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N60

Navigator
Owners Handbo

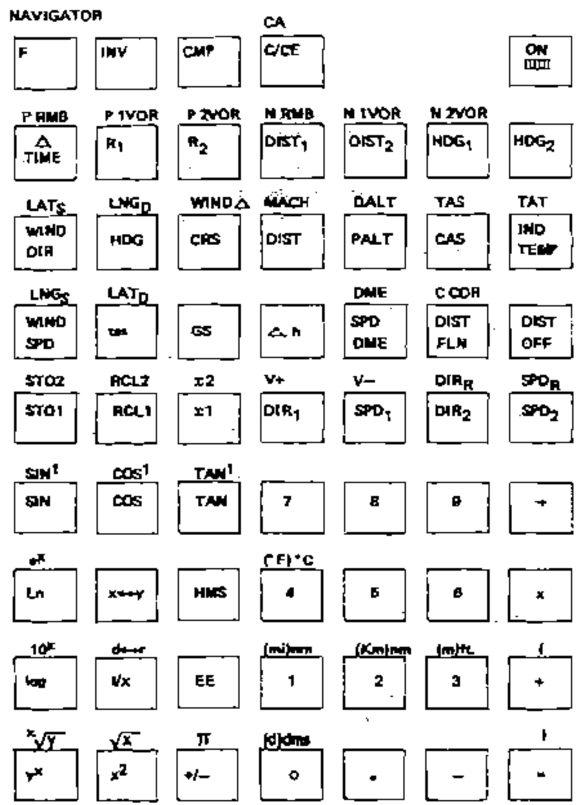
NAVIGATOR 60

TABLE OF CONTENTS

DESCRIPTION		PAGE
I.	KEYBOARD LAYOUT AND KEY INDEX	3-7
II.	OPERATING INSTRUCTIONS – FUNDAMENTAL	8
	1. Power On	8
	2. Display Format	8
	3. Numerical Entry	10
	4. [F] and [inv] Keys	10-11
	5. Clearing –	
	a. To Clear an Erroneous Entry	11
	b. To Clear a Calculation	11
	c. To Clear the Memory Registers	11
	d. To Clear the Calculator	11
	6. Simple Arithmetic	12
	7. Chained Calculations	12
	8. Parenthesis	13
	9. Single Function Keys – X^2, $\sqrt{X}$, 1/X, ln, e^x, log, 10^x, sin, cos, tan, and inverses	14-15
	10. Double Function Keys y^x, $\sqrt[x]{y}$, x↔y	16-17
	11. Hour-Minute-Second Function	18
	12. Degree-Radian Conversion and Mode	19
	13. Unit Conversions	20
	14. Memory Registers and Memory Functions	21
III.	OPERATING-INSTRUCTIONS-NAVIGATIONAL	22
	0. Using your Calculator to solve Navigational Problems	22
	1. Vector Addition and Subtraction	23
	2. DME : DME Speed Correction	24
	3. CCOR : Off-Course Correction	25
	4. TAT : True Air Temperature	26
	5. TAS : True Air Speed	27
	6. DALT : Density Altitude	28
	7. MACH : MACH Number	29
	8. WINDA : Solution of Wind Triangle	30-32
	9. PRMB : Position by Rhumb Line	33
	10. P1VOR : Position by 1VOR	34
	11. P2VOR : Position by 2VOR	35
	12. NRMB : Navigation by Rhumb Line	36

13. N 1VOR : Navigation by 1 VOR 37
14. N 2VOR : Navigation by 2 VOR 38

IV. APPLICATION EXAMPLES 39-77
V. APPENDIX 78-88
A. Error Conditions 78
B. Operating Accuracy 79
C. Glossary of Terms 81-82
D. Battery and AC Adapter/Charger Operation 83
E. Conversions 84-88



KEYBOARD DIAGRAM

KEYBOARD LAYOUT AND INDEX

0 1 2 3 4 5 6 7 8 9 : Numeral keys for data entry (page)

. : decimal point (page 10)

[+] [-] [x] [÷] : Arithmetic operators (page 12)

[=] : Executes all pending arithmetic operations (page 12)

( ) : To begin and end a new set of arithmetic operation during chaining (page 13)

General Functions

[+/-] : Change sign (page 10)

[EE] : Exponent entry (page 10)

[HMS] : Key for entering number in Hour/Degree Minute - Second mode (page 18)

[1/x] : Takes reciprocal of displayed number (page 14)

[x²] √x : Squaring or taking square root of display number (page 14)

[yˣ] ˣ√y : Raising to the xth power or taking the xth root of y. (page 16)

[x⇄y] : Exchange the two operands of arithmetic operations. (page 17)

[log] [ln] [10ˣ] [eˣ] : Common and natural logarithm or antilogarithm (page 14)

[sin] [cos] [tan] sin⁻¹ cos⁻¹ tan⁻¹ : Trigonometric and inverse trigonometric functions (page 15)

d⇄r : To convert the mode and the displayed number into degree or radian (page 19)

π : Generates the constant = 3.141592654 (page 20)

[STO1] [RCL1] [Σ1] STO2 RCL2 Σ2 store recall or add displayed number to Memory 1 or 2 (page 21)

[F] : Key for accessing the above-the-key-top functions (page 10)

[INV] : Inverse key, used in unit conversions (page 11)

[C/CE] : Clear key that clears entry or arithmetic operations (page 11)

CA : Clear all registers except memories 1 and 2. (page 11)

[CMP] : Executes the special navigation functions (page 22)

Vector Manipulation

[DIR₁] [SPD₁] [DIR₂] [SPD₂] : Keys for entering the direction and magnitude of the 1st or 2nd vector in vector addition or subtraction (page 23)

V+ V- : Executes vector addition or subtraction

DIR_R SPD_R : Retrieves the direction or magnitude of the resultant vector (page 23)

Parameters for Wind Triangle

[WIND DIR] : For entering or retrieving the wind direction (page 30)

[WIND SPD] : For entering or retrieving wind speed (page 30)

[HDG] : For entering or retrieving the heading of an aircraft (page 30)

[TAS] : For entering or retrieving the true air speed of an aircraft (page 30)

[CRS] : For entering or retrieving the course of an aircraft (page 30)

[GS] : For entering or retrieving the ground speed of an aircraft (page 30)

General Parameter Entries

[DIST] : For entering or retrieving the distance between the aircraft and its destination (page 37)

[DIST₁] [DIST₂] : For entering or retrieving the distances between two points (used in P 2VOR, C COR, N 2 VOR (page 25, 35, 38)

[Δh] : For entering or retrieving difference in altitude between DME station and aircraft (Used in DME calculation.) (page 24)

SPD DME : For entering or retrieving the speed of an aircraft as measured by DME (used in DME calculation) (page 24)

DIST FLN : Distance flown by aircraft (used in C COR Calculation) (page 25)

DIST OFF : Distance off the planned course (used in C COR Calculation) (page 25)

PALT : Pressure Altitude (Used in MACH, DALT, TAS, TAT Calculations) (page 29, 28, 27, 26)

CAS : Calibrated Air Speed (Used in MACH, DALT, TAS, TAT Calculations) (page 29, 28, 27, 26)

IND TEMP : Indicated Temperature (Used in DALT, TAS, TAT Calculations) (page 28, 27, 26)

TIME : Time elapsed between two events (used in P 1VOR and P RMB Calculations) (page 34, 33)

R1 R2 : Readings from VOR stations (Used in P 1VOR, P 2VOR, DME, N 1VOR, N 2VOR calculations) (page 34, 35, 24, 37, 38)

HDG1 HDG2 : Bearings between objects (used in P 2VOR, N 2VOR) (page 35,38)

LAT_S LNG_S LAT_D, LNG_D : Entering or retrieving the latitudes and longitudes of the starting point and destination (used in NRMB and P RMB) (page 36, 33)

Function Definition Keys

DME : Initiation of DME *(Distance Measuring Equipment)* Speed correction function (page 24)

C COR : Initiates the *off course* correction function (page 25)

WIND△ : Initiates the solution of the *wind triangle* (page 30-32)

MACH : Initiates the calculation of *MACH number* (page 29)

DALT : Initiates the calculation of *density altitude* (page 28)

TAS : Initiates the calculation of *true air speed* (page 27)

TAT : Initiates the calculation of *true air temperature* (page 26)

P RMB : Initiates the function finding current *position by Rhumb line* (page 33)

P 1VOR : Initiates finding *position by 1VOR* (page 34)

P 2VOR : Initiates finding *position by 2 VORs* (page 35)

N RMB : Initiates *n by Rhumb line* (page 36)

N 1VOR : Initiates *navigation by 1VOR* (page 34)

N 2VOR : Initiates *navigation by 2VOR* (page 35)

II. OPERATING INSTRUCTIONS – FUNDAMENTAL

1. **Power On**

   To switch on the calculator, turn the switch to the left. Zero in display indicates that power is on.

2. **Display Format**

   At most, fourteen digits (including sings) can be displayed on your calculator.

