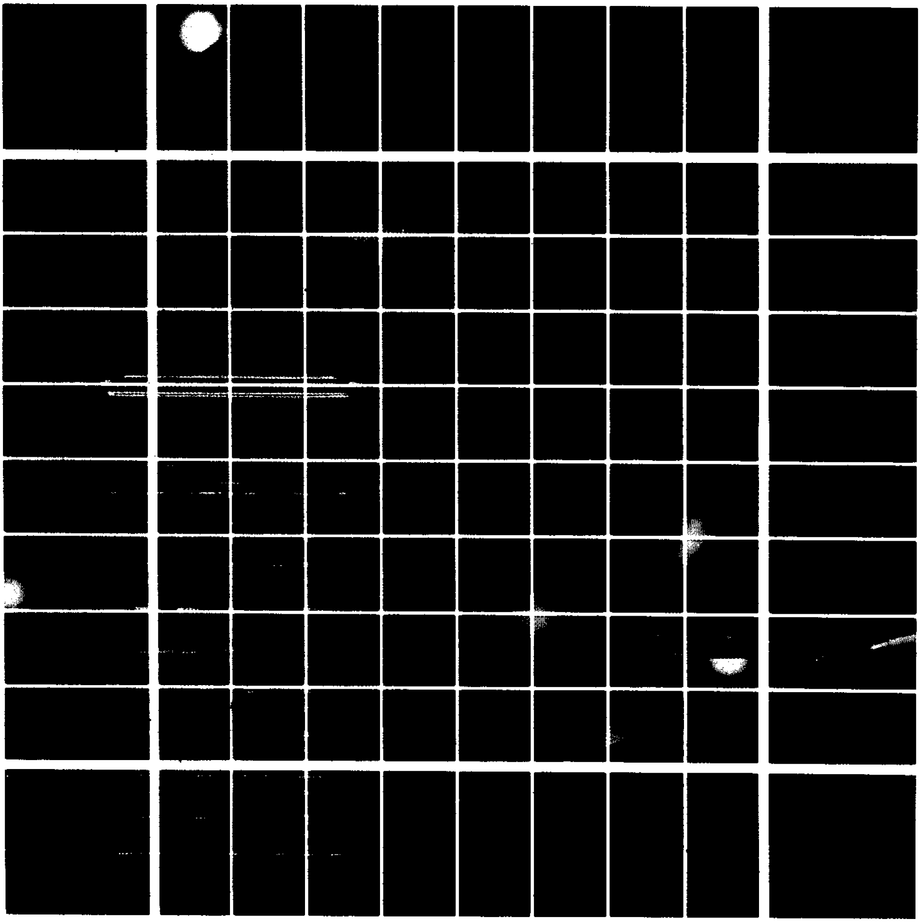
HEWLETT-PACKARD

# HP-41C

# NAVIGATION PAC



## NOTICE

HEWLETT PACKARD

# HEWLETT-PACKARD LISTENS

To provide better calculator support for you, the Application Engineering group needs your help. Your timely inputs enable us to provide higher quality software and improve the existing application pacs for your calculator. Your reply will be extremely helpful in this effort.

1. Pac name ____________________

2. How important was the availability of this pac in making your decision to buy a Hewlett-Packard calculator?

   ☐ Would not buy without it. ☐ Important ☐ Not important

3. What is the major application area for which you purchased the pac?

____________________

4. In the list below, please rate the usefulness of the programs in this pac.

| PROGRAM NUMBER | ESSENTIAL | IMPORTANT BUT NOT REQUIRED | INFREQUENTLY USED | NEVER USED |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |

| PROGRAM NUMBER | ESSENTIAL | IMPORTANT BUT NOT REQUIRED | INFREQUENTLY USED | NEVER USED |
|---|---|---|---|---|
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |

5. Did you purchase a printer? ☐ YES ☐ NO

   If you did, is the printing format in this pac useful? ☐ YES ☐ NO

6. What programs would you add to this pac?

____________________

7. What additional application pacs would you like to see developed?

____________________

THANK YOU FOR YOUR TIME AND COOPERATION.

Name ____________________ Position ____________________

Company ____________________

Address ____________________

City ____________________ State ____________________

Zip ____________________ Phone ____________________

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# INTRODUCTION

The programs in the Navigation Pac were selected to solve the problems that are common to all marine navigators.

Each program in this pac is represented by one program in the Application Module and a section in this manual. The manual provides a description of the program, a set of instructions for using the program, and one or more example problems each of which includes a list of the keystrokes required for its solution.

Before plugging in your Application Module, **turn your calculator off,** and be sure you understand the section "Inserting and Removing Application Modules." Before using a particular program, take a few minutes to read "Format of User Instructions" and "A Word About Program Usage."

You should first familiarize yourself with a program by running it once or twice while following the complete User Instructions in the manual. Thereafter, the program's prompting should provide the necessary instructions, including which variables are to be input, which keys are to be pressed and which values will be output.

We hope that Navigation Pac I will assist in your course planning and celestial navigation. We would appreciate knowing your reactions to the programs in this pac, and to this end we have provided a questionnaire inside the front cover of this manual. Would you please take a few minutes to give us your comments on these programs? It is from your comments that we learn how to increase the usefulness of our programs.

# CONTENTS



## Course Planning Programs

These programs simplify the job of combining the best features of rhumb-line and great-circle sailing. You can obtain a printed list showing your vessel's predicted position after each day's run along with the rhumb-line course between the positions.



## Celestial Navigation Programs

Reducing celestial sights is simplified to keying in date, time, sextant height, and the name of the object sighted. Permissible objects include 57 navigational stars, Polaris, the Sun, the Moon, Venus, Mars, Jupiter, and Saturn. Provision is made for substituting nautical almanac values for the computer almanac. After reducing a sight, you can use one of the Course-Planning programs to update your dead reckoning position.



## Subroutines Used in this Pac

An important feature of these programs is their use of companion programs which are callable as subroutines. Thus a navigator who wishes to write a program of his own can still use many of the valuable routines of the Navigation Pac.

## INSERTING AND REMOVING APPLICATION MODULES

Before you insert an Application Module for the first time, familiarize yourself with the following information.

Up to four Application Modules can be plugged into the ports on the HP-41. While plugged in, the names of all programs contained in the Module can be displayed by pressing ■ [CATALOG] 2.

| CAUTION |
|---|
| Always turn the HP-41 off before inserting or removing any plug-in extension or accessories. Failure to turn the HP-41 off could damage both the calculator and the accessory. |

**To insert Application Modules:**

1. Turn the HP-41 off! Failure to turn the calculator off could damage both the Module and the calculator.

2. Remove the port covers. Remember to save the port covers; they should be inserted into the empty ports when no extensions are inserted.

3. Insert the Application Module with the label facing downward as shown, into any port **after** the last Memory Module. For example, if you have a Memory Module inserted in port 1, you can insert an Application Module in any of ports 2, 3, or 4. (The port numbers are shown on the back of the calculator.) **Never insert an Application Module into a lower numbered port than a Memory Module.**

4. If you have additional Application Modules to insert, plug them into any port after the last Memory Module. Be sure to place port covers over unused ports.
5. Turn the calculator on and follow the instructions given in this book for the desired application functions.

**To remove Application Modules:**

1. Turn the HP-41 off! Failure to do so could damage both the calculator and the Module.
2. Grasp the desired Module handle and pull it out as shown.

3. Place a port cap into the empty ports.

## Mixing Memory Modules and Application Modules

Any optional accessories (such as the HP 82104A Printer) should be treated in the same manner as Application Modules. That is, they can be plugged into any port after the last Memory Module. Also, the HP-41 should be turned off prior to insertion or removal of these extensions.

The HP-41 allows you to leave gaps in the port sequence when mixing Memory and Application Modules. For example, you can plug a Memory Module into port 1 and an Application Module into port 4, leaving ports 2 and 3 empty.

## FORMAT OF USER INSTRUCTIONS

The User Instruction Form—which accompanies each program—is your guide to operating the programs in this Pac.

The form is composed of five labeled columns. Reading from left to right, the first column, labeled STEP, gives the instruction step number.

The INSTRUCTIONS column gives instructions and comments concerning the operations to be performed.

The INPUT column specifies the input data, the units of data if applicable, or the appropriate alpha response to a prompted question. Data input keys consist of 0 to 9 and the decimal point (the numeric keys), [EEX] (enter exponent), and [CHS] (change sign).

The FUNCTION column specifies the keys to be pressed after keying in the corresponding input data.

The DISPLAY column specifies prompts, intermediate and final answers, and their units, where applicable.

Above the DISPLAY column is a box which specifies the minimum number of data storage registers necessary to execute the program. Refer to the Owner's Handbook for information on how the SIZE function affects storage configuration.

The following illustrates the User Instruction Form.

SIZE: 054

| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
|---|---|---|---|---|
| 1 | Initialize program. | | [XEQ] SIGHT | DRL = 0:00:00N? |
| 2 | Key in DR latitude. | DRL, d.ms | [R/S] | DRLO = 0:00:00W? |
| 3 | Key in DR longitude. | DRLo, d.ms | [R/S] | DATE = 0.000000? |
| 4 | Key in date. | mm.ddyyyy | [R/S] | TIME = 0:00:00? |
| 5 | Key in Greenwich Mean Time. | GMT, h.ms | [R/S] | HE = 0. FT? |
| 6 | Key in height of eye in ft. or<br>—HE in m. | HE, ft.<br>HE, m | [R/S]<br>[CHS] [R/S] | HS =? |
| 7 | Key in sextant height. | HS, d.ms | [R/S] | WHICH BODY? |
| 8 | Select which body.<br>a. Key in name (at least first 6 letters).<br>or<br>b. Take HP-41 out of alpha and key in star number. (This is faster.) | <br>NAME†<br><br><br>star # | <br>[R/S]<br><br>[ALPHA]<br>[R/S] | |
| 9 | HP-41 will display intercept<br><br>and azimuth.<br>* Press [R/S] if you are not using a printer.<br>†Note NAME is any member of the list of objects shown in the appendix. If NAME is not found, the default is NA, the Almanac Interpolater. | <br><br> | <br><br>[R/S]* | Name a = 0.0 A or T<br><br>ZN = 0.0 |

# A WORD ABOUT PROGRAM USAGE

## Catalog

When an Application Module is plugged into a port of the HP-41 , the contents of the Module can be reviewed by pressing ■ [CATALOG] 2 (the Extension Catalog). Executing the [CATALOG] function lists the name of each program or function in the Module, as well as functions of any other extensions which might be plugged in.

## ALPHA Mode Notation

This manual uses a special notation to signify ALPHA mode. Whenever a statement on the User Instruction Form is printed in gold, the [ALPHA] key must be pressed before the statement can be keyed in. After the statement is input, press [ALPHA] again to return the calculator to its normal operating mode, or to begin program execution. For example, [XEQ] SIGHT means press the following keys: [XEQ] [ALPHA] SIGHT [ALPHA].

## Optional Printer

When the optional printer is plugged into the HP-41 along with the Navigation Application Module, all results will be printed automatically. You may also want to keep a permanent record of the values input to a certain program. A convenient way to do this is to set the Print Mode switch to NORMAL before running the program. In this mode, all input values and the corresponding keystrokes will be listed on the printer, thus providing a record of the entire operation of the program.

## Downloading Module Programs

If you wish to trace execution, to modify, or to record on magnetic cards a program in this Application Module, it must first be copied into the HP-41 's program memory. For information concerning the HP-41 's COPY function, see the Owner's Handbook. It is not necessary to copy a program in order to run it.

## Program Interruption

These programs have been designed to operate properly when they are run from beginning to end, with or without a printer. If the status of flag 21 is changed from set to clear, these programs may not work as documented. Flag 21 is cleared when the calculator is turned on, unless the printer is plugged in. Most of these programs will set flag 21 initially to halt the calculator for alpha-displays. If the program is interrupted, the calculator turned off, or only a specific subroutine of the program is used, flag 21 may not be set, in which case the program will not stop to display the results (depending on the form of program interruption).

You may wish to take advantage of this feature when executing subroutines that would normally stop to display results and not continue until [R/S] is pushed. If flag 21 was cleared before the program executes the subroutines, the calculator could utilize the answer immediately after returning to the calling program.

### Size

Size 054 is sufficient for programs in this pac. A smaller size is accepted where indicated.

### Use of Labels

If you write programs that use program labels identical to those in the Navigation Pac, the Navigation Pac will execute your programs instead of its own. You might wish to take advantage of this powerful feature to customize aspects of the program operation by substituting your routines for Pac routines.

