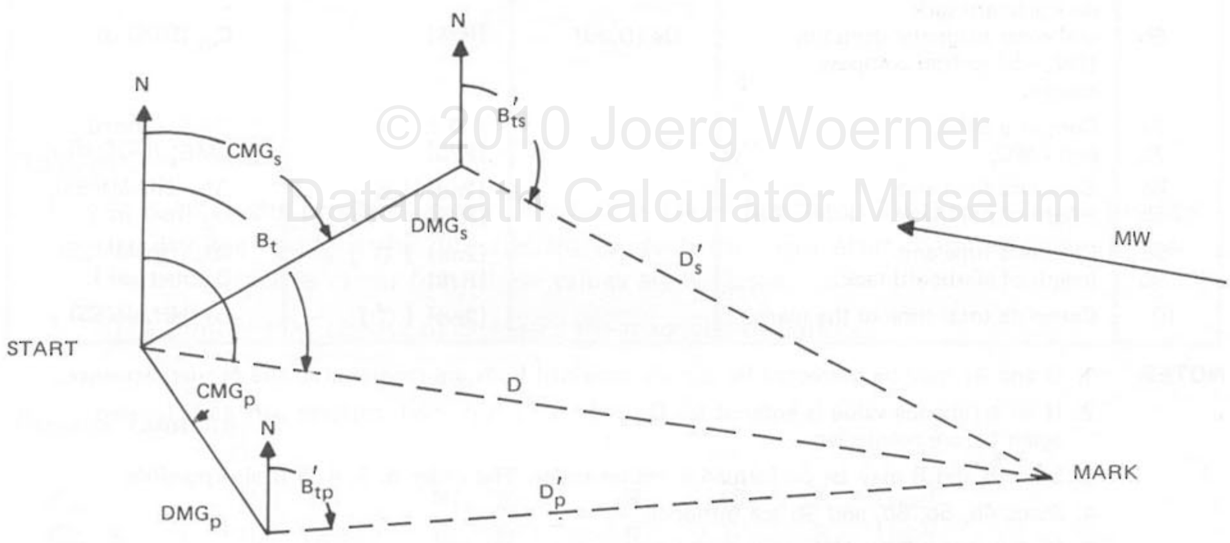


FIGURE 3

Register Contents

R_{00}	R_{05}	R_{10} B_t	R_{15} CMG_s	R_{20} Used
R_{01}	R_{06}	R_{11} D	R_{16}	
R_{02}	R_{07}	R_{12} SMG_p	R_{17} Used	
R_{03}	R_{08}	R_{13} CMG_p	R_{18} Used	
R_{04}	R_{09}	R_{14} SMG_p	R_{19}	

Solid State Software			TI ©1977	
DIST AND BEARING TO MARK				NG-29
	(P)→D′; Bt′	UPDATE	(S)→D′; Bt′	D, Bt
SMGp, CMGp	Δt→DMGp		Δt→DMGs	SMGs, CMGs

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 29	
2	Select degree mode.		[2nd] [Deg]	
3a	Unless stored by a previous program, enter initial distance and	D (nau. mi.)	[2nd] [E′]	prev. D (nau. mi.)
3b	bearing to the mark.	B_t (DDD.dd)	[2nd] [E′]	prev. B_t (DDD.dd)
4a	Unless computed and stored by an earlier program, enter speed	SMG_p (knots)	[A]	prev. SMG_p (knots)
4b	and course made good for port tack.	CMG_p (DDD.dd)	[A]	prev. CMG_p (DDD.dd)
5a	Unless computed and stored by an earlier program, enter speed	SMG_s (knots)	[E]	prev. SMG_s (knots)
5b	and course made good for starboard tack.	CMG_s (DDD.dd)	[E]	prev. CMG_s (DDD.dd)
	IF FIRST LEG IS A PORT TACK:			
6	Enter time spent on tack to find distance made good.	Δt (HH.MMSS)	[B]	DMG_p (nau. mi.)
7a 7b	Compute new distance and true bearing to mark.		[2nd] [B′] [R/S]	D ′ (nau. mi.) B_t' (DDD.d)
	IF FIRST LEG IS A STARBOARD TACK:			
8	Enter time spent on tack to find distance made good.	Δt (HH.MMSS)	[D]	DMG_s (nau. mi.)
9a 9b	Compute new distance and true bearing to mark.		[2nd] [D′] [R/S]	D′ (nau. mi.) B_t' (DDD.d)
10	Perform this step to use computed position as a new start. Make necessary changes in steps 4–5 and compute.		[2nd] [C′]	0.