   Sample display:

- 0 . 1 2 3 4 5 8 7 8 9	9 0

↑ sign of mantissa — ↑ mantissa — ↑ sign of exponent — ↑ exponent

The mantissa is a maximum of ten digits with or without a decimal point. The sign of the mantissa is positive if the sign of the mantissa field is blank and negative if the sign of the mantissa field contains a "–" sign.

The exponent is a maximum of two digits. The sign of the exponent is positive if the sign of the exponent field is blank and negative if the sign of the exponent field contains a "–" sign.

Your calculator has two display dot indicators, one on the left end of the display to indicate the upper function key mode, and the other on the right of the second exponent digit to signify radian mode.

The Navigator 60 also has a busy signal which appears on the left of the left most digit of the display. The busy signal is a dash which appears when a computation is being carried out. Depressing any key while the busy signal is showing does not affect the computation.

Sample display:

2 . 1 4 6 7 5 4 9 8 .

in radian mode

Error Display

If an improper operation is carried out, the word ERROR will appear on your display. To clear the ERROR display, press [C/CE .]

3. Numerical Entry

Enter in a positive number by pressing the digit keys in order, from left to right. When not entered, the decimal point is assumed to be to the right of the least significant digit, which is the last number entered.

To enter negative numbers, simply enter as a positive and then depress [+/−]

To enter exponents, enter the mantissa (maximum 10 digits) and then depress [EE] and enter in the exponent number (maximum 2 digits). To enter in a negative exponent, depress [+/−] after entering in the exponent number.

4. Upper Function Control Key and Inverse Keys

[F] [(inv)]

The [F] key is depressed when an upper case function is required (functions above key tops)

The [(inv)] key is required for obtaining the unit conversions (from Unit 2 to Unit 1).

NOTE: 1) WHEN REQUIRING THE UPPER CASE INVERSE FUNCTIONS (SUCH AS THE UNIT CONVERSIONS), THE ORDER OF ENTRY OF THE [F] AND [(inv)] KEYS IS NOT IMPORTANT.

2) IF THE [F] KEY IS ENTERED ACCIDENTALLY DEPRESS IT ONCE MORE TO REMOVE IT FROM THAT MODE.

5. Clearing

a. To clear an erroneous entry while keeping prior numerical entries intact, depress [C/CE] once.

EXAMPLE. 4 ÷ 2 [C/CE] 4 [=] 1

Pressing [C/CE] once clears the display.

b. To clear a calculation and allow for the entering of another calculation, depress [C/CE] twice successively.

c. To clear the memory registers, depress [F] [CA]

d. To clear the calculation as well as the memory registers, switch off the power and switch it on again.

6. **Simple Arithmetic**

Four functions [+] [−] [×] [÷]

To perform simple addition, subtraction, multiplication or division, simply enter as the problem appears:

Example x + y + z

KEY ENTRY	DISPLAY	EXPLANATION
x	x	
[+]	x	for simple addition*
y	y	
[+]	y	
z	z	
[=]	x + y + z	

*For simple subtraction, multiplication or division, simply press the required key (i.e., [−], [×], or [÷]).

Remark: The [=] key presents the final answer. There is no need to enter the [=] key after the first operation since the result is displayed after the function key is depressed.

7. **Chained Calculations**

Chained calculations involving several operations such as the calculation of the sum of products or the product of sums can be carried out by using parentheses, refer to page 13. Simple chaining can be carried out as follows:—

Example: $\frac{x \times y}{z} \div w$

KEY ENTRY	DISPLAY
x [×]	
y	y
[÷] z	z
[÷] w	w
[=]	$\frac{x \times y}{z} \div w$

Note: Chaining can be carried out with most functions although it is not available for certain advanced functions.

8. **Parentheses** (,)

The use of parentheses is very important in chained calculations because parentheses allow the user to enter the equation exactly as it is written.
To illustrate this point, the following example is provided.

Example: 2 × (5 + 3) =

Enter as follows:

KEY ENTRY		DISPLAY	EXPLANATION
2	[×]	2	
[F]	(	2	
5	[+]	5	
3		3	
[F]	)	8	5 + 3
[=]		16	2 × (5 + 3)

Note: Parentheses may not be available for certain advanced functions.

9. Single Functions

Finding square of numbers [x^2]

To find the square of a number, enter the number, then depress [x^2]

Finding square root of numbers $\sqrt{x}$

To obtain the square root of a number, enter the number, then depress [F] $\sqrt{x}$

Note: Valid for $x \geq 0$

Finding reciprocal of numbers [1/x]

The reciprocal of a number can be obtained by entering in the number and then depressing the key [1/x].

Note: Not valid for x = 0

Finding natural logarithm of numbers [ln]

To find the natural logarithm of a number, enter the number, then depress [ln].

Note: x >0.

Finding e to the power x [F] e^x

To obtain the e to the power x of a number, enter the number, then key in [F] e^x

Finding common logarithm of numbers [log]

The common logarithm of a number can be obtained by entering in the number and then depressing [log].

Note: x>0.

Finding common antilog of numbers 10^x

To calculate the common antilog of a number, enter the number, then key in [F] 10^x

Finding trigonometric functions [Sin], [Cos], [tan].
sin^{-1} cos^{-1} tan^{-1}

To find the sine of a number in degrees enter the number and then depress [Sin]. The Cosine and tangent can be obtained similarly. If you want to calculate the Sine of a number in radians set the calculator in the radian mode by press [F] d↔r and then enter in the number, followed by [Sin]. The Cosine and tangent can be found similarly.

To find the inverse sin of a number, enter the number, then depress [F] sin^{-1}. The inverse of the cosine and tangent can be obtained similarly.

Note: (1) inverse sine and cosine ≤1.

(2) also tan 90° or tan π/2 is invalid.

10. **Double Functions**

Finding y to the power x [y^x]

To raise a positive number to any power, enter as follows:

KEY ENTRY	DISPLAY
y	y
[y^x]	y
x	x
[=]	y^x

Note: x can be an integer or a decimal, negative or positive.

Finding y to the root x [F] $\sqrt[x]{y}$

To obtain the root x, of any positive number y, enter as follows:

KEY ENTRY	DISPLAY
y	y
[F] $\sqrt[x]{y}$	y
x	x
[=]	$\sqrt[x]{y}$

Note: x can be negative or positive, an integer or a decimal. However, y is only positive.

Using the Exchange Register Key x↔y

The exchange key, x↔y reverses the order of the operands. For instance, x ÷ y will become y ÷ x. The exchange key can be used as follows:

KEY ENTRY	DISPLAY
x	x
[÷]	x
y	y
x↔y	x
[=]	y ÷ x

Note: You can use the exchange register key for the following operations: division, subtraction, power and root.

11. Hour-Minute-Second Function (Or Degrees-Minute-Second Function).

a. Hour-Minute-Second Entry

To enter numbers in the hour-minute-second (or degree-minute-second) format, enter the hours or degrees (integer up to 9999) and then depress [HMS]. The minutes can be entered next followed by depressing [HMS]. To enter the seconds, enter the seconds and then depress [HMS] (Both the minutes and the seconds can be entered up to 99, in integer form.)

Supposing we want to enter 30 degrees, 45 minutes and 10 seconds; enter as follows:

KEY ENTRY	DISPLAY	EXPLANATION
30	30	
[HMS]	30-	
45	30-45	
[HMS]	30-45-	
10	30-45-10	30 degrees-45 minutes-10 seconds

If the minutes or seconds entered are greater than 60, depressing an arithmetic operator or the equals key will normalize the answer.

b. Hour-Minute-Second Arithmetic

Arithmetic operations such as addition, subtraction, multiplication or division can be carried out in the H-M-S format. Arithmetic operations where the first factor is expressed in the HMS mode and the second in decimal, will give results in the HMS mode. Addition or subtraction with both factors in the HMS mode will not change the mode.
However, if multiplication or division is carried out the result will appear in decimal form.

c. HMS/Decimal Conversion

To convert the decimal form into the HMS format (i.e. hours/degrees-minutes-seconds) depress [F] (d) dms
To obtain the decimal form when you have the display in the HMS mode, depress [(inv)] [F] (d)dms.

12. Degree/Radian Conversions & Modes

When you require either a degree/radian conversion or a change of degree/radian mode, press:

[F] d↔r

Pressing the above will both do the conversion and reset the mode. In other words, if your calculation is in degree mode and F d↔r is pressed, a degree to radian conversion is done and your calculator is put in radian mode. Likewise, if your calculator is in radian mode and F d↔r is pressed, a radian to degree conversion is done and your calculator is put in degree mode.

Rules for determining your calculator's mode are:

1) When turned on, your calculator is initially in degree mode.
2) If there is a decimal point in the exponent field of the display, your calculator is in radian mode. If not, your calculator is in degree mode.

13. Unit Conversions

The unit conversions available on your NAVIGATOR 60 are as follows:

	QUANTITY	CONVERSION FACTOR Unit 1 to Unit 2	Unit 2 to Unit 1
(mi) nm	statute miles to nautical miles	0.868976241	1.150779448
(km) nm	kilometres to nautical miles	0.539956803	1.852
(m) ft.	metres to feet	3.280839895	0.3048
(°F) °C	degrees Fahrenheit to degrees Centigrade	$(^{\circ}F-32) \div 1.8$	$(^{\circ}C \times \frac{5}{9}) + 32$
(d) dms	decimal degrees to degrees/hour minute-seconds	1 degree = 60 minutes = 3600 seconds	

Pi Constant

To obtain the constant Pi, depress [F] π.