### Label Conflicts With Other Application Pacs

Three labels used in the Navigation Pac have the same name as those used in other Pacs. If you have this Pac and another Pac plugged into your HP-41 at the same time, you should make sure that the Pac whose programs you want to use is in the lowest-numbered port to avoid conflicting use of these labels.

| Label | Pac |
|---|---|
| *IN | Clinical Lab, Machine Design, Surveying |
| *T | Aviation |
| P | Games, Petroleum Fluids, Standard |

## NOTATION USED IN THIS PAC

This pac will recognize or display angles in one of two different formats, depending on the status of flag 00. When flag 00 is set, the initial prompts will be in the format of degrees, minutes, and decimal minutes (0:00.0). If flag 00 is cleared before a prompt for an angle, the angle's format will be degrees, minutes, and seconds (0:00:00). Most of the examples are in degrees, minutes, and seconds format and require that flag 00 is clear to achieve identical results. Time is always expressed in hours, minutes, and seconds. When a program prompts for an angle, be sure to enter the angle in the specified format.

| Display | Status of Flag 00 | Input Required |
|---|---|---|
| *0:00:00N?* | clear | degrees, minutes, seconds |
| *0:00.0N?* | set | degrees, minutes, tenths of minutes |

When the User Instructions indicate the units of an angle which is to be input, d.ms will be used. Usually the display will prompt with old values and the form of the number to be input will be immediately recognized. Negative values must be used for southerly latitudes and declinations and for easterly longitudes and hour angles. On output, the signs are removed and the letters N, S, E, and W are used instead.

When a program prompts for data, it recalls the value used previously and affixes a question mark. If there is no change in the data, simply press [R/S] to skip to the next prompt. Prompts shown in the examples usually have the value zero. Values in actual applications will be non-zero and will depend on the order in which the programs are run. Sometimes much of the data the examples require will be in place already and no further action beyond pressing [R/S] will be required to solve the problem.

## SYMBOLS USED IN THIS PAC

| Symbol | Meaning |
|---|---|
| $\beta$ | celestial latitude |
| $\delta$ | declination |
| $\delta\lambda$ | precession of equinox |
| $\delta\odot$ | Sun's declination |
| $\epsilon$ | obliquity of the ecliptic |
| $\lambda$ | longitude |

| Symbol | Meaning |
|---|---|
| Π | longitude of perihelion |
| ρ | radius vector |
| Ω | longitude of Moon's ascending node |
| A | away |
| a | altitude intercept |
| C | course |
| dec | declination |
| D | day of month, distance |
| DLo | difference in longitude |
| DRL | dead-reckoning latitude |
| DRLo | dead-reckoning longitude |
| d.d | decimal degrees |
| d.ms | degrees, minutes and seconds |
| d.mt | degrees, minutes and tenth-minutes |
| e | eccentricity of the spheroid |
| F | latitude argument |
| G | mean anomaly |
| GC | great circle |
| GHA | Greenwich hour angle |
| GHA♈ | Greenwich hour angle of the Vernal Equinox |
| GMT | Greenwich mean time |
| GST | Greenwich sidereal time |
| HA | hour angle |
| Hc | computed height |
| HE | height of eye |
| Hi | initial heading |
| Ho | corrected sextant height |
| HP | horizontal parallax |
| hs | uncorrected sextant height |
| h.ms | hours, minutes and seconds |
| JD | Julian date |
| L | latitude, celestial longitude |
| Lx | mean longitude of object x |
| LHA | local hour angle |
| Lo | longitude |
| M | month |
| mm.ddyyyy | month, day and year |
| S | speed |
| SD | semidiameter |
| SHA | sidereal hour angle |
| T | centuries from 1900.0, toward |
| t | Julian days from 2000.0, meridian angle |
| Y | year |

# GREAT-CIRCLE COURSE AND DISTANCE

This program calculates the great-circle distance and initial heading between any two points. A subroutine entry point is provided.

SIZE: 011

| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
|---|---|---|---|---|
| 1 | Initialize program. | | [XEQ] GC | L1 = 0:00:00N? |
| 2 | Key in source latitude. | L1,d.ms | [R/S] | L01 = 0:00:00W? |
| 3 | Key in source longitude. | L01,d.ms | [R/S] | L2 = 0:00:00N? |
| 4 | Key in destination latitude. | L2, d.ms | [R/S] | L02 = 0:00:00W? |
| 5 | Key in destination longitude and compute distance and initial heading. | Lo2,d.ms | [R/S]<br>[R/S] * | D = 0.0NMI<br>HI = 0.0 |
| | *Press [R/S] if you are not using a printer. | | | |

To use this program as a subroutine, store L1, Lo1, L2, and Lo2 in decimal form in registers 7 through 10 respectively. Then execute the function *GC. The outputs D and Hi will be in the X- and Y-registers, respectively.

Example:

Determine the great-circle distance and initial heading from (33°31′07″N, 118°38′32″W) to (21°16′N, 157°44′42″W).

| Keystrokes (SIZE ≥ 011) | Display |
|---|---|
| [XEQ] [ALPHA] GC [ALPHA] | *L1=0:00:00N?* |
| 33.3107 [R/S] | *LO1=0:00:00W?* |
| 118.3832 [R/S] | *L2=0:00:00N?* |
| 21.16 [R/S] | *LO2=0:00:00W?* |
| 157.4442 [R/S] | *D=2,193.8 NMI* |
| [R/S] | *HI=260.6* |

# GREAT-CIRCLE POSITION

This program calculates a point on a great circle at a specified distance and initial heading. A subroutine entry point is provided.

SIZE: 011

| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
|---|---|---|---|---|
| 1 | Initialize program. | | [XEQ] GCPOS | L1 = 0:00:00N? |
| 2 | Key in source latitude. | L1,d.ms | [R/S] | LO1 = 0:00:00W? |
| 3 | Key in source longitude. | Lo1,d.ms | [R/S] | D = 0.0NMI? |
| 4 | Key in distance. | D, n.mi. | [R/S] | HI = 0.0? |
| 5 | Key in initial heading and compute new position. | Hi, d.d | [R/S]<br>[R/S]* | L2 =<br>LO2 = |
| | *Press [R/S] if you are not using a printer. | | | |

To use this program as a subroutine, store L1 and Lo1 in decimal form in registers 7 and 8 and store distance and course in registers 1 and 6. Then execute the function *GCPOS. The values L2 and Lo2 will be stored in decimal form in registers 9 and 10, respectively.

Example:

We depart from (33°31′07″N, 118°38′32″W) at 0845 in the direction 260.6. If we could follow a great circle, where would we be at noon assuming a speed of 16 knots?

| Keystrokes (SIZE ⩾011) | Display | Comments |
|---|---|---|
| [XEQ] [ALPHA] GCPOS [ALPHA] | *L1=0:00:00N?* | Displayed |
| 33.3107 [R/S] | *LO1=0:00:00W?* | values assume |
| 118.3832 [R/S] | *D=0.0NMI?* | cleared regis- |
| 3.15 [XEQ] [ALPHA] HR [ALPHA] | *3.3* | ters. Actual dis- |
| 16 [×] [R/S] | *HI=0.0?* | plays will show |
| 260.6 [R/S] | *L2=33:22:22N* | previous values |
| [R/S] | *LO2=119:39:58W* | of the variable. |

# RHUMB-LINE COURSE AND DISTANCE

This program calculates the rhumb-line distance and course between any two points. A subroutine entry point is provided.

For those who wish to be more precise, this program will compute rhumb lines on aspherical surfaces. The following table shows eccentricity values for some spheroids.

**Spheriods in Common Use**

| Spheroid | Eccentricity |
|---|---|
| Sphere | 0.0 |
| Clarke Spheroid of 1866 | 0.08227185422 |
| Clarke Spheroid of 1880 | 0.08248340005 |
| International Spheroid | 0.08199188998 |

| | | | | SIZE: 052 |
|---|---|---|---|---|
| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
| 1 | Initialize program. | | [XEQ] RL | e = 0.00000E0? |
| 2 | Key in eccentricity. | e | [R/S] | L1 = 0:00:00N? |
| 3 | Key in source latitude. | L1,d.ms | [R/S] | L01 = 0:00:00W? |
| 4 | Key in source longitude. | Lo1,d.ms | [R/S] | L2 = 0:00:00N? |
| 5 | Key in destination latitude. | L2, d.ms | [R/S] | L02 = 0:00:00W? |
| 6 | Key in destination longitude and compute distance and course. | Lo2,d.ms | [R/S] | D = 0.0NMI |
| | | | [R/S]* | C = 0.0 |
| | *Press [R/S] if you are not using a printer. | | | |

To use this program as a subroutine, store L1, Lo1, L2, and Lo2 in decimal form in registers 7 through 10 respectively. Be sure the desired eccentricity is stored in R11, then execute the function *RL.

The outputs D and C will be in the X- and Y-registers, respectively.

Example:

Determine the rhumb-line distance and course on a sphere from (33°31′07″N, 118°38′32″W) to (21°16′N, 157°44′42″W).

| Keystrokes (SIZE ≥ 052) | Display |
|---|---|
| [XEQ] [ALPHA] RL [ALPHA] | *e=0.00000E0?* |
| [R/S] | *L1=0:00:00N?* |
| 33.3107 [R/S] | *LO1=0:00:00W?* |
| 118.3832 [R/S] | *L2=0:00:00N?* |
| 21.16 [R/S] | *LO2=0:00:00W?* |
| 157.4442 [R/S] | *D=2,203.2 NMI* |
| [R/S] | *C=250.5* |

# RHUMB-LINE POSITION

This program calculates a point on a rhumb line at a specified distance and initial course. An appropriate value for the Earth's eccentricity should be selected from the table accompanying the Rhumb-Line Course and Distance program.

| | | | | SIZE: 052 |
|---|---|---|---|---|
| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
| 1 | Initialize program. | | [XEQ] RLPOS | e = 0.00000E0? |
| 2 | Key in eccentricity. | e | [R/S] | L1 = 0:00:00N? |
| 3 | Key in source latitude. | L1,d.ms | [R/S] | L01 = 0:00:00W? |
| 4 | Key in source longitude. | Lo1,d.ms | [R/S] | D = 0.0NMI? |
| 5 | Key in distance. | D, n.mi. | [R/S] | C = 0.0? |
| 6 | Key in course and compute new position. | C, d.d | [R/S]<br>[R/S]* | L2 =<br>L02 = |
| | *Press [R/S] if you are not using a printer. | | | |

To use this program as a subroutine, store L1 and Lo1 in decimal form in registers 7 and 8 and store distance and course in registers 1 and 6. Then execute the function *RLPOS. The values L2 and Lo2 will be stored in decimal form in registers 9 and 10.

Example:

We depart from (33°31′07″N, 118°38′32″W) at 0845 in the direction 250.5. Where will we be at noon if we are able to make good a speed of 16 knots? Assume that the Earth is a sphere.

| Keystrokes (SIZE ≥ 052) | Display | Comments |
|---|---|---|
| [XEQ] [ALPHA] RLPOS [ALPHA] | *e=0.00000E0?* | Displayed |
| [R/S] | *L1=0:00:00N?* | values assume |
| 33.3107 [R/S] | *LO1=0:00:00W?* | cleared regis- |
| 118.3832 [R/S] | *D=0.0NMI?* | ters. Actual |
| 3.15 [XEQ] [ALPHA] HR [ALPHA] | *3.3* | displays will |
| 16 [×] [R/S] | *C=0.0?* | show previous |
| 250.5 [R/S] | *L2=33:13:46N* | values of the |
| [R/S] | *LO2=119:37:14W* | variable. |

# GREAT-CIRCLE PLOTTING AND VOYAGE PLANNING

These programs allow you to plot a great-circle track in two ways. You can specify a longitude increment to obtain a list of points on the great circle spaced by that interval, or you can specify a distance to obtain equally-spaced points. The former technique is useful for plotting on a chart, and the latter is useful for predicting daily positions. Both programs provide the rhumb-line course and distance between successive great-circle points. A subroutine entry point is provided.