NOTES:
1. Data may be corrected by reentry provided both parts of the step are reentered in order.
2. If any value to be entered is zero, enter zero.
3. Step 4(5) is not necessary for Step 8(6).
4. Do not clear display after Step 6 or 8.
5. Step 7(9) must follow Step 6(8).
6. Printer usage is optional with this program.

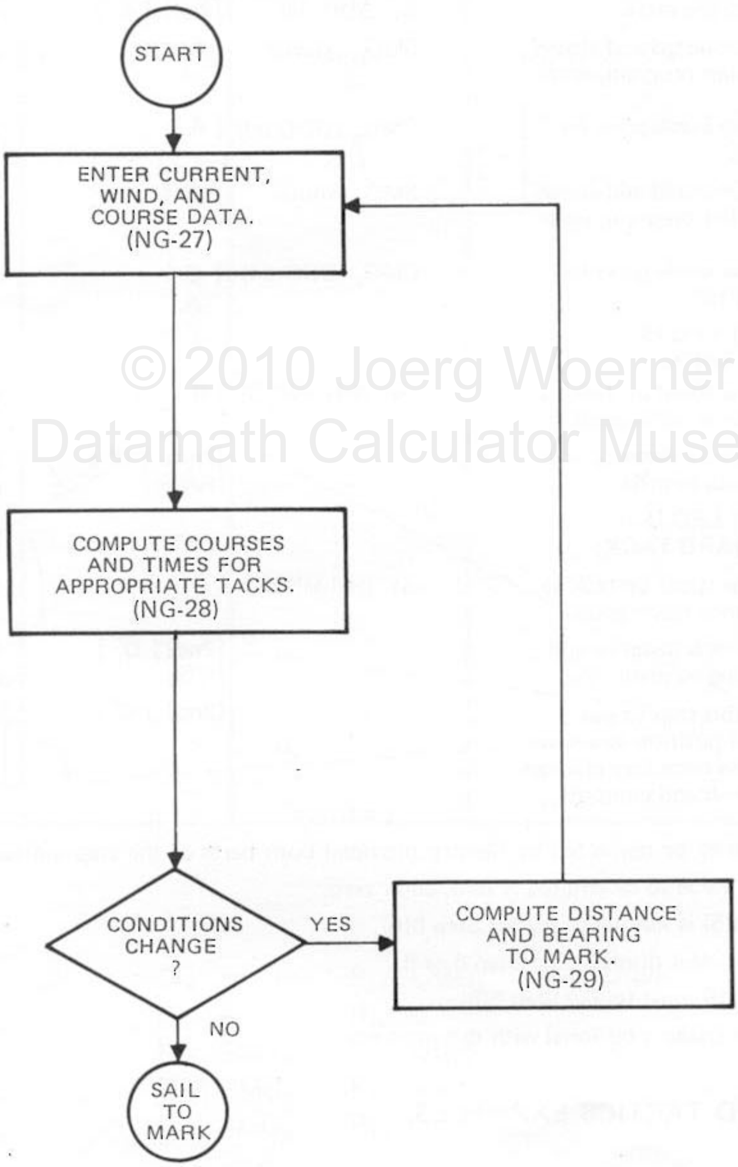
See **SAILING AND TACTICS EXAMPLES.**

SAILING AND TACTICS EXAMPLES

The following table will be used to determine the magnetic deviation with respect to the course being steered for all examples in this section. Remember, $C_m + C_t + V$. Also, each example assumes a magnetic variation of 13°W.