Note: π = 3.141692654

14. Memory Registers and Memory Functions

There are a maximum of two memory registers available for the user.

a. Storing the Display in Memory Register

[STO 1]   STO 2

For storing a number on display in a memory register, simply depress [STO 1] or [F] STO 2. For instance, to store 455 in memory register 1, enter 455 and depress [STO 1].

b. Recalling the Quantity Stored in Memory Register   [RCL 1]   RCL 2

For recalling a value stored in a memory register, simply depress [RCL 1] to recall value in register 1 and depress [F] RCL 2 to recall value in register 2. To recall 455 stored in memory register 1, depress [RCL 1] to obtain 455 on the display.

c. Addition/Subtraction with Memory Register

[Σ 1]   Σ 2

Another important feature of the calculator is that addition or subtraction can be carried out directly to the memory without the need to recall the value. For instance, to add a value a to whatever is stored in memory register 1, enter a and depress [Σ1]. To obtain the answer, press [RCL 1]. Values can be added similarly to memory register 2.

III OPERATING INSTRUCTIONS - NAVIGATIONAL

O. Using Your Navigator Calculator for Solving Navigation Problems.

In general, the key sequence should be as follows:

Step 1: Define the function to be performed:

e.g. [F] WINDΔ (Note: The Function definitions appear above the key tops in special lettering).

Step 2: Enter the parameters required for meaningful computation of the function. The parameters can be entered in any order: e.g. Number

[WIND DIR.] Number [WIND SPD] Number

[HDG] Number [TAS]

Step 3: Start the computation by pressing [CMP] The result will be displayed. If the result is made up of two parts, one of them will be displayed and the other part can be obtained by pressing the appropriate key; e.g. course will be displayed after [CMP] is pressed, to get the ground speed, we have to then press [GS] .

In most cases, the parameters entered will not be changed by the computation, and they can be retrieved by pressing the same key as in the parameter entry, e.g. [TAS] for retrieving true air speed entered, after the computation.

Note: The calculator has to be in degree mode for any navigation problems.

Navigation Problems

1. Vector Addition and Subtraction (V+ V-)

   a. V+ : $(\overrightarrow{DIR_R, SPD_R}) = (\overrightarrow{DIR_1, SPD_1}) + (\overrightarrow{DIR_2, SPD_2})$

   b. V- : $(\overrightarrow{DIR_R, SPD_R}) = (\overrightarrow{DIR_1, SPD_1})$ $(\overrightarrow{DIR_2, SPD_2})$

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F CA	Clear the parameter registers before entering a new set of vectors (omit F CA in case of chaining)
Direction of 1st vector	[DIR_1]	
Magnitude of 1st vector	[SPD_1]	
Direction of 2nd vector	[DIR_2]	
Magnitude of 2nd vector	[SPD_2]	
	[F] V+ or [F] V-	This will carry out the vector addition or subtraction, and direction of resultant vector will be displayed automatically.
	[F] SPD_R	To get magnitude of the resultant vector.

Note: After evaluation of the resultant vector, DIR_1 and SPD_1 will be replaced by DIR_R and SPD_R to facilitate further operations, i.e., $\overline{V}_1 + \overline{V}_2 + \overline{V}_3 + ... + \overline{V}n$

2. DME: **DME Speed Correction**

To correct for the ground speed obtained from the DME speed indicator when the aircraft is not flying directly to or from the DME station, data may be entered as follows:

KEY SEQUENCE INPUT/DATA	KEY STROKE	COMMENTS
	[F] [DME]	Start sequence by defining the DME function.
Speed of aircraft as obtained from DME reading (in knots)	[SPD DME]	
Direction to or from DME station	[R_1]	
Course of the aircraft	[CRS]	
Difference in altitude between aircraft and station (in feet)	[Δh]	
Distance to DME station (in nautical miles)	[DIST] [CMP]	The actual ground speed in knots of the aircraft will be displayed.

Caution: When course and VOR radial near 90° angle speed correction becomes very sensitive to errors in DME speed reading.

3. C COR: **Off-Course Correction**

To calculate the distance between the destination and the off-course position, the following key stroke may be used:

KEY SEQUENCE INPUT/DATA	KEY STROKE	COMMENTS
	[F] [C COR]	Start sequence by defining the COR function.
Total distance between the starting point and the destination	[$DIST_1$]	
Distance flown	[DIST FLN]	
Distance off course	[DIST OFF]	
	[CMP]	The change in course required to fly directly from the current position to destination will be displayed.
	[DIST]	To find the distance between the current position and destination. Pressing [HDG_1] will return course correction to display.

4. TAT: True Air Temperature

The True Air Temperature can be calculated given the pressure altitude, the calibrated air speed in knots and the indicated temperature. To obtain the true air temperature, the following key sequence may be used:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F TAT	Start sequence by defining the TAT function
Pressure altitude (in feet)	PALT	
Calibrated air speed (in knots)	CAS	
Indicated temperature (in °C)	IND TEMP	
	CMP	True air temperature in °C will be displayed.

5. TAS : True Air Speed

The True Air Speed is the equivalent airspeed corrected for density altitude (i.e. pressure and temperature). The parameters may be entered as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F TAS	Start sequence by defining the TAS function.
Pressure altitude (in feet)	PALT	
Calibrated air speed (in knots)	CAS	
Indicated temperature (°C)	IND TEMP	
	CMP	True air speed in knots will be displayed.

6. DALT : Density Altitude

The Density Altitude can be calculated by entering as follows:

KEY SEQUENCE		
INPUT/DATA	KEY STROKE	COMMENTS
	F DALT	Start sequence by defining the DALT function.
Pressure altitude (in feet)	PALT	
Calibrated air speed (in knots)	CAS	
Indicated air temperature (°C)	IND TEMP	
	CMP	Density altitude in feet will be displayed.

Note: If true air temperature instead of indicated air temperature is to be entered as parameters, enter D as the CAS.

7. MACH : MACH Number

To obtain the MACH number, enter parameters as follows:

KEY SEQUENCE		
INPUT/DATA	KEY STROKE	COMMENTS
	F MACH	Start sequence by defining MACH function,
Pressure altitude (in feet)	PALT	
Calibrated air speed (in knots)	CAS	
	CMP	Mach number will be displayed.

8. WINDΔ : **Solution of Wind Triangle**

There are four cases in this function:

a. Given wind direction, wind speed, true air speed and course, we want to find the heading and ground speed of the aircraft. The key sequence is:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F WINDΔ	Start sequence by defining WINDΔ function.
Wind direcdoo	WINO DIR	
Wind speeo	WIND SPD	
True air speed	tas	
Course	CRS	
	CMP	Heading of the aircraft will be displayed.
	GS	Press to get ground speed.

Note: tas on key top is for entering parameters of true air speed. The TAS above the CAS key top is for defining the TAS function.

An error message will be displayed upon pressing the CMP key if the parameters eotered do oot conform to any of the four cases described here.

b. Given wind direction wind speed, heading and true air speed, we want to find the course and ground speed. The key sequence is:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F WINDΔ	Start sequeoce by defining WINDΔ function.
Wiod direction	WIND DIR	
Wind speed	WIND SPD	

Heading	HDG	
True air speed	tas	
	CMP	Course will be displayed.
	GS	Press to get ground speed.

c. Given wind direction, wind speed, ground speed and course, we want to find the heading and true air speed. The key sequence is as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F WINDΔ	Start sequeoce by defining WINDΔ fonction.
Wind direction	WIND OIR	
Wioo speed	WINO SPD	
Ground speed	GS	
Course	CRS	
	CMP	Heading will be displayed.
	tas	Press to get true air speed.

d. Given heading, true air speed, ground speed and course of the aircraft, we want to find the wind direction and wind speed. The key sequence is as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F WINDΔ	Start sequence by defining WINDΔ function.
Heading	HDG	
True air speed	tas	
Ground speed	GS	
Course	CRS	
	CMP	Wind direction will be displayed
	WIND SPD	Press to get wind speed.

9. PRMB : **Position by Rhumb Line**

Given the Latitude and Longitude of the starting point or last position, the course and ground speed of the aircraft, and the flying or elapsed time. We want to find our current position in terms of LAT and LNG. The parameters may be entered as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F PRMB	Start sequence by defining PRMB function.
Latitude of the starting point	F LAT_S	
Longitude of the starting point	F LNG_S	
Course	CRS	
Ground speed (in knots)	GS	
Elapsed time (in hours)	Δ TIME	
	CMP	The latitude of our current position will be displayed.
	F LNG_D	Press to get the longitude.

Note: After the computation, LAT_S and LNG_S are replaced by LAT_D and LNG_D for further chaining. Δ TIME is also destroyed.