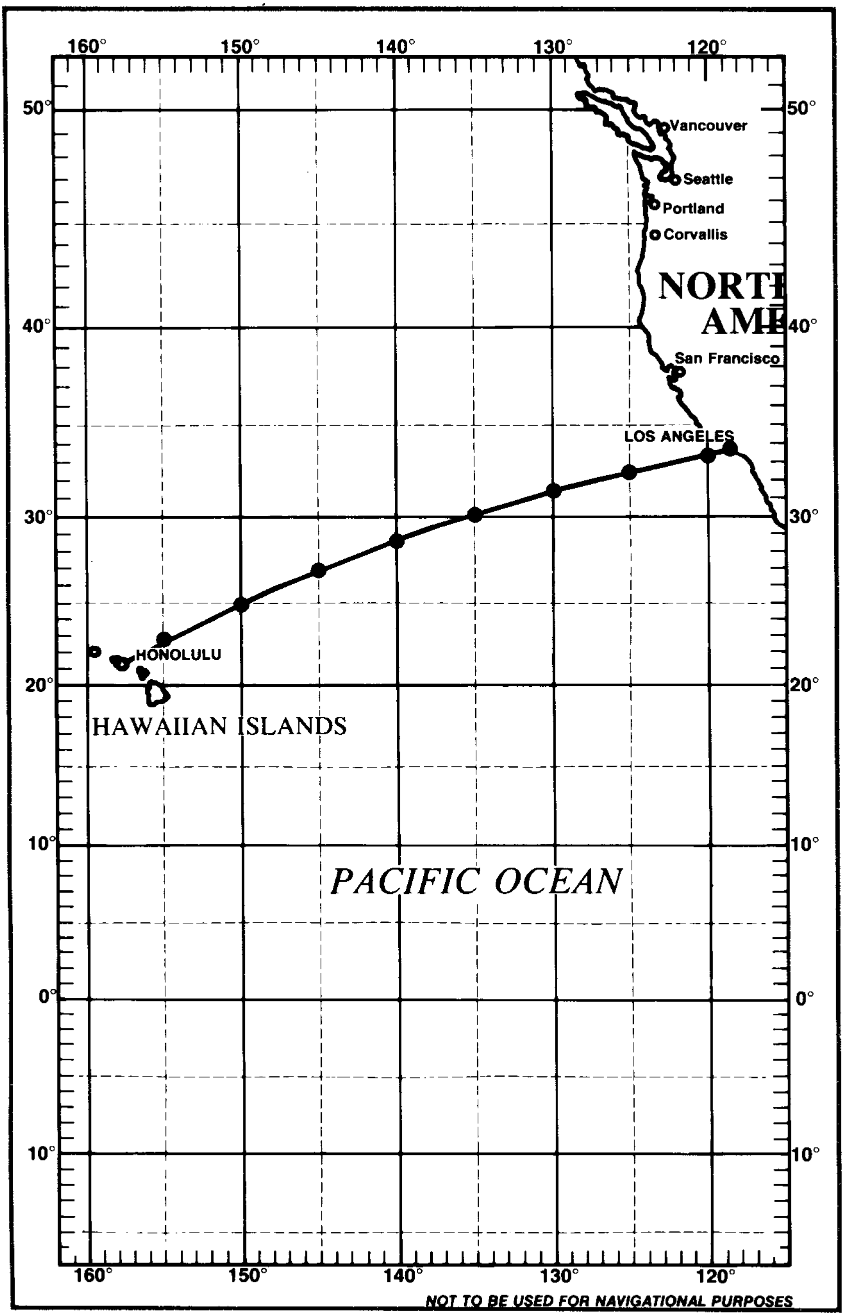
| | | | | SIZE: 054 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| **To Plot a Great-Circle Track (constant longitude increment)** | | | | |
| 1 | Initialize program. | | [XEQ] GCPLOT | e = 0.00000E0? |
| 2 | Key in eccentricity. | e | [R/S] | L1 = 0:00:00N? |
| 3 | Key in source latitude. | L1,d.ms | [R/S] | L01 = 0:00:00W? |
| 4 | Key in source longitude. | Lo1,d.ms | [R/S] | L2 = 0:00:00N? |
| 5 | Key in destination latitude. | L2,d.ms | [R/S] | L02 = 0:00:00W? |
| 6 | Key in destination longitude. | Lo2,d.ms | [R/S] | DLO = 0:00:00? |
| 7 | Key in the longitude increment and the calculator will produce a list of great-circle points with rhumb line course and distance between them. | DLo,d.ms | [R/S] | |

Example 1:

Produce a plot of the great circle from (33°31′07″N, 118°38′32″W), off Catalina, to (21°16′N, 157°44′42″W), east of Diamond Head, using a longitude increment of 5 degrees. Assume that the Earth is a sphere.

| Keystrokes (SIZE ≥ 054) | Display |
|---|---|
| [XEQ] [ALPHA] GCPLOT [ALPHA] | *e=0.00000E0?* |
| [R/S] | *L1=0:00:00N?* |
| 33.3107 [R/S] | *LO1=0:00:00W?* |
| 118.3832 [R/S] | *L2=0:00:00N?* |
| 21.16 [R/S] | *LO2=0:00:00W?* |
| 157.4442 [R/S] | *DLO=0:00:00?* |
| 5 [R/S] | |

```
L1=33:31:07N
LO1=118:38:32W

C=260.3
D=68.99 NMI

L2=33:19:27N
LO2=120:00:00W

C=258.5
D=257.03 NMI

L3=32:28:17N
LO3=125:00:00W

C=255.8
D=262.57 NMI

L4=31:24:03N
LO4=130:00:00W

C=253.2
D=269.25 NMI

L5=30:06:22N
LO5=135:00:00W

C=250.7
D=277.02 NMI

L6=28:34:56N
LO6=140:00:00W

C=248.3
D=285.78 NMI

L7=26:49:25N
LO7=145:00:00W

C=246.1
D=295.38 NMI

L8=24:49:40N
LO8=150:00:00W

C=244.0
D=305.62 NMI

L9=22:35:37N
LO9=155:00:00W

C=242.5
D=172.30 NMI

L10=21:16:00N
LO10=157:44:42W
```


160°
150°
140°
130°
120°
50°
40°
30°
20°
10°
0°
Vancouver
Seattle
Portland
Corvallis
NORTH
AMER
San Francisco
LOS ANGELES
HONOLULU
HAWAIIAN ISLANDS
PACIFIC OCEAN
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

| | | | | SIZE: 049 |
|---|---|---|---|---|
| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
| **To Plan a Voyage (equally spaced points)** | | | | |
| 1 | Initialize program. | | [XEQ] GCPLAN | e = 0.00000E0? |
| 2 | Key in eccentricity. | e | [R/S] | L1 = 0:00:00N? |
| 3 | Key in source latitude. | L1,d.ms | [R/S] | L01 = 0:00:00W? |
| 4 | Key in source longitude. | Lo1,d.ms | [R/S] | L2 = 0:00:00N? |
| 5 | Key in destination latitude. | L2,d.ms | [R/S] | L02 = 0:00:00W? |
| 6 | Key in destination longitude. | Lo2,d.ms | [R/S] | D = 0.0000? |
| 7 | Key in the distance increment and the calculator will produce a list of great-circle points with rhumb-line course and distance between them. | D,n.mi. | [R/S] | |

To use these programs as subroutines, store L1, Lo1, L2, and Lo2 in decimal form in registers 12, 13, 14, and 15. Store the distance in register 1 and execute *GCPLAN or store the longitude increment in register 5 and execute *GCPLOT. The programs will proceed as if you had performed step 7 of either set of instructions.

Example 2:

Produce a list of daily positions from (33°13′45″N, 119°37′13″W) to (21°16′N, 157°44′42″W), assuming a vessel speed of 16 knots. Assume that the Earth is a sphere.

| **Keystrokes (SIZE ≥ 049)** | **Display** |
|---|---|
| [XEQ] [ALPHA] GCPLAN [ALPHA] | *e=0.00000E0?* |
| [R/S] | *L1=0:00:00N?* |
| 33.1345 [R/S] | *L01=0:00:00W?* |
| 119.3713 [R/S] | *L2=0:00:00N?* |
| 21.16 [R/S] | *L02=0:00:00W?* |
| 157.4442 [R/S] | *D=0.0000?* |
| 16 [ENTER↑] 24 [×] | *384.0000* |
| [R/S] | |

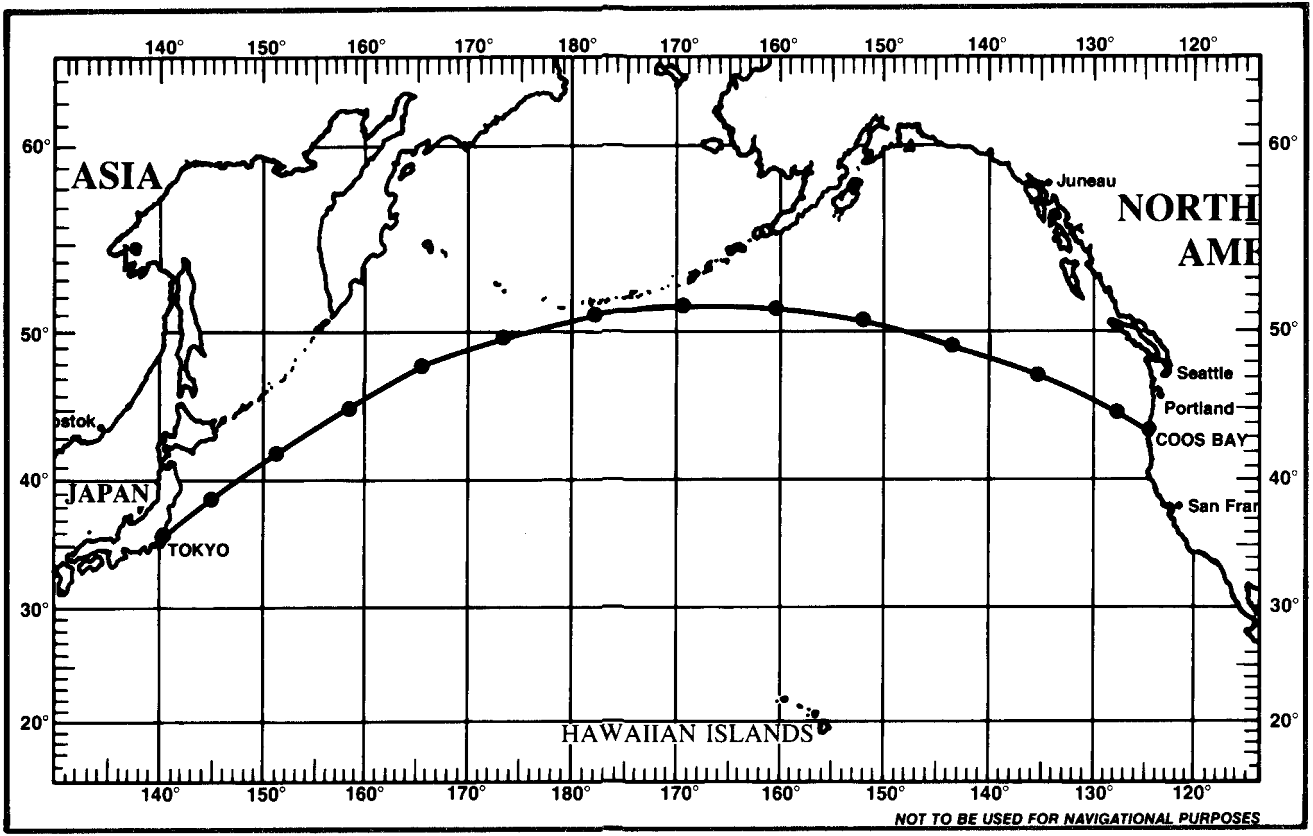
```
L1=33:13:45N
LO1=119:37:13W

C=258.3
D=384.08 NMI

L2=31:55:44N
LO2=127:03:32W

C=254.4
D=384.07 NMI

L3=30:12:31N
LO3=134:15:27W

C=250.9
D=384.06 NMI

L4=28:06:36N
LO4=141:10:58W

C=247.7
D=384.04 NMI

L5=25:40:39N
LO5=147:49:20W

C=244.8
D=384.03 NMI

L6=22:57:26N
LO6=154:10:51W

C=242.9
D=222.57 NMI

L7=21:16:00N
LO7=157:44:42W
```

Example 3:

A ship leaves Tokyo (35°40′N, 139°45′E) bound for Coos Bay, Oregon, (43°22′N, 124°13′W). Plot her position every 336 miles. Assume that the Earth is a sphere.

| **Keystrokes** | **Display** |
|---|---|
| [XEQ] [ALPHA] GCPLAN [ALPHA] | *e=0.00000E0?* |
| [R/S] | *L1=0:00:00N?* |
| 35.40 [R/S] | *L01=0:00:00W?* |
| 139.45 [CHS] [R/S] | *L2=0:00:00N?* |
| 43.22 [R/S] | *L02=0:00:00W?* |
| 124.13 [R/S] | *D=0.0000?* |
| 336 [R/S] | |

```
L1=35:40:00N
L01=139:45:00E

C=51.8
D=336.05 NMI

L2=39:07:36N
L02=145:17:44E

C=55.5
D=336.07 NMI

L3=42:17:51N
L03=151:23:20E

C=59.8
D=336.09 NMI

L4=45:06:48N
L04=158:05:22E

C=64.8
D=336.12 NMI

L5=47:29:55N
L05=165:25:42E

C=70.4
D=336.15 NMI

L6=49:22:28N
L06=173:23:13E

C=76.7
D=336.18 NMI

L7=50:39:55N
L07=178:07:36W

C=83.4
D=336.20 NMI

L8=51:18:40N
L08=169:17:03W

C=90.3
D=336.21 NMI

L9=51:16:42N
L09=160:19:24W

C=97.3
D=336.20 NMI

L10=50:34:08N
L010=151:30:20W

C=103.9
D=336.18 NMI

L11=49:13:09N
L011=143:03:48W

C=110.1
D=336.15 NMI

L12=47:17:28N
L012=135:09:42W

C=115.7
D=336.12 NMI

L13=44:51:40N
L013=127:53:02W

C=119.6
D=181.63 NMI

L14=43:22:00N
L014=124:13:00W
```



140° 150° 160° 170° 180° 170° 160° 150° 140° 130° 120°
60°
50°
40°
30°
20°
ASIA
JAPAN
TOKYO
NORTH
AMI
Juneau
Seattle
Portland
COOS BAY
San Fra
HAWAIIAN ISLANDS
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

# DEAD RECKONING

This program calculates a point on a rhumb line at a specified distance and initial course and stores that point as your new position. Thus it can be used to determine a position from a vessel's sailing history, or to update a DR position using the data reduced from a celestial sight.