C_m	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
De	0°	4°E	2°E	3°E	2°E	0°	3°W	4°W	3°W	5°W	3°W	2°W

The flowchart shown below illustrates how the programs of this section may be used together as a system.



EXAMPLE: This example demonstrates the combined use of the **SAILING AND TACTICS** programs.

You wish to reach a mark which is two nautical miles from your present position at a true bearing of 305°. The drift of the current is 1.5 knots at 080°. Steering a compass course of 280° on the starboard tack at a speed of 4 knots through the water, the apparent wind speed is 11 knots at an apparent angle of 032°. Determine the amount of time to spend on the starboard tack. What course should you steer on the port tack and how long will it take to reach the mark after switching tacks? What will be the total time required to reach the mark? Assume that your heel angle is 25°. (Do not turn off the calculator or clear its memories after completing the above as the stored data will be needed in the remainder of the example.)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 27		Select Program
	[2nd] [Deg]		Select Degree Mode
	[E]	1.	Starboard
13†	[2nd] [A′]	13.	V
1.5†	[2nd] [B′]	0.*	Dr
80†	[2nd] [B′]	0.*	St
2†	[2nd] [E′]	0.*	D
305†	[2nd] [E′]	0.*	B_t
4†	[B]	4.	S
11†	[C]	11.	AW
25†	[R/S]	25.	HA
32†	[D]	47.02948216†	$W_a^\circ \rightarrow$ Tk (DDD.d)
	[R/S]	8.174107049†	MW
280†	[2nd] [D′]	280.	C_{cs}
4**	[R/S]	310.0294822†	De $\rightarrow W_m^\circ$ (DDD.d)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 28		Select Program
	[E]	263.†	C_{ts} (DDD.d)
	[D]	2.503286956†	SMG_s
	[R/S]	264.7971099†	CMG_s (DDD.d)
	[A]	357.0589643†	C_{tp} (DDD.d)
1**†	[+/–] [R/S]	9.05896432†	De $\rightarrow C_{cp}$ (DDD.d)
	[B]	4.441248558†	SMG_p
	[R/S]	16.64262114†	CMG_p (DDD.d)
	[2nd] [D′]	.4901043994†	Δt_s (HH.MMSS)
	[2nd] [B′]	.1847415431†	Δt_p (HH.MMSS)
	[2nd] [C′]	1.074845942†	Δt (HH.MMSS)

*Display will differ if a previous example has been run or corrections are made.

**Found in the table.

†Printed if PC-100A is connected.

Summary

You should remain on the starboard tack for another 49 minutes and 1 second. Then, while steering a compass course of 009° to achieve the port tack, you should reach the mark after 18 minutes and 47 seconds of sailing.

After 20 minutes on the starboard tack, you discover that the wind has shifted and will allow you to steer a course closer to the mark. Steering a compass course of 300°, the apparent wind angle remains 032°, but the apparent speed is now 14 knots and your speed through the water is 4.7 knots. The heel angle remains at 25°. Find the new distance and true bearing to the mark at the above time. When should you change to port tack and how long will it be before reaching the mark after changing tacks? Also, what will the length of the port tack be?

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 29		Select Program
.2†	[D]	.8344289853†	$\Delta t \rightarrow DMG_s$
	[2nd] [D']	1.465280255†	D
	[R/S]	326.5669949†	B_t (DDD.d)
	[2nd] [C']	0.	update