10. P 1VOR : Position by 1VOR

The Navigator allows you to calculate the distance of an aircraft from a VOR station. Information required for the computation: ground speed and course of the aircraft, first and second radial readings from the VOR, and the elapsed time between the two readings. The parameters may be entered as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F P 1VOR	Start sequence by defining P 1VOR function.
Course	CRS	
Ground speed	GS	
Radial reading 1	R_1	
Radial reading 2	R_2	
Elapsed time (in hours)	Δ TIME	
	CMP	Distance will be displayed.

11. P 2VOR : Position by 2VOR

The Navigator also allows you to calculate the distance between one of the two VORs and the aircraft. Information required: Distance between VOR_1 and VOR_2, bearing of VOR_2 and VOR_1 radials from VOR_1 and VOR_2. The parameters may be entered as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F P 2VOR	Start sequence by defining P 2VOR function.
Distance between the two VORs	$DIST_1$	
Bearing of VOR_2 from VOR_1	HDG_1	
Radial from VOR_1	R_1	
Radial from VOR_2	R_2	
	CMP	Distance of aircraft from VOR_1 will be displayed

12. N RMB : **Navigation by Rhumb Line**

The rhumb line course and distance can be calculated between two coordinate points on the globe by entering as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F N RMB	Start sequence by defining N RMB function.
Latitude of starting point	F LAT$_S$	
Longitude of starting point	F LNG$_S$	
Latitude of destination	F LAT$_D$	
Longitude of destination	F LNG$_D$	
	CMP	The course will be displayed.
	DIST	Press to get the distance in nautical miles.

Note: To facilitate chaining of Rhumb line, LAT$_S$ and LNG$_S$ will be replaced by LAT$_D$ and LNG$_D$ after computation.

13. N 1VOR : **Navigation by 1VOR**

To compute the course to destination and distance between destination and aircraft the following information is required: Distance and bearing of destination from VOR station, radial reading from VOR and distance of aircraft from VOR. To obtain the course, enter as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	F N 1VOR	Start sequence by defining N 1VOR function.
Distance between destination and VOR	DIST$_1$	
Bearing of destination from VOR	R$_1$	
Distance between aircraft and VOR	DIST$_2$	
Bearing of aircraft from VOR (radial)	R$_2$	
	CMP	Course will be displayed
	DIST	Press to get distance to destination.

Note: R$_2$ is destroyed during computation.

14. N 2VOR : Navigation by 2VOR

To navigate between any two points provided signals can be received from two VOR stations, the following information is required: Distance and bearing of destination from VOR_1, distance and bearing of VOR_2 from VOR_1 and radials from VOR_1 and VOR_2. To obtain the distance and headings, enter parameters as follows:

KEY SEQUENCE

INPUT/DATA	KEY STROKE	COMMENTS
	[F] N 2VOR	Start sequence by defining N 2VOR function
Distance between destination and VOR 1	[$DIST_1$]	
Bearing of destination from VOR_1	[HDG_1]	
Distance of VOR_2 from VOR_1	[$DIST_2$]	
Bearing of VOR_2 from VOR_1	[HDG_2]	
Radial from VOR_1	[R_1]	
Radial from VOR_2	[R_2]	
	[CMP]	Course will be displayed
	[DIST]	Press to find distance

Note: During computation, HDG_1, HDG_2, R_1 and R_2 are destroyed in register.

IV APPLICATION EXAMPLES

1. Vector and Subtraction
2. DME Speed Correction (DME)
3. Off-Course Correction (C COR)
4. True Air Temperature (TAT), True Air Speed (TAS) Density Altitude (DALT) and Mach Number (MACH)
5. Solution of Wind Traingle (WIND)
6. Rhumb line Navigation (NRMB)
7. Position by 1VOR (P 1VOR)
8. Position by 2VOR (P 2VOR)
9. Navigation by Rhumbline Method (P RMB)
10. Navigation by 1VOR (N 1VOR)
11. Navigation by 2VOR (N 2VOR)
12. Miscellaneous Navigational Problems Using Basic Functions.
    - A. Weight and Balance of Aircraft
    - B. Head Wind and Cross Wind
    - C. Turn Performace
    - D. Great Circle Plotting
    - E. Rate of CLimb and Descent

IV APPLICATION EXAMPLES

1. Vector Addition/Subtraction

Two forces, F1 and F2, are applied to a unit mass. Calculate the resultant force, Ft acting on the mass if:

F1 = direction 3, magnitude 5

F2 = direction 4,3, magnitude 6,2

$$\vec{Ft} = \vec{F1} + \vec{F2}$$

Solution:

Enter as follows:

ENTRY	DISPLAY	EXPLANATION
3	3	
[DIR_1]	3-00-00	
5	5	
[SPD_1]	5	
4,3	4.3	
[DIR_2]	4-18-00	
6.2	6.2	
[SPD_2]	6.2	
[F] V+	3-43-11	
[F] SPDR	11.19928756	

The resultant force is (3° 43' 11", 11.20).

2. DME Speed Correction (DME)

This function calculates ground speed from the DME speed indicator when the aircraft is not flying directly to or from a DME station.

$$GS = \left| \frac{SPD_{DME}}{\cos(DIR_1, -CRS)} \right|$$

If the altitude of the aircraft and its distance from the DME station is known, a more accurate result can be obtained:

$$GS = \left| \frac{SPD_{DME}}{\cos(DIR_1, -CRS)} \right| \sqrt{\frac{(\Delta h)^2 + DIST^2}{DIST}}$$

where SPD_{DME} is speed obtained from DME speed indicator,

DIR_1, is direction to or from DME station

CRS is magnetic course of the aircraft,

Δh is altitude of the aircraft,

DIST is distance of the aircraft from the DME station,

Note: Accuracy of the function suffers when the aircraft crosses the DME radials at an angle larger than 60°

Examole : An aircraft flying a course of 245° intercepts the 197° to radial of a DME station. The indicated DME soeed is 129 knots. Find the ground speed. What is the ground speed if the aircraft is actually 5 nm away and at an altitude 15,000 feet above the DME station.

ENTRY	DISPLAY	EXPLANATION
F DME	0	define function DME
245	245	
CRS	245-00-00	enter course
197	197	
R_1	197	enter radial
129	129	
SPD DME	129	enter DME speed
CMP	192.7874749	ground speed is computed
F DME	0	define function DME
5	5	
DIST	5	enter distance from station
15,000	15,000	
ΔH	15,000	enter Δaltitude
CMP	215.0056684	ground speed is computed

3. Off-Course Correction (C COR)

This function comoutes the course correction required to reach destination directly in an off course situation. The distance to destination is also computed.

$$\phi = \sin^{-1} \frac{\text{DIST OFF}}{\text{DIST FLN}}$$

$$\theta = \tan^{-1} \frac{\text{DIST OFF}}{\text{DIST}_1 - (\text{DIST FLN}) \cos \phi}$$

$$\Delta\text{CRS} = \phi + \theta$$

$$\text{DIST} = \frac{\text{DOC}}{\sin \theta}$$

where:

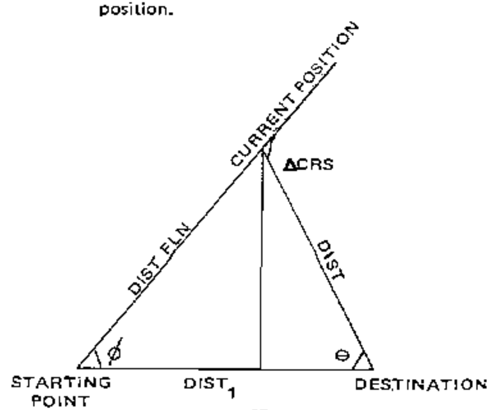
DIST OFF is distance away from intended course,

DIST FLN is distance flown,

$DIST_1$ is total distance between starting point and destination,

CRS is change in course required to reach destination directly, and

DIST is distance to destination from current position.



Example : After flying 64 miles, the pilot discovers that he is 7 miles to the right of the course. If distance between starting point and destination is 200 miles, find the change in course to fly directly to destination and also distance to fly.

ENTRY	DISPLAY	EXPLANATION
[F] [C COR]	0	define function C COR
64	64	
[DIST FLN]	64	enter distant flown
7	7	
[DIST OFF]	7	enter distance off course
200	200	
[$DIST_1$]	200	enter distance between starting point and destination
[CMP]	9-13-03	change in course is computed
[DIST]	136.5634861	distance to destination

So a change in course of 9^{0} 13' to the left is required and distance to destination is 136.6 miles.

4. True Air Temperature (TAT), True Air Speed (TAS), Density Altitude (DALT) and Mach Number (MACH)

$$M^2 = 5\left[\left(\frac{1}{Pr}\left\{\left(\left[1 + 0.2\left(\frac{CAS}{661.5}\right)^2\right]^{3.5} - 1\right\} + 1\right)^{0.2867} - 1\right]$$

$$TAT = C_T\left(\frac{IT + 273}{0.205\ M^2 + 1} - (ZT + 273)\right) + (ZT + 273)$$

$$TAS = 30\ M\sqrt{TAT + 273}$$

$$DALT = 145366\left[1 - \left(\frac{288.15}{TAT + 273}\ Pr\right)^{0.235}\right]$$

where $P_{r_o} = \left(1 - 6.879 \times 10^{-6}\ PALT\right)^{5.256}$

and CT is the aircraft recovery coefficient which can vary from 0.6 to 1, but is 0.8 for most aircraft.