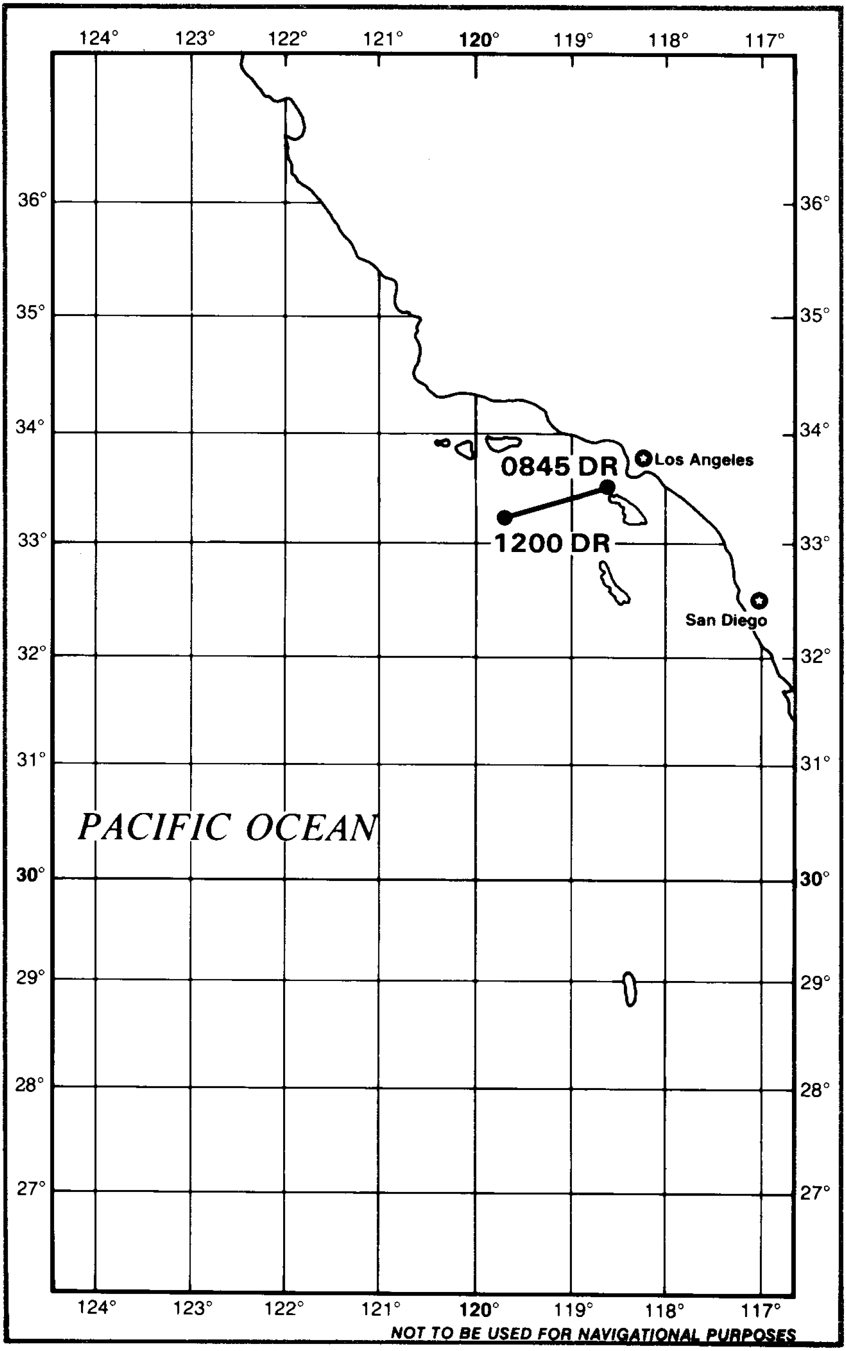
| | | | | SIZE: 012 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Initialize program. | | [XEQ] DR | e = 0.00000E0? |
| 2 | Key in eccentricity. | e | [R/S] | L1 = 0:00:00N? |
| 3 | Key in source latitude. | L1,d.ms | [R/S] | L01 = 0:00:00W? |
| 4 | Key in source longitude. | L01,d.ms | [R/S] | D = 0.0000? |
| 5 | Key in distance. | D, n.mi. | [R/S] | C = 0.0000? |
| 6 | Key in course and compute new position.<br>*Press [R/S] if you are not using a printer. | C,d.d | [R/S]<br>[R/S]* | DRL =<br>DRLO = |

To use this program as a subroutine, store L1 and Lo1 in decimal form in registers 7 and 8 and store distance and course in registers 1 and 6. Then execute the function *DR. The values DRL and DRLo will be stored in decimal form in registers 9 and 10 and also in registers 7 and 8.

Example:

We depart from (33°31′07″N, 118°38′32″W) at 0845 in the direction 250.5. What is our position at noon if we are able to make good a speed of 16 knots?

| **Keystrokes (SIZE ⩾ 012)** | **Display** | **Comments** |
|---|---|---|
| [XEQ] [ALPHA] DR [ALPHA] | *e = 0.00000E0?* | Displayed values assume cleared registers. Actual displays will show previous values of the variable. |
| [R/S] | *L1 = 0:00:00N?* | |
| 33.3107 [R/S] | *LO1 = 0:00:00W?* | |
| 118.3832 [R/S] | *D=0.0000?* | |
| 3.15 [XEQ] [ALPHA] HR [ALPHA] | *3.2500* | |
| 16 [×] [R/S] | *C=0.0000?* | |
| 250.5 [R/S] | *DRL=33:13:46N* | |
| [R/S] | *DRLO=119:37:14W* | |


124°
123°
122°
121°
120°
119°
118°
117°
36°
35°
34°
33°
32°
31°
30°
29°
28°
27°
0845 DR
1200 DR
Los Angeles
San Diego
PACIFIC OCEAN
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

# SIGHT REDUCTION

This program calculates an altitude intercept for any of the objects listed in *The Nautical Almanac:* 58 stars, including Polaris, the Sun, Venus, Mars, Jupiter, Saturn, and the Moon. The inputs required are date, time, height of eye, sextant height (angle), and which body sighted. The suffixes U and L are used with SUN and MOON to indicate upper or lower limb.

Mean refraction and dip corrections are applied to the sextant height for all bodies. For the Sun and Moon, semidiameter corrections are made for upper- or lower-limb sights. For the Moon, horizontal parallax is computed and included in the corrections.

| | | | | SIZE: 054 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Initialize program. | | [XEQ] SIGHT | DRL = 0:00:00N? |
| 2 | Key in DR latitude. | DRL, d.ms | [R/S] | DRLO = 0:00:00W? |
| 3 | Key in DR longitude. | DRLo, d.ms | [R/S] | DATE = 0.000000? |
| 4 | Key in date. | mm.ddyyyy | [R/S] | TIME = 0:00:00? |
| 5 | Key in Greenwich Mean Time. | GMT, h.ms | [R/S] | HE = 0. FT? |
| 6 | Key in height of eye in ft. or<br>—HE in m. | HE, ft.<br>HE, m | [R/S]<br>[CHS] [R/S] | <br>HS = ? |
| 7 | Key in sextant height. | HS, d.ms | [R/S] | WHICH BODY? |
| 8 | Select which body.<br>a) Key in name (at least first 6 letters).<br><br>b) Take HP-41 out of alpha and key in star number. | <br>NAME†<br><br>star # | <br>[R/S]<br><br>[ALPHA]<br>[R/S] | |
| 9 | HP-41 will display intercept<br><br>and azimuth.<br>* Press [R/S] if you are not using a printer.<br>†Note NAME is any member of the list of objects shown in the appendix. If NAME is not found, the default is NA, the Almanac Interpolater. | <br><br> | <br><br>[R/S]* | Name a = 0.0 A or T<br><br>ZN= 0.0 |

Example:

At 19:45:20 GMT on May 12, 1980, a navigator shoots the lower limb of the noon Sun. His height of eye is 10 feet and the sextant reading is 74°40′. His DR is (33°13′46″N, 119°37′14″W). What is the intercept resulting from this sight?

If the dead reckoning example has just been run, the DR position will be correctly stored. If other values are stored, key in the proper ones when prompted.

| Keystrokes (SIZE ⩾ 054) | Display |
|---|---|
| [XEQ] [ALPHA] SIGHT [ALPHA] | *DRL=33:13:46N?* |
| [R/S] | *DRLO=119:37:14W?* |
| [R/S] | *DATE=0.000000?* |
| 5.121980 [R/S] | *TIME=0:00:00?* |
| 19.4520 [R/S] | *HE=0. FT?* |
| 10 [R/S] | *HS=?* |
| 74.40 [R/S] | *WHICH BODY?* |
| SUNL [R/S] | *SUN a=4.2 A* |
| [R/S] | *ZN=171.3* |

# PERPETUAL ALMANAC

This program is based on equations developed at the United States Naval Observatory†. It calculates the Greenwich hour angle and declination for the celestial bodies most commonly used by navigators: 57 navigational stars, Polaris, the Sun, Venus, Mars, Jupiter, Saturn, and the Moon.

Star positions are corrected for the effects of precession, nutation, aberration, and proper motion.

For the stars and the Sun, accuracy is much better than one minute of arc. For the inner planets, Venus and Mars, it is better than two minutes of arc, and for the outer planets, Jupiter and Saturn, it is approximately three minutes of arc. The Moon, always more difficult to predict, may be in error by as much as five minutes of arc.

The inputs required are date, time, and the name of the body observed. If the index number of a particular star is known, it can be used instead of spelling out the name. The stars Al Na'ir and Zubenelgenubi are spelled using commas instead of apostrophes: "AL NA,IR" and "ZUBEN, UBI".

| | | | | SIZE: 054 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Initialize program. | | [XEQ] BODY | DATE = 0.000000? |
| 2 | Key in date. | mm.ddyyyy | [R/S] | TIME = 0:00:00? |
| 3 | Key in GMT. | GMT, h.ms | [R/S] | WHICH BODY? |
| 4 | Select which body. | | | |
| | a) Key in name (at least first 6 letters). | NAME† | [R/S] | |
| | or | | | |
| | b) Take HP-41 out of alpha and key in star number. | star # | [ALPHA] [R/S] | |
| 5 | HP-41 will display GHA and declination. | | [R/S]* | NAME GHA = DEC = |
| | * Press [R/S] if you are not using a printer. | | | |
| | †Note NAME is any member of the list of objects shown in the appendix. If NAME is not found, the default is NA, the Almanac Interpolater. | | | |

†Van Flandern and Pulkkinen. "Low-Precision Formulae for Planetary Positions", *Astrophysical Journal Supplement Series*, 41:391-411, November, 1979.

Example:

On March 8, 1980, Regulus, Mars, and Jupiter formed a small triangle. What were the coordinates of these bodies at 0600 GMT?

| Keystrokes (SIZE ⩾ 054) | Display | Comments |
|---|---|---|
| [XEQ] [ALPHA] BODY [ALPHA] | *DATE=0.000000?* | |
| 3.081980 [R/S] | *TIME=0:00:00?* | |
| 6.0000 [R/S] | *WHICH BODY?* | |
| REGULUS [R/S] | *REGULUS GHA=* | |
| | *104:16:33* | |
| [R/S] | *DEC=12:03:52N* | |
| [XEQ] [ALPHA] BODY [ALPHA] | *DATE=3.081980?* | |
| [R/S] | *TIME=6:00:00?* | |
| [R/S] | *WHICH BODY?* | |
| MARS [R/S] | *MARS GHA=* | |
| | *101:19:55* | |
| [R/S] | *DEC=14:55:51N* | |
| [XEQ] [ALPHA] BODY [ALPHA] | *DATE=3.081980?* | |
| [R/S] | *TIME=6:00:00?* | |
| [R/S] | *WHICH BODY?* | |
| JUPITER [R/S] | *JUPITER GHA=* | |
| | *100:00:41* | |
| [R/S] | *DEC=11:23:32N* | |

# ALMANAC INTERPOLATER

This program provides the SIGHT program with a method of obtaining positions of celestial bodies using *The Nautical Almanac.* It is ordinarily run by first executing SIGHT. You will be prompted for date, time, height of eye, and sextant height as with any other sight. When the prompt WHICH BODY? appears, key in NA (Nautical Almanac). The program determines what kind of sight (star, planet, Sun, or Moon) you desire by inspecting your answer to the question SD OR HP? A semidiameter of zero is used for stars; one near zero (say .01), for planets; and one of about 16′ for the Sun. If a value near 60′ is used, the program interprets it as the Moon's horizontal parallax. For upper limb sights, SD or HP must be entered as a negative quantity (i.e. press [CHS]).