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 27		Select Program
	[E]	1.	Starboard
4.7†	[B]	4.7	S
14†	[C]	14.	AW
25†	[R/S]	25.	HA
32†	[D]	45.49390593†	$W_a^\circ \rightarrow$ Tk (DDD.d)
	[R/S]	10.67369434†	MW
300†	[2nd] [D']	300.	C_{cs} (DDD.d)
3*	[R/S]	329.4939059†	De $\rightarrow W_m^\circ$ (DDD.d)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 28		Select Program
	[E]	284.†	C_{ts} (DDD.d)
	[D]	3.38511581†	SMG_s
	[R/S]	294.3832523†	CMG_s (DDD.d)
	[A]	14.98781187†	C_{tp} (DDD.d)
4*†	[+/–] [R/S]	23.98781187†	De $\rightarrow C_{cp}$ (DDD.d)
	[B]	5.504198305†	SMG_p
	[R/S]	29.28850962†	CMG_p (DDD.d)
	[2nd] [D']	.2310087295†	Δt_s (HH.MMSS)
	[2nd] [B']	.0832334154†	Δt_p (HH.MMSS)
	[R/S]	.7833302172†	D_p
	[2nd] [C']	.3142421449†	Δt (HH.MMSS)

†Printed if PC-100A is connected.
*Found in the table.

Summary

After adjusting your course, you should spend another 23 minutes and 10 seconds on the starboard tack. At that time you will be 0.78 nautical miles from the mark and will reach it after 8 minutes and 32 seconds on the port tack. A compass course of 024° is required for the port tack. The total time before reaching the mark is 31 minutes and 42 seconds when computation is made.

UNIT CONVERSIONS

This program provides conversions between various units of length, weight, volume, and temperature as outlined below.

[A] converts yards to nautical miles (n. mi. = yds × .0004937365).

[2nd] [A′] converts nautical miles to yards.

[B] converts miles to nautical miles (n. mi. = mi. × .86897624).

[2nd] [B′] converts nautical miles to miles.

[C] converts U.S. gallons to liters (liters = gallons × 3.785411784).

[2nd] [C′] converts liters to U.S. gallons.

[D] converts pounds to kilograms (kg = lbs × .45359237).

[2nd] [D′] converts kilograms to pounds.

[E] converts degrees fahrenheit to degrees celsius [°C = 5/9 (°F - 32)].

[2nd] [E′] converts degrees celsius to degrees fahrenheit.

These conversions may be completed without affecting a calculation in progress. No data registers are used by this program.

Solid State Software			TI ©1977	
UNIT CONVERSIONS				NG-30
n.mi → yds	n.mi → mi	lit → gal(U.S.)	kg → lb	°C → °F
yds → n.mi	mi → n.mi	gal(U.S.) → lit	lb → kg	°F → °C

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program.		[2nd] [Pgm] 30	
	Length Conversions:			
2	Yards to nautical miles	Yards	[A]	Nau. mi.
3	Nautical miles to yards	Nau. mi.	[2nd] [A′]	Yards
4	Miles to nautical miles	Miles	[B]	Nau. mi.
5	Nautical miles to miles	Nau. mi.	[2nd] [B′]	Miles
	Volume Conversions:			
6	U.S. gallons to liters	Gallons	[C]	Liters
7	Liters to U.S. gallons	Liters	[2nd] [C′]	Gallons
	Weight Conversions:			
8	Pounds to kilograms	Pounds	[D]	Kg.
9	Kilograms to pounds	Kg.	[2nd] [D′]	Pounds
	Temperature Conversions:			
10	°F to °C	°F	[E]	°C
11	°C to °F	°C	[2nd] [E′]	°F

Example:

Perform the following conversions.

Convert .8 miles to nautical miles and then to yards.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 30		Select Program
.8	[B]	0.695180992	Mi. → n. mi.
	[2nd] [A′]	1408.	N. mi. → yds.

Now convert 72° F to °C and 5 pounds to kilograms.

68	[E]	20.	°F → °C
5	[D]	2.26796185	Lbs. → kgs.