PALT, and CAS are required for finding MACH.

PALT, CAS and IND TEMP are required for finding TAS and TAT.

PALT, CAS and IND TEMP or PALT and true temperature are required for finding DALT. In the latter case, enter true air temperature by the key sequence 0 [CAS] number [IND TEMP].

Note: The pressure altitude is limited to below 36089 feet for these functions. Accuracy of these functions also decreases for supersonic speeds.

Example 1 : Find the true air speed for a pressure altitude of 22,000 ft., calibrated air speed of 320 knots, and an indicated air temperature of 8°C.

ENTRY	DISPLAY	EXPLANATION
[F] TAS	0	define function TAS
22,000	22,000	
[PALT]	22,000	enter pressure altitude
320	320	
[CAS]	320	enter calibrated air speed
8	8	
[IND TEMP]	8	enter indicated temperature
[CMP]	452.3190284	true air speed is computed

True air speed is 452 knots.

What is the true air speed for a pressure altitude of 55,000 ft. with all other data unchanged?

ENTRY	DISPLAY	EXPLANATION
[F] TAS	0	define function TAS
55,000	55,000	
[PALT]	55,000	enter pressure altitude
[CMP]	798.5814091	true air speed is computed

True air speed is 798.6 knots.

Example 2 : For a pressure altitude of 19,000 feet and a calibrated air speed of 295 knots, what is the flight mach number? If the indicated air temperature is 13°C, what is the true air speed?

ENTRY	DISPLAY	EXPLANATION
[F] MACH		define function MACH
19,000	19,000	
[PALT]	19,000	enter pressure altitude
295	295	
[CAS]	295	enter calibrated air speed
[CMP]	0.628994058	Mach number is completed
[F] TAS	0	define function true air speed
13 [+/-]	-13	
[IND TEMP]	-13	enter indicated temperature, PALT and CAS remain unchanged.
[CMP]	333.8807784	true air speed is computed

The Flight Mach number is 0.63.

The True Air Speed is 384 knots.

Example 3 : What is the true air temperature for a calibrated air speed of 320 knots, a pressure altitude of 15,000 feet and an indicated air temperature of -4°C?

ENTRY	DISPLAY	EXPLANATION
[F] TAT	0	define function TAT
320	320	
[CAS]	320	enter calibrated air speed
15,000	15,000	
[PALT]	15,000	enter pressure altitude
4 [+/-]	-4	
[IND TEMP]	-4	enter indicated air temperature
[CMP]	-19.88964821	true air temperature is computed

The true air temperature is -19.89°C.

Example 4 : Find the density altitude for a pressure altitude of 7,000 ft. and a true air temperature of -12°C.

ENTRY	DISPLAY	EXPLANATION
[F] DALT	0	define function DALT
7,000	7,000	
[PALT]	7,000	enter pressure altitude
0 [CAS]	0	
12 [+/-]	-12	
[IND TEMP]	-12	enter true air temperature
[CMP]	5397.746326	density altitude is computed

Density altitude is 5,398 feet.

Note: In the calculations of true air speed, true air temperature and density altitude, we assumed the aircraft recover coefficient, C_T, to be 0.8 which is true for most aircraft. To enter a different C_T, insert the key sequence:

C_T value [Δh] every time before hitting the [CMP] key.

Example 5
For a calibrated air speed of 595 knots, pressure altitude of 18,000 feet, indicated temperature of 12°C and a recovery coefficient of 0.9, what are the density altitude, true air temperature and true air speed?

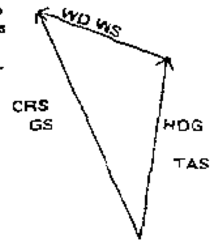
ENTRY	DISPLAY	EXPLANATION
[F] DALT		define function DALT
18,000	18,000	
[PALT]	18,000	enter pressure altitude
12 [+/-]	-12	
[IND TEMP]	-12	enter indicated temperature
595	595	
[CAS]	595	enter calibrated air speed
0.9	0.9	
[Δh]	0.9	enter recovery coefficient
[CMP]	12296.36034	obtain density altitude
[F] TAT	0	define true air temperature
0.9	0.9	
[Δh]	0.9	enter recovery coefficient
595	595	
[CAS]	595	enter calibrated air speed
[CMP]	-63.54116837	obtain true air temperature
[F] TAS	0	define true air speed
0.9	0.9	
[Δh]	0.9	enter recovery coefficient
[CMP]	669.8174295	obtain true air speed

Density altitude = 12,296 ft.
True air temperature = -63.5°C.
True air speed = 669.8 knots.

5. **Wind Triangle (Wind Δ)**

A wind triangle is made up of six entities – course, ground speed, heading, true air speed, wind direction and wind speed.

Theoretically, given any four of the six quantities, we can solve for the other two. The calculator provides solutions to four cases of the wind triangles a navigator may encounter.



a) Solving for heading and ground speed.
b) Solving for heading and true air speed.
c) Solving for course and ground speed.
d) Solving for wind direction and wind speed.

An error message will be generated when the CMP key is pressed if insufficient or more than sufficient data has been entered for meaningful solution of the wind triangle.

Speeds can be expressed in MPH, knots or kilometers per hour, and directions can be magnetic or true, provided the chosen units are used consistently throughout the problem.

To convert magnetic directions into true directions, add the magnetic variation (- for W and + for E) to the magnetic directions.

Example 6 : Find the magnetic heading and ground speed for a true air speed of 210 MPH, magnetic course of 124°, magnetic variation of 12°W and wind is 60 MPH from 100° true.

ENTRY	DISPLAY	EXPLANATION
[F] WINDΔ	0	define function wind Δ
210	210	
[tas]	210	enter true air speed
124	124	magnetic course
[-] 12	12	magnetic variation (- for W)

ENTRY	DISPLAY	EXPLANATION
[=]	112	true course
[CRS]	112-00-00	enter true course
60	60	
[WIND SPD]	60	enter wind speed
100	100	
[WIND DIR]	100-00-00	enter wind speed
[CMP]	108-35-40	true heading is displayed
[+] 12	12	
[=]	120-35-40	magnetic heading is displayed
[GS]	150.940297	ground speed is displayed

So the magnetic heading of the aircraft should be 120° 36' and the ground speed is 151 MPH.

Example 1 : Find the true air speed and true heading to make good a flight schedule knowing the true course as 64°, desired ground speed 145 knots and wind is coming from 130° true at 50 knots.

ENTRY	DISPLAY	EXPLANATION
[F] WINDΔ	0	define function windΔ
64	64	
[CRS]	64-00-00	enter true course
145	145	
[GS]	145	enter ground speed
130	130	
[WIND DIR]	130-00-00	enter wind direction
50	50	
[WIND SPD]	50	enter wind speed
[CMP]	79-26-38	true heading is computed
[tas]	171.5304093	true air speed

So the aircraft has to fly with a true heading of 79° 27' and a true air speed of 172 knots.

Example 2 : Given a true air speed of 166 MPH magnetic heading of 284°, a magnetic variation of 8° W, and wind is blowing at 60 MPH from 180° true. What is the true course and ground speed?

ENTRY	DISPLAY	EXPLANATION
[F] WINDΔ	0	define function windΔ
166	166	
[tas]	166	enter true air speed
284	284	magnetic heading
[-] 8	8	magnetic variation (- for w)
[=]	276	true heading
[HDG]	276-00-00	enter true heading
50	50	
[WIND SPD]	50	enter wind speed
180	180	
[WIND DIR]	180-00-00	enter wind direction

ENTRY	DISPLAY	EXPLANATION
CMP	292-11-38	true course is computed
GS	178.3007922	ground speed

So the true course of the aircraft is 292° with a ground speed of 178 MPH.

Example 9 : What is the actual wind direction and speed for a true air speed of 510 MPH, true course of 182°, true heading of 169° and ground speed is 490 MPH?

ENTRY	DISPLAY	EXPLANATION
F WINDΔ	0	define function windΔ
510	510	
tas	510	enter true air speed
182	182	
CRS	182-00-00	enter true course
169	169	
HDG	169-00-00	enter true heading
490	490	
GS	490	enter ground speed
CMP	95-27-22	wind direction is displayed
WIND SPD	114.9340751	wind speed

Wind direction is 95° 27' and the speed is 115.4 MPH.

6. **Rhumbline Navigation (N RMB)**

This function computes the rhumbline course and distance between any two points. The shortest distance between two points on the globe is the great circle. However, great circle navigation involves constant changes in heading while rhumbline is the constant heading path between the points. In low and mid-latitudes the rhumpline is sufficient for practically all course and distance calculations which private pilots encounter.

$$CRS = \tan^{-1}\left[\frac{\pi}{180}(LNG_s - LNG_d)\ \frac{\tan(45^\circ + ½\,LAT_s)}{\tan(45^\circ + ½\,LAT_D)}\right]$$

$$DIST = \begin{cases} 60\,(LAT_D\ 0\ LAT_S)/\cos CRS & \text{if } CRS \neq 90 \text{ or } 270^\circ \\ 60\,(LNG_O \cdot LNG_S)\cos LAT_S & \text{otherwise:} \end{cases}$$

where: LNG_S is longitude of the starting point

LAT_S is latitude of the starting point

LNG_D is longitude of the destination

LAT_D is latitude of the destination

Note: Accuracy deteriorates as distance increases or at high latitudes. The course should not pass through the north or south pole.
To facilitate further computations, LAT_S and LNG_S are replaced by LAT_D and LNG_D respectively.
Southern latitudes and eastern longitudes are entered as negative quantities.