**SIZE: 054**

| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
|---|---|---|---|---|
| 1 | Initialize program. | | [XEQ] SIGHT | DRL = 0:00:00N? |
| 2 | Key in latitude of DR. | L, d.ms | [R/S] | DRLO =<br>0:00:00W? |
| 3 | Key in longitude of DR. | Lo, d.ms | [R/S] | DATE =<br>0.000000? |
| 4 | Key in the date. | mm.ddyyyy | [R/S] | TIME = 0:00:00? |
| 5 | Key in GMT. | GMT, h.ms | [R/S] | HE = 0. FT.? |
| 6 | Key in HE in ft. or<br>− HE in m. | HE, ft.<br>HE, m | [R/S]<br>[CHS] [R/S] | <br>HS = ? |
| 7 | Key in sextant height. | HS, d.ms | [R/S] | WHICH BODY? |
| 8 | Now select the almanac. | NA | [R/S] | SD OR HP = ? |
| **For star sights:** | | | | |
| 9 | Use 0 for SD. | 0 | [R/S] | GHAY<hh> =<br>0:00:00? |
| 10 | Key in GHA Aries at previous whole hour. | GHAY, d.ms | [R/S] | GHAY<hh> =<br>0:00:00? |
| 11 | Key in GHA Aries at next whole hour. | GHAY, d.ms | [R/S] | SHA = 0:00:00? |
| 12 | Key in SHA. | SHA, d.ms | [R/S] | DEC = 0:00:00N? |
| 13 | Key in DEC and compute | DEC, d.ms | [R/S] | A<br>STAR a =<a> or<br>T |
| 14 | Compute azimuth.<br>* Press [R/S] if you are not using a printer. | | [R/S]* | ZN = |

| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY |
|---|---|---|---|---|
| **For Sun Sights:** | | | | |
| 9 | Use Sun's semidiameter. ([CHS] for upper limb) | SD, m.m | [R/S] | GHA<h>= 0:00:00? |
| 10 | Key in GHA at previous whole hour. | GHA(h) | [R/S] | GHA<h+1>= 0:00:00? |
| 11 | Key in GHA at next hour. | GHA(h+1) | [R/S] | DEC<h>= 0:00:00N? |
| 12 | Key in DEC at previous whole hour. | DEC(h) | [R/S] | DEC<h+1>= 0:00:00N? |
| 13 | Key in DEC at next hour and compute intercept. | DEC(h+1) | [R/S] | SUN a=<a> A or T |
| 14 | Compute azimuth<br>* Press [R/S] if you are not using a printer. | | [R/S]* | ZN= |
| **For Moon Sights:** | | | | |
| 9 | Use Moon's horizontal parallax. ([CHS] for upper limb) | HP, m.m | [R/S] | GHA<h> = 0:00:00? |
| 10 | Continue with step 10 under Sun Sights. | | | |
| **For Planet Sights:** | | | | |
| 9 | Use 0.01 for SD | .01 | [R/S] | GHA<h> = 0:00:00? |
| 10 | Key in GHA at previous whole hour. | GHA(h) | [R/S] | GHA<h+1> = 0:00:00? |
| 11 | Key in GHA at next hour. | GHA(h + 1) | [R/S] | DEC<h> = 0:00:00N? |
| 12 | Key in DEC at previous whole hour. | DEC(h) | [R/S] | DEC<h+1> = 0:00:00N? |
| 13 | Key in DEC at next hour and compute intercept. | DEC(h+1) | [R/S] | PLANET a = <a> A or T |
| 14 | Compute azimuth<br>* Press [R/S] if you are not using a printer. | | [R/S]* | ZN = |

Note that you can also use this program with BODY to compute and display a body's GHA and DEC.

Example:

Use the extract from *The Nautical Almanac* shown here to reduce a Venus sight from June 19, 1975 at 1625 GMT. The navigator's height of eye was 4 m and the sextant height was 66°55.3′. His DR was (38°N, 32°W).

| Keystrokes (SIZE ⩾ 054) | Display | Comment |
|---|---|---|
| ■ [SF] 00 | | Select D.MT mode. |
| [XEQ] [ALPHA] SIGHT [ALPHA] | *DRL=0:00.0N?* | |
| 38 [R/S] | *DRLO=0:00.0W?* | |
| 32 [R/S] | *DATE=0.000000?* | |
| 6.191975 [R/S] | *TIME=0:00:00?* | |
| 16.25 [R/S] | *HE=0. FT?* | |
| 4 [CHS] [R/S] | *HS=?* | |
| 66.553 [R/S] | *WHICH BODY?* | |
| NA [R/S] | *SD OR HP=?* | |
| .01 [R/S] | *GHA<16>=0:00.0?* | |
| 11.066 [R/S] | *GHA<17>=0:00.0?* | |
| 26.067 [R/S] | *DEC<16>= 0:00.0N?* | |
| 18.402 [R/S] | *DEC<17>= 0:00.0N?* | |
| 18.394 [R/S] | *PLANET a=1.4 T* | |
| [R/S] | *ZN=142.5* | |

## 1975 JUNE 18, 19, 20 (WED., THURS., FRI.)

| G.M.T. d | h | ARIES G.H.A. | VENUS −3.9 G.H.A. | VENUS Dec. | MARS +0.8 G.H.A. | MARS Dec. | JUPITER −1.9 G.H.A. | JUPITER Dec. | SATURN +0.4 G.H.A. | SATURN Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| 18 | 00 | 265 36.8 | 131 03.1 | N19 12.9 | 246 02.2 | N 6 27.7 | 246 57.2 | N 6 34.5 | 155 04.6 | N22 01.2 |
| | 01 | 280 39.3 | 146 03.1 | 12.1 | 261 02.9 | 28.4 | 261 59.3 | 34.6 | 170 06.7 | 01.1 |
| | 02 | 295 41.8 | 161 03.2 | 11.3 | 276 03.7 | 29.1 | 277 01.4 | 34.7 | 185 08.9 | 01.1 |
| | 03 | 310 44.2 | 176 03.3 | ·· 10.5 | 291 04.5 | ·· 29.8 | 292 03.4 | ·· 34.9 | 200 11.0 | ·· 01.1 |
| | 04 | 325 46.7 | 191 03.3 | 09.7 | 306 05.2 | 30.5 | 307 05.5 | 35.0 | 215 13.1 | 01.0 |
| | 05 | 340 49.2 | 206 03.4 | 08.9 | 321 06.0 | 31.2 | 322 07.6 | 35.2 | 230 15.3 | 01.0 |
| | 06 | 355 51.6 | 221 03.5 | N19 08.1 | 336 06.8 | N 6 31.8 | 337 09.7 | N 6 35.3 | 245 17.4 | N22 00.9 |
| W | 07 | 10 54.1 | 236 03.5 | 07.2 | 351 07.5 | 32.5 | 352 11.8 | 35.5 | 260 19.5 | 00.9 |
| E | 08 | 25 56.6 | 251 03.6 | 06.4 | 6 08.3 | 33.2 | 7 13.9 | 35.6 | 275 21.7 | 00.9 |
| D | 09 | 40 59.0 | 266 03.7 | ·· 05.6 | 21 09.1 | ·· 33.9 | 22 16.0 | ·· 35.7 | 290 23.8 | ·· 00.8 |
| N | 10 | 56 01.5 | 281 03.8 | 04.8 | 36 09.8 | 34.6 | 37 18.1 | 35.9 | 305 25.9 | 00.8 |
| E | 11 | 71 03.9 | 296 03.8 | 04.0 | 51 10.6 | 35.3 | 52 20.2 | 36.0 | 320 28.1 | 00.7 |
| S | 12 | 86 06.4 | 311 03.9 | N19 03.2 | 66 11.4 | N 6 35.9 | 67 22.3 | N 6 36.2 | 335 30.2 | N22 00.7 |
| D | 13 | 101 08.9 | 326 04.0 | 02.4 | 81 12.1 | 36.6 | 82 24.4 | 36.3 | 350 32.4 | 00.7 |
| A | 14 | 116 11.3 | 341 04.1 | 01.6 | 96 12.9 | 37.3 | 97 26.5 | 36.4 | 5 34.5 | 00.6 |
| Y | 15 | 131 13.8 | 356 04.1 | 19 00.8 | 111 13.7 | ·· 38.0 | 112 28.6 | ·· 36.6 | 20 36.6 | ·· 00.6 |
| | 16 | 146 16.3 | 11 04.2 | 18 59.9 | 126 14.4 | 38.7 | 127 30.6 | 36.7 | 35 38.8 | 00.5 |
| | 17 | 161 18.7 | 26 04.3 | 59.1 | 141 15.2 | 39.3 | 142 32.7 | 36.9 | 50 40.9 | 00.5 |
| | 18 | 176 21.2 | 41 04.4 | N18 58.3 | 156 16.0 | N 6 40.0 | 157 34.8 | N 6 37.0 | 65 43.0 | N22 00.5 |
| | 19 | 191 23.7 | 56 04.5 | 57.5 | 171 16.7 | 40.7 | 172 36.9 | 37.1 | 80 45.2 | 00.4 |
| | 20 | 206 26.1 | 71 04.6 | 56.7 | 186 17.5 | 41.4 | 187 39.0 | 37.3 | 95 47.3 | 00.4 |
| | 21 | 221 28.6 | 86 04.7 | ·· 55.9 | 201 18.3 | ·· 42.1 | 202 41.1 | ·· 37.4 | 110 49.4 | ·· 00.3 |
| | 22 | 236 31.1 | 101 04.8 | 55.0 | 216 19.0 | 42.8 | 217 43.2 | 37.6 | 125 51.6 | 00.3 |
| | 23 | 251 33.5 | 116 04.8 | 54.2 | 231 19.8 | 43.4 | 232 45.3 | 37.7 | 140 53.7 | 00.3 |
| 19 | 00 | 266 36.0 | 131 04.9 | N18 53.4 | 246 20.6 | N 6 44.1 | 247 47.4 | N 6 37.8 | 155 55.8 | N22 00.2 |
| | 01 | 281 38.4 | 146 05.0 | 52.6 | 261 21.3 | 44.8 | 262 49.5 | 38.0 | 170 58.0 | 00.2 |
| | 02 | 296 40.9 | 161 05.1 | 51.8 | 276 22.1 | 45.5 | 277 51.6 | 38.1 | 186 00.1 | 00.1 |
| | 03 | 311 43.4 | 176 05.2 | ·· 50.9 | 291 22.9 | ·· 46.2 | 292 53.7 | ·· 38.3 | 201 02.2 | ·· 00.1 |
| | 04 | 326 45.8 | 191 05.3 | 50.1 | 306 23.6 | 46.8 | 307 55.8 | 38.4 | 216 04.4 | 00.1 |
| | 05 | 341 48.3 | 206 05.4 | 49.3 | 321 24.4 | 47.5 | 322 57.9 | 38.5 | 231 06.5 | 00.0 |
| | 06 | 356 50.8 | 221 05.5 | N18 48.5 | 336 25.2 | N 6 48.2 | 338 00.0 | N 6 38.7 | 246 08.6 | N22 00.0 |
| | 07 | 11 53.2 | 236 05.6 | 47.7 | 351 25.9 | 48.9 | 353 02.1 | 38.8 | 261 10.8 | 21 59.9 |
| T | 08 | 26 55.7 | 251 05.7 | 46.8 | 6 26.7 | 49.5 | 8 04.2 | 39.0 | 276 12.9 | 59.9 |
| H | 09 | 41 58.2 | 266 05.8 | ·· 46.0 | 21 27.5 | ·· 50.2 | 23 06.3 | ·· 39.1 | 291 15.0 | ·· 59.9 |
| U | 10 | 57 00.6 | 281 05.9 | 45.2 | 36 28.2 | 50.9 | 38 08.4 | 39.2 | 306 17.2 | 59.8 |
| R | 11 | 72 03.1 | 296 06.0 | 44.4 | 51 29.0 | 51.6 | 53 10.5 | 39.4 | 321 19.3 | 59.8 |
| S | 12 | 87 05.5 | 311 06.1 | N18 43.5 | 66 29.8 | N 6 52.3 | 68 12.6 | N 6 39.5 | 336 21.4 | N21 59.7 |
| D | 13 | 102 08.0 | 326 06.3 | 42.7 | 81 30.5 | 52.9 | 83 14.7 | 39.7 | 351 23.6 | 59.7 |
| A | 14 | 117 10.5 | 341 06.4 | 41.9 | 96 31.3 | 53.6 | 98 16.7 | 39.8 | 6 25.7 | 59.7 |
| Y | 15 | 132 12.9 | 356 06.5 | ·· 41.1 | 111 32.1 | ·· 54.3 | 113 18.8 | ·· 39.9 | 21 27.8 | ·· 59.6 |
| | 16 | 147 15.4 | 11 06.6 | 40.2 | 126 32.8 | 55.0 | 128 20.9 | 40.1 | 36 30.0 | 59.6 |
| | 17 | 162 17.9 | 26 06.7 | 39.4 | 141 33.6 | 55.7 | 143 23.0 | 40.2 | 51 32.1 | 59.5 |
| | 18 | 177 20.3 | 41 06.8 | N18 38.6 | 156 34.4 | N 6 56.3 | 158 25.1 | N 6 40.4 | 66 34.2 | N21 59.5 |
| | 19 | 192 22.8 | 56 06.9 | 37.8 | 171 35.1 | 57.0 | 173 27.2 | 40.5 | 81 36.4 | 59.5 |
| | 20 | 207 25.3 | 71 07.1 | 36.9 | 186 35.9 | 57.7 | 188 29.3 | 40.6 | 96 38.5 | 59.4 |
| | 21 | 222 27.7 | 86 07.2 | ·· 36.1 | 201 36.7 | ·· 58.4 | 203 31.4 | ·· 40.8 | 111 40.6 | ·· 59.4 |
| | 22 | 237 30.2 | 101 07.3 | 35.3 | 216 37.4 | 59.0 | 218 33.5 | 40.9 | 126 42.7 | 59.3 |
| | 23 | 252 32.7 | 116 07.4 | 34.4 | 231 38.2 | 6 59.7 | 233 35.6 | 41.0 | 141 44.9 | 59.3 |
| 20 | 00 | 267 35.1 | 131 07.5 | N18 33.6 | 246 39.0 | N 7 00.4 | 248 37.7 | N 6 41.2 | 156 47.0 | N21 59.3 |
| | 01 | 282 37.6 | 146 07.7 | 32.8 | 261 39.7 | 01.1 | 263 39.8 | 41.3 | 171 49.1 | 59.2 |
| | 02 | 297 40.0 | 161 07.8 | 31.9 | 276 40.5 | 01.7 | 278 41.9 | 41.5 | 186 51.3 | 59.2 |
| | 03 | 312 42.5 | 176 07.9 | ·· 31.1 | 291 41.3 | ·· 02.4 | 293 44.0 | ·· 41.6 | 201 53.4 | ·· 59.1 |
| | 04 | 327 45.0 | 191 08.0 | 30.3 | 306 42.0 | 03.1 | 308 46.1 | 41.7 | 216 55.5 | 59.1 |
| | 05 | 342 47.4 | 206 08.2 | 29.4 | 321 42.8 | 03.8 | 323 48.2 | 41.9 | 231 57.7 | 59.1 |
| | 06 | 357 49.9 | 221 08.3 | N18 28.6 | 336 43.6 | N 7 04.5 | 338 50.3 | N 6 42.0 | 246 59.8 | N21 59.0 |
| | 07 | 12 52.4 | 236 08.4 | 27.8 | 351 44.3 | 05.1 | 353 52.4 | 42.1 | 262 01.9 | 59.0 |
| | 08 | 27 54.8 | 251 08.6 | 26.9 | 6 45.1 | 05.8 | 8 54.5 | 42.3 | 277 04.1 | 58.9 |
| F | 09 | 42 57.3 | 266 08.7 | ·· 26.1 | 21 45.9 | ·· 06.5 | 23 56.6 | ·· 42.4 | 292 06.2 | ·· 58.9 |
| R | 10 | 57 59.8 | 281 08.8 | 25.3 | 36 46.6 | 07.2 | 38 58.7 | 42.6 | 307 08.3 | 58.9 |
| I | 11 | 73 02.2 | 296 09.0 | 24.4 | 51 47.4 | 07.8 | 54 00.8 | 42.7 | 322 10.5 | 58.8 |
| D | 12 | 88 04.7 | 311 09.1 | N18 23.6 | 66 48.2 | N 7 08.5 | 69 02.9 | N 6 42.8 | 337 12.6 | N21 58.8 |
| A | 13 | 103 07.2 | 326 09.2 | 22.8 | 81 48.9 | 09.2 | 84 05.0 | 43.0 | 352 14.7 | 58.7 |
| Y | 14 | 118 09.6 | 341 09.4 | 21.9 | 96 49.7 | 09.9 | 99 07.2 | 43.1 | 7 16.9 | 58.7 |
| | 15 | 133 12.1 | 356 09.5 | ·· 21.1 | 111 50.5 | ·· 10.5 | 114 09.3 | ·· 43.2 | 22 19.0 | ·· 58.7 |
| | 16 | 148 14.5 | 11 09.7 | 20.2 | 126 51.2 | 11.2 | 129 11.4 | 43.4 | 37 21.1 | 58.6 |
| | 17 | 163 17.0 | 26 09.8 | 19.4 | 141 52.0 | 11.9 | 144 13.5 | 43.5 | 52 23.3 | 58.6 |
| | 18 | 178 19.5 | 41 10.0 | N18 18.6 | 156 52.8 | N 7 12.6 | 159 15.6 | N 6 43.6 | 67 25.4 | N21 58.5 |
| | 19 | 193 21.9 | 56 10.1 | 17.7 | 171 53.5 | 13.2 | 174 17.7 | 43.8 | 82 27.5 | 58.5 |
| | 20 | 208 24.4 | 71 10.3 | 16.9 | 186 54.3 | 13.9 | 189 19.8 | 43.9 | 97 29.6 | 58.5 |
| | 21 | 223 26.9 | 86 10.4 | ·· 16.1 | 201 55.1 | ·· 14.6 | 204 21.9 | ·· 44.1 | 112 31.8 | ·· 58.4 |
| | 22 | 238 29.3 | 101 10.6 | 15.2 | 216 55.8 | 15.2 | 219 24.0 | 44.2 | 127 33.9 | 58.4 |
| | 23 | 253 31.8 | 116 10.7 | 14.4 | 231 56.6 | 15.9 | 234 26.1 | 44.3 | 142 36.0 | 58.3 |
| Mer. Pass. | | h m 6 12.6 | v 0.1 | d 0.8 | 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 40.3 | S40 24.0 |
| Achernar | 335 48.2 | S57 21.4 |
| 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 21.0 | N49 26.3 |
| Al Na'ir | 28 19.2 | 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 57.2 |
| Altair | 62 35.7 | N 8 48.2 |
| Ankaa | 353 43.8 | S42 26.0 |
| Antares | 113 00.9 | S26 22.7 |
| Arcturus | 146 21.5 | N19 18.6 |
| Atria | 108 27.8 | S68 59.1 |
| Avior | 234 30.2 | S59 26.1 |
| Bellatrix | 279 02.9 | N 6 19.6 |
| Betelgeuse | 271 32.5 | 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 26.6 | N61 53.2 |
| Elnath | 278 49.0 | N28 35.2 |
| Eltanin | 90 58.8 | N51 29.6 |
| Enif | 34 14.9 | 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 20.7 |
| Kaus Aust. | 84 21.2 | S34 23.7 |
| Kochab | 137 18.0 | N74 15.6 |
| Markab | 14 06.6 | N15 04.4 |
| Menkar | 314 45.1 | N 3 59.6 |
| Menkent | 148 41.0 | S36 15.2 |
| Miaplacidus | 221 46.3 | S69 37.3 |
| Mirfak | 309 21.6 | N49 46.3 |
| Nunki | 76 33.2 | S26 19.6 |
| Peacock | 54 03.5 | S56 48.6 |
| Pollux | 244 02.9 | N28 05.2 |
| Procyon | 245 29.8 | N 5 17.2 |
| Rasalhague | 96 32.5 | N12 34.7 |
| Regulus | 208 13.9 | N12 05.2 |
| Rigel | 281 39.8 | S 8 13.8 |
| Rigil Kent. | 140 30.2 | S60 44.3 |
| Sabik | 102 44.9 | S15 41.7 |
| Schedar | 350 13.2 | N56 24.0 |
| Shaula | 97 00.2 | S37 05.2 |
| Sirius | 258 59.2 | S16 41.1 |
| 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 | 224 29.0 | 15 16 |
| Mars | 339 44.6 | 7 34 |
| Jupiter | 341 11.4 | 7 28 |
| Saturn | 249 19.8 | 13 34 |