APPENDIX A: PROGRAM REFERENCE DATA

Program Number	Title	No. of Steps	Data Registers Used	Flags Used	SBR Levels	Paren. Levels	Calls Pgm.	Special Functions Used	x ≷ t	ABS Address	EE*	Program Number
01	Diagnostic	112	1-6, 21		1	4	11	N/A	CP	X		01
02	Time-Speed-Distance With Current Sailing	224	1-3, 6, 7 12, 14, 19-21		2	6		D.MS P/R	X	X		02
03	Distance Short of, Beyond, or To Horizon	221	0-3, 15		2	4		D.MS		X		03
04	Velocity Needed To Change Relative Position	146	1-4, 14, 17 18, 20-22		1	4		D.MS P/R	X	X		04
05	Velocity, VMG, and Current Vectors	197	6, 7, 12, 13, 16-18, 20	0†	2	3		P/R	X	X		05
06	Course to Steer and SMG	160	6, 7, 12, 13, 16-18, 20		1	6		D.MS P/R	X	X		06
07	Distance Off 1 Object and TNA	196	1-3, 6, 7, 12, 14-24, 26		1	5	10	D.MS P/R	X	X		07
08	DMG, SMG, CMG from 2 Objects	191	1-3, 6, 7, 12-15, 17-25		1	5		D.MS P/R	X	X		08
09	Course Made Good from 3 Bearings	160	1-3, 13-16, 19, 20, 26		1	4	10	D.MS P/R	X	X		09
10	Dead Reckoning	195	1-3, 15, 17-19, 21, 22, 26		2	4	11	D.MS P/R	X	X		10
11	Rhumbline Navigation	229	0-3, 15, 18-22, 26		2	5	10	D.MS P/R	X	X	X	11
12	Chart Initialization	78	4, 5, 8-13, 16, 20-24		1	4		D.MS				12
13	Running Fix from 1 Object	204	1-11, 14-19, 26-29		1	4	10	D.MS P/R	X	X		13
14	Fix from 2 Objects	111	1, 2, 4, 5, 8-11, 15, 16 26, 28, 29		1	3	10	D.MS P/R	X	X		14
15	Time of Sunrise/ Sunset/Twilight	140	0-10		3	4	16	D.MS	CP	X		15
16	Planet Location	170	0-7, 11, 12,	0†	2	6	19	D.MS	CP	X		16
17	Star Identification	197	1-9	0†	3	4	16	D.MS	CP	X		17
18	Sextant Correction	210	0, 2-4, 8, 10, 12, 14, 16, 18, 20, 21	0†	2	5	16,23	D.MS	CP	X		18

*Does not run in ENG format

APPENDIX A: PROGRAM REFERENCE DATA (Cont.)

Program Number	Title	No. of Steps	Data Registers Used	Flags Used	SBR Levels	Paren. Levels	Calls Pgm.	Special Functions Used	x ≷ t	ABS Address	EE*	Program Number
19	Sight Reduction (Sun)	161	1-21	0†	3	5	16,17	D.MS	CP	X		19
20	Sight Reduction (Moon)	102	1-4, 6-21	0†	3	5	16,19	D.MS	CP			20
21	Sight Reduction (Planet)	61	1-4, 6-21	0†	3	5	16,19 20	D.MS	CP			21
22	Sight Reduction (Star)	79	1-21	0†	3	5	16,19	D.MS	CP			22
23	Fix By 2 Observations	162	0-19		2	5	25	D.MS P/R	X	X		23
24	LAN and Sun Lines	108	0-5		2	4	16	D.MS				24
25	Noon Sight Fix	163	0, 2, 3, 8, 20, 21		2	5	16	D.MS	CP	X		25
26	Great Circle Sailing	161	0-7		3	4	16,24 25	D.MS				26
27	Modified Wind	160	1, 2, 4-11, 16, 17, 19, 20, 26		1	2	10	P/R	X	X		27
28	SMG, CMG and Time to Lay-Line	208	1, 6-18, 20, 21		2	5	27	D.MS P/R	X	X		28
29	Distance and Bearing to the Mark	131	10-15, 17, 18, 20		1	5	27	D.MS P/R	X	X		29
30	Unit Conversions	122			1	2						30
	Pointers and Counters	241										

*Does not run in ENG format.
†Ensure that flag 0 is reset when you use this program.

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WARRANTEE

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