Example
Find the leg lengths and ground course for a flight from A(18°50'S,15°12'W) to B(60°21'N, 75°18'W) using the point C(30°12'N, 37°37'W) as an intermediate point of heading change.

ENTRY	DISPLAY	EXPLANATION
F NRMB	0	define function NRMB
18 HMS 50	18-50	
+/-	–18-50	
F LAT_S	–18-50-00	enter latitude of starting point
15 HMS 12	15-12	
F LNG_S	15-12-00	enter longitude of starting point
30 HMS 12	30-12	
F LAT_D	30-12-00	enter latitude of intermediate point
37 HMS 37	37-37	
F LNG_D	37-37-00	enter longitude of intermediate point
CMP	336-13-31	course is computed
DIST	3214.818519	distance is displayed
F NRMB	0	define function NRMB
60 HMS 21	60-21	
F LAT_D	60-21-00	enter latitude of destination
75 HMS 18	75-18	
F LNG_D	75-18-00	enter longitude of destination
CMP	319-42-48	course is computed
DIST	2371.464394	distance is displayed

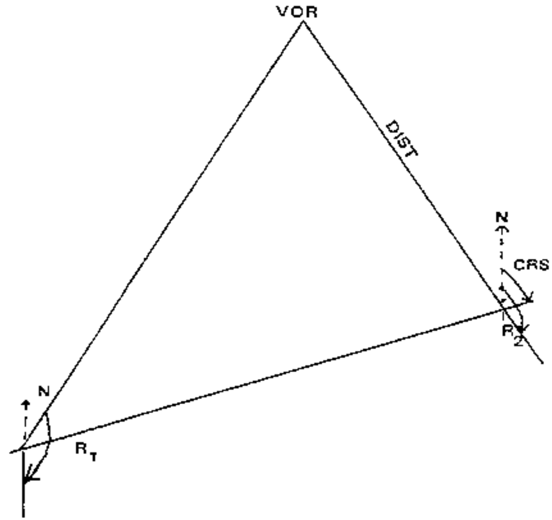
The course for the first leg is 336°14' and that for the second leg 319°43'. Leg distances are 3215 and 2372 n.m.

7. Position by 1VOR (P 1VOR)

This function calculates the distance between the aircraft and a VOR station.

$$DIST = (GS \times \Delta TIME) \frac{\sin(CRS - R1)}{\sin(R1 - R2)}$$

where: GS is the ground speed of aircraft.
CRS is magnetic course of aircraft.
R1 is the first VOR reading.
R2 is the second VOR reading.
Δ TIME is time elapsed between the two VOR readings.



Example : An aircraft is flying at a magnetic course of 27° and a ground speed of 172 knots. At 5-16-18 the OMNI indicates a heading of 310° to the station. At 5-28-23 the VOR reads 227° to the station. Find the distance between the aircraft and the station.

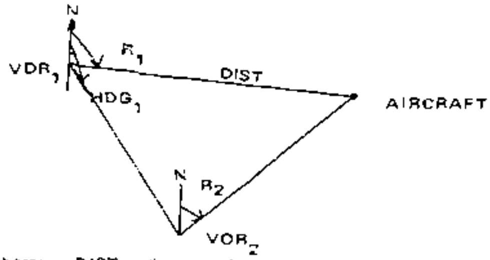
ENTRY	DISPLAY	EXPLANATION
[F] P 1VOR	0	define function P 1VOR
27	27	
[CRS]	27-00-00	enter magnetic course
172	172	
[GS]	172	enter ground speed
310	310	
[R1]	310	enter VOR reading 1
227	227	
[R2]	227	enter VOR reading 2
5 [HMS] 28 [HMS] 23	5-28-23	t2
[–]	5-28-23	
5 [HMS] 16 [HMS] 18	5-16-18	t1
=	0-12-05	$\Delta t = t2 - t1$
[△ TIME]	0-12-05	enter △TIME
[CMP]	34.00456125	distance is computed

The distance between the aircraft and the station is 34 n.m.

8. **Position by 2VOR (P 2VOR)**

This function computes the distance of one of two VOR from the aircraft.

$$DIST = \left| \frac{DIST_1 \sin(HDG_1 - R2)}{\sin(R1 - R2)} \right|$$



where: DIST = distance of aircraft from VOR_1.

$DIST_1$ = distance between the two VORs.

HDG_1 = magnetic heading of VOR_2 from VOR_1.

R1 = radial from VOR_1.

R2 = radial from VOR_2.

Note: The aircraft and the VORs should not be on a straight line.

Example : What is the distance between the aircraft and VOR_1 if the radial from it reads 195° and that from VOR_2 which is 30 n.m. and 137° from VOR_1 reads 280°?

ENTRY	DISPLAY	EXPLANATION
[F] P 2VOR	0	define function P 2VOR
195	195	
[R1]	195	enter radial from VOR_1
30	30	
[$DIST_1$]	30	enter distance between VOR_1 and VOR_2
137	137	
[HDG_1]	137-00-00	enter bearing of VOR_2 from VOR_1
280	280	
[R2]	280.	enter radial from VOR_2
[CMP]	18.12341576	distance is computed

So VOR_1 is 18 n.m. away from the aircraft.

9. Position by Rhumbline Method (P RMB)

This function computes the position of an aircraft given the latitude and longitude of the starting point, the ground speed, and true course of the aircraft and the flying time.

$$LAT_D = LAT_S + \frac{\Delta TIME \times GS}{60} \cos CRS$$

$$LNG_D = LNG_S - \frac{180}{\pi} (\tan CRS) \ln \frac{\tan(45^\circ + \frac{1}{2} LAT_D)}{\tan(45^\circ + \frac{1}{2} LAT_S)}$$

if $CRS \neq 90^\circ$ or 270°

$LNG_D =$

$$LNG_S - \frac{\Delta TIME \times GS \sin CRS}{60 \cos LAT_S} \quad \text{otherwise}$$

where: LAT_S is latitude of starting position,

LNG_S is longitude of starting position,

TIME is flying time,

GS is ground speed of aircraft in knots,

CRS is true course of the aircraft,

LAT_D is the latitude of the aircraft at the end of the flying time,

LNG_D is the longitude of the aircraft at the end of the flying time.

To facilitate further computation at the end of calculation, LAT_S is replaced by LAT_D and LNG_S is replaced by LNG_D.

Time is destroyed.

NOTE: The flight path may not pass through south or north pole. Southern latitudes and eastern longitudes are entered as negative quantities.

Example : Starting from 25°50'S, 15°45'W and going at 608 knots ground speed and a course of 385°, what is the position after 2 hours of flight?

If then the true course is changed to 255° and ground speed changed to 572 knots, find the position of the aircraft after another 1½ hours.

ENTRY	DISPLAY	EXPLANATION
[F] P RMB		define function P RMB
25 [HMS] 50	25-50	
[+/-]	-25-50	
[F] LAT_S	-25-50-00	enter latitude of starting point
15 [HMS] 45	15-45	
[F] LNG_S	15-45-00	enter longitude of starting point
608	608	
[GS]	608	enter ground speed
385	25	
[CRS]	25-00-00	enter true course
2	2	
[ΔTIME]	2-00-00	enter time of flight
[CMP]	7-27-56	latitude of aircraft is computed
[F] LNG_D	6-45-53	longitude of aircraft is displayed

So the position of the aircraft after flying two hours is 7°28'S, 6°46'W.

To continue with the problem:

ENTRY	DISPLAY	EXPLANATION
[F] P RMB		define function P RMB
255	255	
[CRS]	255-00-00	enter new course
572	572	
[GS]	572	enter new ground speed

ENTRY	DISPLAY	EXPLANATION
1.5	1.5	
[Δ TIME]	1-30-00	enter flight time
[CMP]	-11-10-00	latitude of aircraft
[F] LNG_D	20-45-52	longitude of aircraft

Thus after another 1½ hours, the aircraft will be at 11°10'S, 20°46'W.

10. Navigation by 1VOR (N 1VOR)

This function calculates the course and distance to destination with signal coming from a VOR of known distance from the aircraft.

$$(\overrightarrow{DIST, CRS}) = (\overrightarrow{DIST_1, R1}) \quad (\overrightarrow{DIST_2, R2})$$

where: DIST is between the aircraft and destination.

CRS is magnetic course to destination from the aircraft.