# SUBROUTINES

This module contains many subroutines that are valuable to anyone concerned with navigational astronomy. Most programs documented elsewhere in this book can be used as subroutines with or without their associated prompts. In addition there are a number of subroutines which are not of interest to most navigators but might very well be useful to people writing their own programs.

The programs are listed here and documented more fully in the following pages.

| | Subroutine Name | Meaning |
|---|---|---|
| | *SRT | Sight Reduction Table |
| | JD | Julian Date |
| **Astronomy** | D · T | Date & Time |
| | GST | Greenwich Sidereal Time |
| **Routines** | STAR | Star Almanac |
| | FA | Fundamental Arguments |
| | LBRYZX | Convert LBR to YZX |
| | ZYXdHA | Convert ZYX to dHA |
| | LOTOL | LOngitude TO Latitude |
| | DSPHAd | DiSPlay HA and dec |
| **Input/** | *IN1 | INput 1 point |
| | *IN | INput points |
| **Output** | *DMT | Degrees, Minutes, and Tenths |
| | *DMS | Degrees, Minutes, and Seconds |
| **Routines** | *HR | HouRs |
| | *T | Time |
| | DSPP2 | DiSPlay Point |
| | DSPL | DiSPlay Latitude |
| | DSPLO | DiSPlay LOngitude |

# SIGHT REDUCTION TABLE

This program evaluates the sight reduction table equation

$$Z_n = 180 + \tan^{-1} \frac{\sin t}{\cos t \sin L - \tan d \cos L}$$

$$H_c = \sin^{-1} (\sin d \sin L + \cos d \cos L \cos t)$$

where t = meridian angle (negative if east)
L = latitude (negative if south)
d = declination (negative if south)
Hc = computed altitude
Zn = azimuth from north

In addition to the altitude and azimuth problem, the sight reduction table can also be employed to solve star identification, great-circle heading and distance, and great-circle position problems. The trick is to call the program with altered inputs as shown.

Star identification
Use Zn instead of t
Use Ho instead of d
Get t instead of Zn
Get d instead of Ho

Great Circle Heading and Distance
Use DLo instead of t
Use L2 instead of d
Get Hi instead of Zn
Get (90–D/60) instead of Hc

Great Circle Position
Use Hi instead of t
Use (90–D/60) instead of d
Get DLo instead of Zn
Get L2 instead of Hc

| | | | | SIZE: 054 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Initialize program. | | [XEQ] SRT | T = ? |
| 2 | Key in meridian angle. | t, deg | [R/S] | L = ? |
| 3 | Key in latitude. | L, deg | [R/S] | D = ? |
| 4 | Key in declination and compute altitude. | d, deg | [R/S] | Hc = |
| 5 | Display azimuth. | | [R/S]* | ZN = |
| | * Press [R/S] if you are not using a printer. | | | |

Example 1:

What is the altitude of the Sun on the date of the Vernal Equinox observed from 45°N when its LHA is 30°?

| Keystrokes (SIZE ≥ 054) | Display |
|---|---|
| ■ [FIX] 2 | *0.00* |
| [XEQ] [ALPHA] SRT [ALPHA] | *T=?* |
| 30 [R/S] | *L=?* |
| 45 [R/S] | *D=?* |
| 0 [R/S] | *Hc=37.76* |
| [R/S] | *ZN=219.23* |

To use this program as a subroutine, first set up the stack with t, L, and d in Z, Y, and X respectively. Then press [XEQ] *SRT and the computed altitude and azimuth will be returned in X and Y.