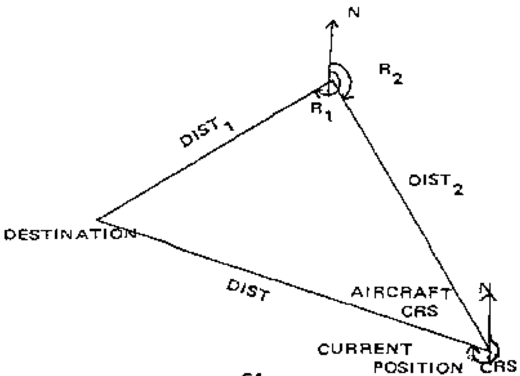
$DIST_1$ is distance between destination and VOR station.

R1 is magnetic bearing of destination from VOR station.

$DIST_2$ is distance between aircraft and VOR station.

R2 is magnetic bearing of aircraft from VOR station.

Note: R2 is *destroyed during computation.*



11. Navigation by 2VOR (N 2VOR)

This function computes the course and distance to destination with signals coming from 2VOR stations.

$$D = \left| \frac{DIST_2 \sin(HDG_2 - R2)}{\sin(R1 - R2)} \right|$$

$$(\overrightarrow{DIST, CRS}) = (\overrightarrow{DIST_1, HDG_1}) - (\overrightarrow{D, R_1})$$

where: $DIST_2$ is distance between VOR_1 and VOR_2.

HDG_2 is magnetic bearing of VOR_2 from VOR_1.

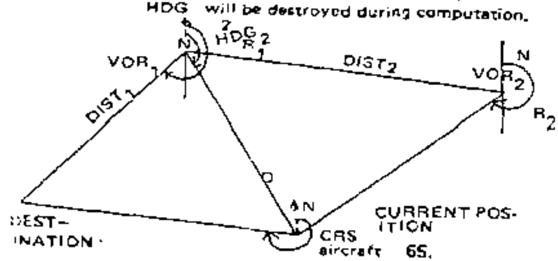
R2 is radial from VOR_2.

R1 is radial from VOR_1.

$DIST_1$ is distance between VOR_1 and destination.

HDG_1 is magnetic bearing of destination from VOR_1.

Note: VOR_1 and VOR_2 should not be in a straight line with the aircraft. R1, R2, HDG_1 and HDG_2 will be destroyed during computation.



Example : VOR_2 is 15 n.m. and 135° from VOR_1. Destination is 22 n.m. and 260° from VOR_1. If radials from VOR_1 and VOR_2 read 180° and 240° respectively, what should be the course and distance to destination?

ENTRY	DISPLAY	EXPLANATION
[F] N 2VOR	0	define function N2VOR
15	15	
[$DIST_2$]	15	enter distance between VOR_1 and VOR_2
135	135	
[HDG_2]	135-00-00	enter magnetic bearing of VOR_2 from VOR_1
22	22	
[$DIST_1$]	22	enter distance between VOR_1 and destination
260	260	
[HDG_1]	260-00-00	enter magnetic bearing of destination from VOR_1
180	180	
[R1]	180	enter radial from VOR_1.
240	240	
[R2]	240	enter radial from VOR_2
[CMP]	300-47-23	magnetic course is displayed
[DIST]	25.22053573	distance to destination

The distance to destination is 25 n.m. and the magnetic course is 300°

12. Miscellaneous navigational problems using basic functions.

The Navigation calculator provides programmed solutions to most problems a navigator may encounter. However, with all the basic functions available to him, an intelligent user can get more out of the calculator in addition to the preprogrammed functions. The following section gives examples on how the calculator can be used to solve problems not preprogrammed, but may be of interest to a navigator.

A. Weight and Balance of Aircraft

It is very easy to calculate the total gross weight and movement or gross weight and center of gravity that are used to determine your position in the weight-balance envelope furnished with your aircraft. Knowing that:

$$\text{Movement} = \text{Weight} \times \text{Arm}$$

$$\text{Center of Gravity} = \frac{\Sigma \text{ Movement}}{\Sigma \text{ Weight}}$$

we can use multiplication, division and sum to memory keys to solve our problem.

Example I : The following table gives weight and balance data for an aircraft.

Item	Weight (lb)	Arm	Movement
Empty Plane	1,500		18000
Pilot	180	10.25	
Passenger	125	38	
Oil	15		-500
Fuel	130	25	

Find the gross weight, total movement and center of gravity.

ENTRY	DISPLAY	EXPLANATION
1500	1500	weight of plane
[STO1]	1500	store weight of plane
18000	18000	movement of plane
[F] STO2	18000	store movement of plane
180	180	weight of pilot

ENTRY	DISPLAY	EXPLANATION
[Σ 1]	180	Σ weight
[x] 10.25	10.25	arm
[=]	1845	movement of pilot
[F] Σ 2	1845	Σ movement
125	125	weight of passenger
[Σ 1]	125	Σ weight
[x] 38	38	arm
[=]	4750	movement of passenger
[F] Σ 2	4750	Σ movement
15	15	Σ weight of oil
[Σ 1]	15	Σ weight
500 +/-	-500	movement of oil
[F] Σ 2	-500	Σ movement
130	130	weight of fuel
[Σ 1]	130	Σ weight
[x] 25	25	arm
[=]	3250	movement of fuel
[F] Σ 2	3250	movement
[F] RCL2	27345	total movement
[÷]		
[RCL1]	1950	total weight
[=]	14.02307692	center of gravity

Weight = 1,950 lb.

Center of Gravity = 14.02

Movement = 27,345

B. Head Wind and Cross Wind

The head wind and cross wind components can be computed as follows:

HW = WS cos (WD - HDG - V)

CW = WSsin (WD - HDG - V)

where:

WS is wind speed

WD is wind direction

HDG is magnetic heading of aircraft

V is magnetic variation

A positive HW means head wind and negative means tail wind.
A positive CW means right cross wind and negative means left cross wind.

Note: V is zero when winds are reported in magnetic direction. Wind directions reported by the control tower are magnetic and the variation need not be input for take off and landings. Other wind directions are reported in true directions and variation must be included.

Magnetic variation is + for E and - for W.

Example : At altitude the wind is reported as 210° and 50 knots. Your magnetic heading is 305°. Find the head wind and cross wind components if the magnetic variation is 19° W.

ENTRY	DISPLAY	EXPLANATION
210	210	enter wind direction
[-] 305	305	minus magnetic heading
[-]	-95	magnetic variation
19[=]	-114	WD-HDG-V
[STO1]	-114	store WD-HDG-V
[COS]	-0.405736643	
[x] 50	50	wind speed
[=]	-20.33683215	head wind
[RCL1]	-114	WD-HDG-V

ENTRY	DISPLAY	EXPLANATION
[sin]	-0.913545457	
[×] 50	50	wind speed
[=]	-45.6772788	cross wind

So the tail wind is 20.34 knots and the left cross wind is 45.68 knots

C. **Turn Performance**

The parameters involved in a turn: the G-force, turn diameter, time required to complete a 360° turn, and stall speed can be computed using the following formula:

$$G = \frac{1}{\cos \beta}$$

$$\text{Diameter} = \frac{TAS^2}{34208 \tan \beta}$$

$$\text{Time} = \frac{0.0055 \cdot TAS}{\tan \beta}$$

$$\text{Stall} = (\text{normal stall})/\sqrt{\cos \beta}$$

Where: β = bank angle of the aircraft

TAS = true air speed

Example : Calculate the ⓐ G-force, ⓑ diameter of turn, ⓒ time required for a 360° turn, and ⓓ the stall speed for an aircraft in a 45° bank angle with a cruising speed of 115 knots and a stall speed of 60 knots.

Solution:

ⓐ to obtain the G-force, enter as follows:

ENTRY	DISPLAY	EXPLANATION
45	45	bank angle
[cos]	0.707106781	
[1/x]	1.1414213562	G-force

G-force = 1.141

(b) to obtain the diameter of turn, enter as follows:

ENTRY	DISPLAY	EXPLANATION
115	115	true air speed
[x^2]	13225	
[÷] 34208	34208	
[÷]	0.386605472	
45 [tan]	1	
[=]	0.386605472	diameter of turn

Diameter of turn = 0.387 nautical mile

(c) to find the time to turn 360°, enter as follows:

ENTRY	DISPLAY	EXPLANATION
0.0055	0.0055	
[x] 115	115	true air speed
[÷]	0.6325	
45 [tan]	1	
[=]	0.6325	time to turn 360°

Time to turn 360° = 0.633

(d) to find the stall speed, enter as follows:

ENTRY	DISPLAY	EXPLANATION
80	80	normal stall
[÷] 45 [cos]	0.707106781	
[F] √x	0.840896415	
[=]	95.1365692	stall speed

Stall speed = 95.14 knots

D. Great Circle Plotting

Given the latitude and longitude of two points on the globe and an intermediate longitude, we can calculate the latitude corresponding to the intersection of the great circle route and the intermediate longitude.

$$LAT_1 = \tan^{-1}\left[\frac{A - B}{\sin(LNG_D - LNG_S)}\right]$$

where:

$A = (\tan LAT_D \cos LNG_S - \tan LAT_S \cos LNG_D)$

$\quad \times \sin LNG_I$

$B = (\tan LAT_D \sin LNG_S - \tan LAT_S \sin LNG_D)$

$\quad \times \cos LNG_I$

NOte: No leg may pass exactly half way around the earth, and lines of longitude may not be plotted. Southern latitudes and eastern longitudes are expressed as negative quantities.