Example 2:

What is the distance from (0°N,150°W) to (45°N, 120°W)?

| Keystroke | Display | |
|---|---|---|
| 120 [ENTER↑] 150 [-] | *–30.00* | |
| 0 [ENTER↑] | *0.00* | |
| 45 [XEQ] [ALPHA] *SRT [ALPHA] | *37.76* | |
| 90 [-] 60 [CHS] [×] | *3,134.33* | D in nautical miles |
| [X≷Y] | *26.57* | D in degrees |

Example 3:

A star is observed through the clouds in the approximate direction 115°. Our latitude is approximately 33.5°N, and the star's direction is 57°35′. Which star did we observe?

| Keystroke | Display | |
|---|---|---|
| 115 [ENTER↑] | *115.00* | |
| 33.5 [ENTER↑] | *33.50* | |
| 57.35 [XEQ] [ALPHA] HR [ALPHA] | *57.58* | |
| [XEQ] [ALPHA] *SRT [ALPHA] | *16.08* | This is the star's declination, so it must be Aldebaran. |
| [X≷Y] | *329.63* | This is the star's local hour angle. |

# CALENDAR FUNCTIONS

These routines consist of a date and time input routine, D→T, and a Julian date calculator, JD. The routine D→T prompts you for date and time and stores them in registers 30 and 34. The JD routine converts a date of the form mm.ddyyyy in the X-register and a time in register 34 to a Julian date which it leaves in the X-register. It also stores T, the number of Julian centuries from 1900.0, and t, the number of Julian days until 2000.0. The calendar routine works correctly from October 15, 1582, onwards.

| STEP | INSTRUCTIONS | INPUT | FUNCTION | DISPLAY (SIZE: 037) |
|---|---|---|---|---|
| | **To input date and time.** | | | |
| 1 | Initialize program. | | [XEQ] D→T | DATE = 0.000000? |
| 2 | Key in date. | mm.ddyyyy | [R/S] | TIME = 0:00:00? |
| 3 | Key in GMT. | GMT, h.ms | [R/S] | GMT, hours |
| | **To compute Julian date.** | | | |
| 1 | Be sure time is stored by running D+T or by storing it directly in R34. | | | |
| 2 | Key in date or recall it from R30. | | [RCL] 30 | Date |
| 3 | Compute Julian date. | DATE | [XEQ] JD | JD |

These programs use storage registers as follows:

| | |
|---|---|
| 29 Year | 34 GMT |
| 30 Date | 35 T (Centuries from 1900.0) |
| 31 Month | 36 t (JD from 2000.0) |
| 32 Day | |

Example:

What is the Julian date corresponding to Greenwich mean noon on September 26, 1980?

| **Keystrokes (SIZE ≥ 037)** | **Display** |
|---|---|
| ■ [FIX] 3 | |
| 12 [STO] 34 | |
| 9.261980 [XEQ] [ALPHA] JD | |
| [ALPHA] | *2,444,509.000* |

## GREENWICH SIDEREAL TIME

This program calculates Greenwich sidereal time from the Greenwich mean time stored in R34 and the value of T, the centuries from 1900.0, stored in R35. The value for GST is stored in the X-register.

| | | | | SIZE: 037 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Store date and time directly or by using D+T. | | | |
| 2 | Compute T using JD. (Date must be in X.) | | [RCL] 30<br>[XEQ] JD | Date<br>JD |
| 3 | Compute GST. | | [XEQ] GST | GST |

Example:

What is the Greenwich Sidereal Time at 1500 GMT on October 27, 1980?

| **Keystrokes (SIZE ⩾037)** | **Display** |
|---|---|
| [XEQ] [ALPHA] D+T [ALPHA] | *DATE=0.000000?* |
| 10.271980 [R/S] | *TIME=0:00:00?* |
| 15 [R/S] [RCL] 30 | *10.2720* |
| [XEQ] [ALPHA] JD [ALPHA] | *2,444,540.125* |
| [XEQ] [ALPHA] GST [ALPHA] | *261.1238* |

# STAR ALMANAC

This program is a subroutine of the BODY program documented earlier, but it is interesting in its own right. The routine is used to determine a star's Greenwich hour angle and declination.

| | | | | SIZE: 051 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Initialize program. | | [XEQ] STAR | DATE = 0.000000? |
| 2 | Key in date. | mm.ddyyyy | [R/S] | TIME = 0:00:00? |
| 3 | Key in time. | GMT, h.ms | [R/S] | STAR NO. = ? |
| 4 | Key in star number. | star no. | [R/S] | 0.0000 |
| 5 | The results are now stored as follows:<br>NAME in ALPHA<br>GST in R44<br>GHA☆ in R45<br>dec☆ in R46 | | | |

Example 1:

What is the declination of POLARIS on 1 JAN 1980? What will it be on 1 JAN 2080?

| **Keystrokes (SIZE ⩾ 051)** | **Display** | |
|---|---|---|
| [XEQ] [ALPHA] STAR [ALPHA] | *DATE=0.000000?* | |
| 1.011980 [R/S] | *TIME=0:00:00?* | |
| [R/S] | *STAR NO.=?* | |
| 0 [R/S] | *0.0000* | |
| [RCL] 46 | *89.1721* | Declination<br>1 JAN 1980 |
| [XEQ] [ALPHA] STAR [ALPHA] | *DATE=1.011980?* | |
| 1.012080 [R/S] | *TIME=0:00:00?* | |
| [R/S] | *STAR NO.=?* | |
| 0 [R/S] | *0.0000* | |
| [RCL] 46 | *89.6531* | Declination<br>1 JAN 2080 |

A useful feature of this routine is that it can be called without prompts with the name *STAR. The routine expects the fundamental arguments subroutine, FA, to have been run already. You can skip some of the computation by setting flag 6 if all you want are approximate answers.

An example will clarify the reasons for some of these features.

**Example 2:**

Construct a routine which searches the star list for stars having nearly the same declination as you specify.

There are many ways to do this job, some nicer than others, but the following routine is a reasonable place to start.

```
01♦LBL "WHICH?"
02 STO 05
03 1.057
04 STO 47
05♦LBL 47
06 SF 06
07 XROM "*STAR"   (see note)
08 X<>Y
09 FIX 0
10 RND
11 RCL 05
12 RND
13 X=Y?
14 GTO 00
15 ISG 47
16 GTO 47
17 STOP
18♦LBL 00
19 AVIEW
20 ISG 47
21 GTO 47
22 .END.
```

This little program is used by keying in the declination of the unknown star and then executing WHICH?. All stars having the specified declination will be listed.

Example:

A star's declination is determined to be 16°. Which star is it?

| **Keystrokes** | **Display** |
|---|---|
| 16 [XEQ] | |
| [ALPHA] WHICH? [ALPHA] | ***ALDEBARAN*** |

**NOTE:** XROM "*STAR" is input with the keystrokes [XEQ] [ALPHA] *STAR [ALPHA] while the Navigation module is plugged in.

# FUNDAMENTAL ARGUMENTS

This subroutine (FA) is basic to the entire long-term almanac. It computes mean longitude L, mean anomaly G, and latitude argument F for the navigational planets, the Sun and the Moon. All 33 arguments used by Van Flandern and Pulkkinen* are not calculated by this program, because the series for the various objects are truncated. The truncation is such that the maximum error due to missing terms should not exceed 1 minute of arc.

The routine requires the time stored in R34 (decimal hours), the date (mm.ddyyyy) in the X-register, and a minimum size of 045. Its outputs are located from R12 to R36 as shown.

| | | | |
|---|---|---|---|
| R12 | Lm | R25 | G6 |
| R13 | Gm | R26 | L2 |
| R14 | Fm | R27 | L4 |
| R15 | D = Lm−Ls | R28 | $\Omega$ m = Lm−Fm |
| R16 | Ls | R29 | $\epsilon$ |
| R17 | Gs | R30 | Date |
| R18 | G2 | R31 | $-\delta\lambda$ |
| R19 | F2 | R32 | Day of month |
| R20 | G4 | R33 | (not used) |
| R21 | F4 | R34 | GMT |
| R22 | L5 | R35 | T (Centuries from 1900.0) |
| R23 | G5 | R36 | t(JD from 2000.0) |
| R24 | L6 | | |

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*op. cit

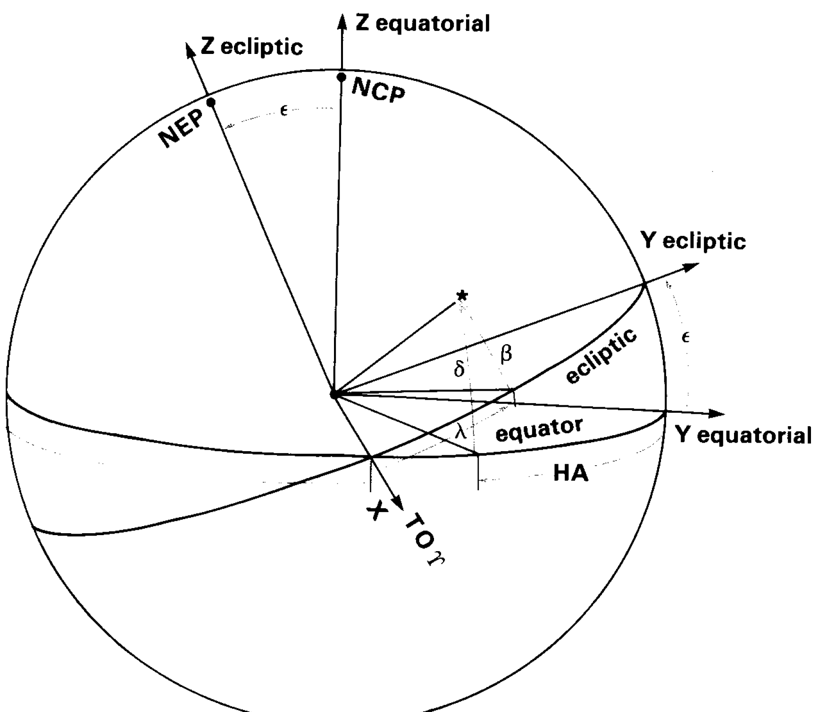
## ASTRONOMICAL COORDINATE CONVERSION

These programs interconvert spherical and rectangular coordinates in equatorial and ecliptic coordinate systems. They are used as subroutines by the perpetual almanac program.

Ecliptic spherical coordinates are longitude, latitude, and radius vector. Equatorial rectangular coordinates are X, the direction of the Vernal equinox; Y, the direction of 90° longitude on the equator; and Z, the direction of the north celestial pole. Equatorial spherical coordinates are hour angle, declination, and radius vector (which is ignored, because it is not needed).

When converting from spherical coordinates to rectangular coordinates, the value in R29 is used for the obliquity of the ecliptic. An obliquity of zero results in conversion from equatorial coordinates rather than from ecliptic coordinates. The fundamental arguments routine, FA, can be used to calculate the obliquity of the ecliptic when it is needed.

The names of these two functions are intended to indicate the stack contents on entry and exit. Thus, LBRYZX expects Longitude, Beta, and Radius vector and produces Y, Z, and X. ZYXdHA converts Z, Y, and X to declination and Hour Angle.



| | | | | SIZE: 030 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| **To convert equatorial spherical to equatorial rectangular coordinates** | | | | |
| 1 | Store zero for the obliquity. | 0 | [STO] 29 | |
| 2 | Key in negative longitude. | —L0,d.ms | [ENTER↑] | |
| 3 | Key in latitude. | L, d.ms | [ENTER↑] | |
| 4 | Key in radius vector (usu. 1). | r | [XEQ] LBRYZX | X |
| 5 | Inspect other coordinates. | | [R↓]<br>[X≷Y] | Z<br>Y |
| **To convert ecliptic spherical to equatorial rectangular coordinates** | | | | |
| 1 | Store obliquity of ecliptic. (Use FA to compute obliquity if desired) | $\epsilon$ | [STO] 29 | |
| 2 | Key in celestial longitude. | Lo | [ENTER↑] | |
| 3 | Key in celestial latitude. | $\beta$ | [ENTER↑] | |
| 4 | Key in radius vector. | $\rho$ | [XEQ] LBRYZX | X |
| 5 | Inspect other coordinates. | | [R↓]<br>[X≷Y] | Z<br>Y |
| **To convert equatorial rectangular to equatorial spherical coordinates** | | | | |
| 1 | Key in Z-coordinate. | Z | [ENTER↑] | |
| 2 | Key in Y-coordinate. | Y | [ENTER↑] | |
| 3 | Key in X-coordinate and compute hour angle. | X | [XEQ] ZYXdHA | HA |
| 4 | Inspect declination. | | [X≷Y] | d |

Example 1:

An ephemeris lists the coordinates of the Sun as X = 0.1487897, Y = −0.8917501, and Z = −0.3866720. What are its hour angle and declination?

| **Keystrokes (SIZE ≥ 030)** | **Display** | |
|---|---|---|
| ■ [FIX] 8 | | |
| .3866720 [CHS] [ENTER↑] | | |
| .8917501 [CHS] [ENTER↑] | | |
| .1487897 [XEQ] [ALPHA] ZYXdHA | | |
| [ALPHA] | *440.5273830* | |
| 360 [XEQ] [ALPHA] MOD [ALPHA] | *80.52738300* | HA |
| [X≷Y] | *−23.15628516* | dec |

Example 2:

The ephemeris also lists the coordinates of the Sun in terms of ecliptic longitude, 278°42′11.61″, ecliptic latitude, −0.58″, and radius vector, 0.9832965. For an obliquity of 23.441884°, compute the equatorial rectangular coordinates of the Sun.

| Keystrokes | Display | |
|---|---|---|
| ■ [FIX] 8 | | |
| 23.441884 [STO] 29 | ***23.44188400*** | |
| 278.421161 [XEQ] [ALPHA] HR | | |
| [ALPHA] | ***278.7032250*** | |
| .000058 [CHS] [XEQ] [ALPHA] HR | | |
| [ALPHA] | ***−0.00016111*** | |
| .9832965 [XEQ] [ALPHA] LBRYZX | | |
| [ALPHA] | ***0.14878894*** | X |
| [R↓] | ***−0.38667203*** | Z |
| [X≷Y] | ***−0.89175030*** | Y |

# LONGITUDE TO LATITUDE

This program calculates the latitude at which a specified longitude is reached on a great circle defined by two points.

| | | | | SIZE: 016 |
|---|---|---|---|---|
| **STEP** | **INSTRUCTIONS** | **INPUT** | **FUNCTION** | **DISPLAY** |
| 1 | Initialize program. | | [XEQ] LOTOL | L1 = 0:00:00N? |
| 2 | Key in source latitude. | L1, d.ms | [R/S] | LO1 = 0:00:00W? |
| 3 | Key in source longitude. | LO1, d.ms | [R/S] | L2 = 0:00:00N? |
| 4 | Key in destination latitude. | L2, d.ms | [R/S] | LO2 = 0:00:00W? |
| 5 | Key in destination longitude. | Lo2, d.ms | [R/S] | LOI = ? |
| 6 | Key in intermediate longitude. | Loi, d.ms | [R/S] | LI = |

To use this program as a subroutine, store L1, Lo1, L2, and Lo2 in decimal form in registers 7, 8, 14, and 15. Store the intermediate longitude in register 10, and execute *LOTOL. The corresponding intermediate latitude will be in the X-register.

Example:

At what latitude does the great circle from (33°31′07″N, 118°38′32″W) to (21°16′N, 157°44′42″W) cross longitude 135°W?

| **Keystrokes (SIZE ⩾ 016)** | **Display** |
|---|---|
| [XEQ] [ALPHA] LOTOL [ALPHA] | *L1=0:00:00N?* |
| 33.3107 [R/S] | *LO1=0:00:00W?* |
| 118.3832 [R/S] | *L2=0:00:00N?* |
| 21.16 [R/S] | *LO2=0:00:00W?* |
| 157.4442 [R/S] | *LOI=?* |
| 135 [R/S] | *LI=30:06:22N* |

## INPUT/OUTPUT ROUTINES

The Navigation ROM contains several subroutines which are useful to people writing their own programs. The essential details of these routines are outlined here. Angles are stored in decimal form, and are input and displayed in degrees, minutes and seconds or degrees minutes and tenths of minutes depending on the status of flag 00.

| Subroutine | Label | Initial Registers | Initial Stack | Final Registers | Final Stack | Alpha | Remarks |
|---|---|---|---|---|---|---|---|
| Date | | | | | | | |
| and | D+T | | | 30 Date | | | |
| Time | | | | 34 Time | | | |
| | | | X Date | 29 Year | X JD | | |
| Julian | JD | | | 30 Date | | | |
| Day | | | | 31 Month | | | |
| | | | | 32 Day | | | |
| | | | | 34 GMT | | | |
| | | | | 35 T | | | Centuries from 1900.0 |
| | | | | 36 t | | | JD from 2000.0 |
| Display | DSPHAd | 44 GST | | | | GHA= | |
| Hour Angle | | 45 GHA | | | | DEC= | |
| and | | 46 DEC | | | | | |
| declination | | | | | | | |

| Subroutine | Label | Initial Registers | Initial Stack | Final Registers | Final Stack | Alpha | Remarks |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Input P1 | *IN1 | | | 7 L1<br>8 Lo1 | | | Prompts for L1 and Lo1 |
| Input P1 and P2 | *IN | | | 7 L1<br>8 Lo1<br>9 L2<br>10 Lo2 | | | Calls *IN1 and then prompts for L2 and Lo2 |
| Degrees minutes and tenths | *DMT | | X d.d | | X D.MT | D:M.t | Converts and adds angle to display |
| Degrees minutes and seconds | *DMS | | X d.d | | X DMS | D:M:S | If flag 0 is set then *DMT is done instead |
| Hours | *HR | | X d.ms<br>or<br>d.mt | | X D.d | | Depends on flag 00 |

| Subroutine | Label | Initial Registers | Initial Stack | Final Registers | Final Stack | Alpha | Remarks |
|---|---|---|---|---|---|---|---|
| Time | | | X h.h | | Z H<br>Y M<br>X S | TIME=<br>H:M:S | |
| Display Point | DSPP2 | 9 L<br>10 Lo<br>48 index | | same | | Li=<br>LOi= | Displays GC point |
| Display Latitude | DSPL | | X L | | | =<L> N or S | Flag 5 is set if L is south |
| Display Longitude | DSPLO | | X Lo | | | =<Lo> W or E | Flag 5 is clear if Lo is east |

## Notes

Appendix A

# ALMANAC OBJECTS

The objects listed below are in the perpetual almanac programmed in this ROM. There are 57 navigational stars, Polaris, the Sun, Venus, Mars, Jupiter, Saturn, and the Moon. The stars are listed both alphabetically and numerically for your convenience on the back of the fold-out star chart.

Solar system objects

| The Sun | The Moon | The Navigational Planets |
|---|---|---|
| SUN | MOON | VENUS |
| SUNL | MOONL | MARS |
| SUNU | MOONU | JUPITER |
| | | SATURN |

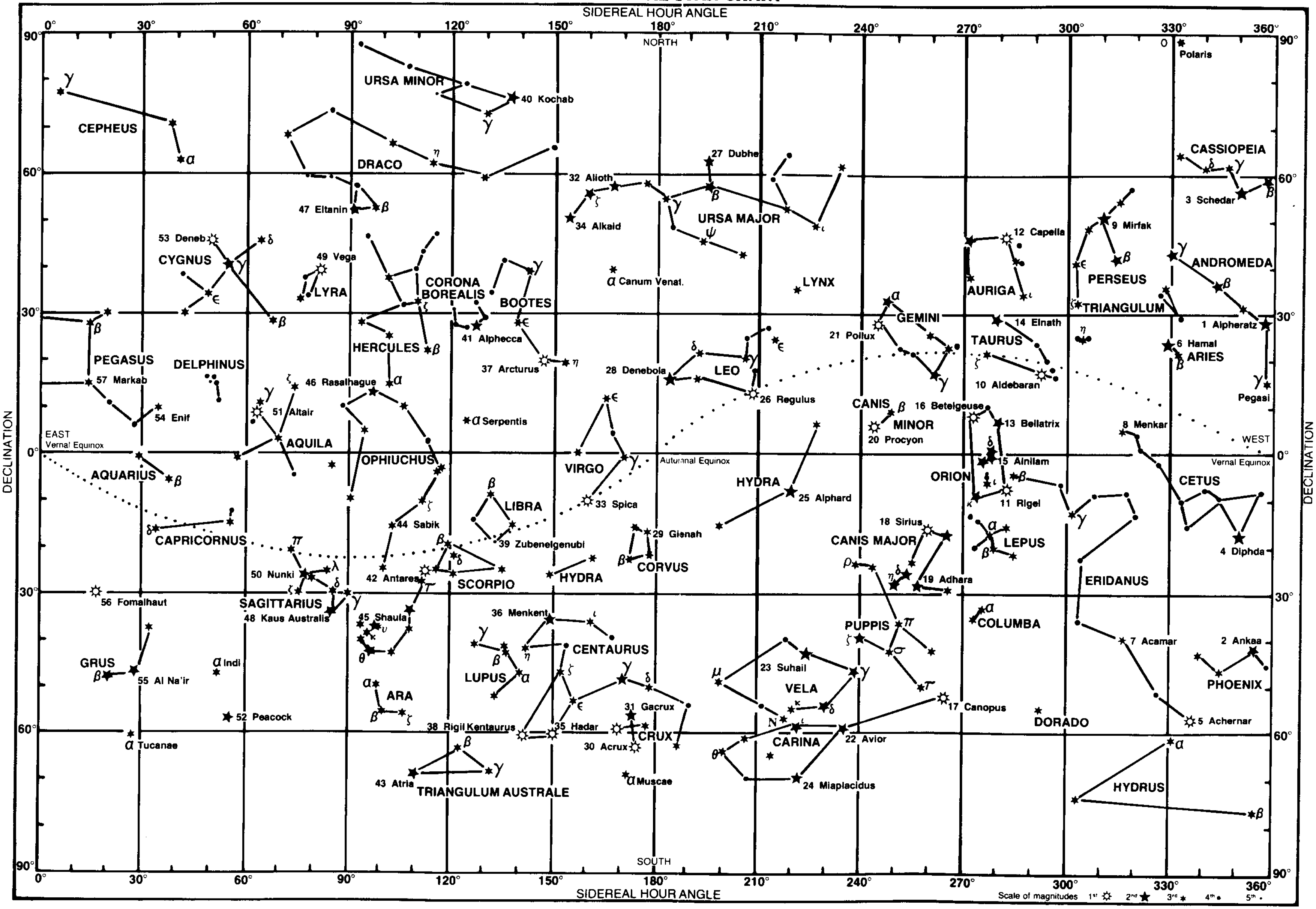
Stars

| | | | |
|---|---|---|---|
| ACAMAR | ARCTURUS | GACRUX | PROCYON |
| ACHERNAR | ATRIA | GIENAH | RASALHAGUE |
| ACRUX | AVIOR | HADAR | REGULUS |
| ADHARA | BELLATRIX | HAMAL | RIGEL |
| ALDEBARAN | BETELGEUSE | KAUS AUSTRALIS | RIGIL KENTAURUS |
| ALIOTH | CANOPUS | KOCHAB | SABIK |
| ALKAID | CAPELLA | MARKAB | SCHEDAR |
| AL NA,IR | DENEB | MENKAR | SHAULA |
| ALNILAM | DENEBOLA | MENKENT | SIRIUS |
| ALPHARD | DIPHDA | MIAPLACIDUS | SPICA |
| ALPHECCA | DUBHE | MIRFAK | SUHAIL |
| ALPHERATZ | ELNATH | NUNKI | VEGA |
| ALTAIR | ELTANIN | PEACOCK | ZUBEN, UBI |
| ANKAA | ENIF | POLARIS | |
| ANTARES | FOMALHAUT | POLLUX | |

All Nautical Almanac Objects

NA (This mnemonic calls up the almanac interpolator program.)

# NAVIGATIONAL STAR CHART



## INDEX TO SELECTED STARS

| No. | Name | No. | Name |
|---|---|---|---|
| 0 | *Polaris* | 30 | *Acrux* |
| 1 | *Alpheratz* | 31 | *Gacrux* |
| 2 | *Ankaa* | 32 | *Alioth* |
| 3 | *Schedar* | 33 | *Spica* |
| 4 | *Diphda* | 34 | *Alkaid* |
| 5 | *Achernar* | 35 | *Hadar* |
| 6 | *Hamal* | 36 | *Menkent* |
| 7 | *Acamar* | 37 | *Arcturus* |
| 8 | *Menkar* | 38 | *Rigil Kentaurus* |
| 9 | *Mirfak* | 39 | *Zubenelgenubi* |
| 10 | *Aldebaran* | 40 | *Kochab* |
| 11 | *Rigel* | 41 | *Alphecca* |
| 12 | *Capella* | 42 | *Antares* |
| 13 | *Bellatrix* | 43 | *Atria* |
| 14 | *Elnath* | 44 | *Sabik* |
| 15 | *Alnilam* | 45 | *Shaula* |
| 16 | *Betelgeuse* | 46 | *Rasalhague* |
| 17 | *Canopus* | 47 | *Eltanin* |
| 18 | *Sirius* | 48 | *Kaus Australis* |
| 19 | *Adhara* | 49 | *Vega* |
| 20 | *Procyon* | 50 | *Nunki* |
| 21 | *Pollux* | 51 | *Altair* |
| 22 | *Avoir* | 52 | *Peacock* |
| 23 | *Suhail* | 53 | *Deneb* |
| 24 | *Miaplacidus* | 54 | *Enif* |
| 25 | *Alphard* | 55 | *Al Na'ir* |
| 26 | *Regulus* | 56 | *Fomalhaut* |
| 27 | *Dubhe* | 57 | *Markab* |
| 28 | *Denebola* | | |
| 29 | *Gienah* | | |

Appendix B

# DATA STRUCTURE

00 Scratch
01 D or S
02 $\Delta T$
03 not used
04 not used
05 $\Delta\lambda$
06 Hi or C
07 Li
08 Loi
09 Li+1

10 Loi+1
11 e
12 Lm L1
13 Gm Lo1 GCPLOT
14 Fm L2
15 D=Lm−Ls Lo2
16 Ls
17 Gs

R18 G2
R19 F2
R20 G4
R21 F4
R22 L5
R23 G5
R24 L6
R25 G6
R26 L2
R27 L4

R28 $\Omega m = Lm - Fm$
R29 Y, $\epsilon$
R30 Date
R31 M, $-\delta\lambda$
R32 D, SD
R33 $\delta \odot$
R34 GMT
R35 T (Centuries from 1900.0)

R36 t (JD from 2000.0)
R37 GHA $\odot$
R38 $\lambda+\delta\lambda$, Xs
R39 $\beta$, Ys
R40 RP, Zs
R41 $\lambda$, Xp
R42 $\beta$, Yp
R43 R, Zp
R44 GST
R45 SHA ☆, GHA planet
R46 declination
R47 Star #
R48 Star Name, temp.
R49 HE
R50 $\odot$
R51 Ho=hs−Rm−Dip
R52 Scratch
R53 HP, # rhumb lines

| Flag | Meaning when set |
|---|---|
| 00 | Angles displayed as d.mt |
| 05 | *DMS is negative, HE is negative |
| 06 | Don't repeat FA |
| 07 | Moon |
| 08 | Used by NA |
| 09 | Used by GCPLOT |

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# HP-41 Navigation Pac Addendum Card

The program GCPLOT works very well when the longitudinal separation is less than or equal to 90°. For longitudinal separations greater than 90°, the program GCPLAN should be used to generate intermediate points less than 90° apart. Then GCPLOT can be used for the intervals between the intermediate points. GCPLOT will not work completely on intervals greater than 90°.

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