Example : Find the corresponding latitude for an intermediate point at 27°25'W on the great circle route from point A (12°12'S, 20°34'W) to point B (40°55'N, 37°40'W)

ENTRY	DISPLAY	EXPLANATION
40 [HMS] 55	40-55	LAT_D
[tan] [x]*	0.866736457	
20 [HMS] 34	20-34	LNG_S
[sin] [=]	0.304481927	
[F] (12 [HMS]	-12-12	LAT_S
12 [+/-]		
[tan] [x]	-0.216207652	
37 [HMS] 40	37-40	LNG_D
[sin] [F])	-0.13211728	
[Σ]	0.436599207	

ENTRY	DISPLAY	EXPLANATION
27 [HMS] 25	27-25	LNG
[cos]	0.88768148	
[=] [STO 1]	0.38756103	

ENTRY	DISPLAY	EXPLANATION
40 [HMS] 55	40-55	LAT_O
[tan] [x]	0.866736457	
20 [HMS] 34	20-34	LNG_S
[cos] [-]	0.811494203	
[F] [(] 12 [HMS] 12 [+/-]	-12-12	LAT_S
[tan] [x]	-0.216207652	
37 [HMS] 40	37-40	LNG_D
[cos] [F] [)]	-0.171145474	
[x]	0.982639678	
27 [HMS] 25	27-25	LNG_S
[sin]	0.46045802	
[-]	0.45246432	A
[RCL 1]	0.38756103	B
[÷]	6.490329009-02	A-B
[F] [(] 37 [HMS] 40	37-40	
[-] 20 [HMS] 34	20-34	$LNG_O \cdot LNG_S$
[F] [)]	17-06-00	
[sin]	0.294040325	
[=]	0.220729214	
[F] [tan⁻¹]	12.44726451	
[F] [(d)dms]	12-26-50	
		LAT_I

So the intermediate point on the great circle route is (12°28'N, 27°25'W).

E. Rate of Climb and Descent

The rate of climb required to change altitude in the specified distance is given by:

$$ROC = \frac{TAS\ (\Delta\ ALT)}{60\sqrt{DIST^2 + (\Delta ALT)^2}}$$

where: TAS is true air speed

Δ ALT is elevation change

DIST is the distance over which the change in elevation is to take place.

On the other hand, if the rate of climb is specified, the distance required to make the change can be computed as follows:

$$DIST = \sqrt{\frac{TAS \times (\Delta ALT)^2}{60\ ROC} - (\Delta ALT)^2}$$

where: ROC is the rate of climb

Example 1 : 40 n.m. east of San Francisco (elevation 3000 ft.) lies a mountain pass having an elevation of 7400 ft. Assuming a climbout TAS of 95 knots, what is the minimum ROC you must maintain to clear the pass by 1500 feet?

Δ ALT = 7400-3000+1500 = 5,900 ft.

ENTRY	DISPLAY	EXPLANATION
5900 [÷]	5900	Δ ALT
6076 [=]	0.971033574	Δ ALT in n.m.
[STO1]		
[x] 95	95	TAS
[÷] [F] [(]	92.2481896	
40	40	DIST
[x²] [+]	1600	$DIST^2$

ENTRY	DISPLAY	EXPLANATION
[RCL1] [x²]	0.942906203	$(\Delta ALT)^2$
[F] [)]	1600.942906	$DIST^2 + (\Delta ALT)^2$
[F] [√x]	40.01178459	
[÷]	2.305525498	ROC in knots
60 [x]	3.842542497-02	ROC in n.m./min.
6076 [=]	233.4728821	ROC in feet/min.

So the rate of climb is 233.47 feet/min.

Example 2 : If a different aircraft climbs out at 650 ft/min and maintains an airspeed of 100 knots. What is the distance required for it to climb to 8000 feet? (Again, Δ ALT = 5,900 feet.)

ENTRY	DISPLAY	EXPLANATION
100 [x]	100	TAS in knots
6076 [÷]	507600	TAS in feet/hr.
60 [x]	10126.66667	TAS in feet/min.
5900	5900	Δ ALT
[÷] 650	650	ROC
[+]	91918.97436	
[x²] [=]	6449189766	
5900 [x²]	34810000	$(\Delta ALT)^2$
[=]	8414379766	
[F] [√x]	91729.92841	DIST in feet
[÷] 6076 [=]	15.09709157	DIST in n.m.

So it takes 15.1 n.m. for the aircraft to climb to 8,000 feet.

Appendix A

Error Conditions

An error condition results when an improper operation is performed or when the result of an operation overflows or under flows the absolute range of the calculator.

When an error condition occurs the word "ERROR" is displayed.

Press the clear key to clear the error condition.

Improper Operation:

X ÷ Y	where Y = 0
[y^x]	where $y < 0$
[F] $x\sqrt{y}$	where $X < 0$
[F] $\sqrt{x}$	where $X < 0$
[1/x]	where $X = 0$
[ln] X	where $X < 0$
[log] X	where $X < 0$
[F] $\sin^{-1}$ X	where $X > 1$
[F] $\cos^{-1}$ X	where $X > 1$

Overflow

Occurs when a computed result is greater than $9.999999999 \times 10^{99}$

Underflow

Occurs when a computed result is less than 1.0×10^{-99}

Appendix B

Operating Accuracy

The precision of your calculator depends upon the operation being performed. Basic addition, subtraction, multiplication, division, reciprocal assignments and unit conversions have a maximum error + one count in the tenth or least significant digit.

While countless computations may be performed with complete accuracy, the accuracy limits of particular operations depend upon the input argument as shown below.

FUNCTION	INPUT ARGUMENT	MANTISSA ERROR(MAX.)
[F] $\sqrt{x}$	positive x	1 count in D_{10}
[ln] x	$x > 0$	1 count in D_{10}
[log] x	$x > 0$	1 count in D_{10}
[F] e^x		1 count in D_{10}
[F] 10^x		1 count in D_{10}
[Y^X]	$Y > 0$	4 counts in D_{10}
[sin] ϕ	$0° \leq \phi \leq 360°$ or $0° \leq \phi \leq 2\pi$	1 count in D_9
[cos] ϕ	$0° \leq \phi \leq 360°$ or $0° \leq \phi \leq 2\pi$	1 count in D_9
[tan] ϕ	$0° \leq \phi \leq 89°$	4 counts in D_{10}
	$89° \leq \phi \leq 89.95°$	1 count in D_6
[F] $\sin^{-1}x$	$10^{-10} \leq x \leq 1$	$E < 5 \times 10^{-10}$
[F] $\cos^{-1}x$	$10^{-10} \leq x \leq 1$	$E < 5 \times 10^{-10}$
[F] $\tan^{-1}x$		$E < 5 \times 10^{-10}$

Navigational Functions

Accuracy for the navigational problems depends on the parameters and also on the function. Generally, the accuracy is very good, the error being 2 counts in the ninth digit.

Appendix C

A QUICK GLOSSARY OF TERMS

BEARING: The horizontal angle at a given point, measured clockwise from a specific reference datum, to a second point. The direction of one point relative to another, as measured from a specific reference datum.

CALIBRATED AIRSPEED (CAS): Indicated airspeed corrected for pitotstatic installation and/or the altitude of the aircraft.

COURSE: The intended direction of travel.

DENSITY ALTITUDE: Pressure altitude corrected for temperature.

DEVIATION: Compass error due to electrical equipment and metal parts on the aircraft.

DISTANCE MEASURING EQUIPMENT (DME): Equipment for measuring the distance between an aircraft and a ground station.

GROUND SPEED (GS): The actual speed of an aircraft relative to the surface of the earth.

HEADING: The angular direction of the longitudinal axis of an aircraft measured clockwise from a reference point.

INDICATED AIR TEMPERATURE (IND TEMP): The uncorrected reading from the free air temperature gauge.

MACH NUMBER: The ratio of the velocity of a body to that of sound in the medium in which the craft is moving.

MAGNETIC VARIATION: The difference between magnetic and true north. Variation is positive for westerly and negative for easterly. Thus True Course + Variation = Magnetic Course.30.48

NAUTICAL MILE (NM): A unit of distance used in navigation, 6,080 ft.; the mean length of one minute of longitude on the equator; approximately 1 minute of latitude; 1.15 statute miles.

PRESSURE ALTITUDE: Reading on the altimeter when it is set at 29.92.

RHUMB LINE: A line on the surface of a sphere which makes equal oblique angles with all meridians. A loxodromic curve.

TRUE AIRSPEED (TAS): Equivalent airspeed corrected for density altitude (pressure and temperature).

TRUE AIR TEMPERATURE (TAT): Basic air temperature corrected for the heat of compression error. Also known as outside air temperature (OAT).

VARIATION: The difference between magnetic and true north. Variation is positive for westerly and negative for easterly. Thus true course + variation = magnetic course.

VERY HIGH FREQUENCY OMNIDIRECTIONAL RADIO RANGE (VOR): A ground transmitter radiating directional signals by which an aircraft finds its bearing.

APPENDIX D

Rechargeable Battery

AC Operation

Connect the charger to any standard electrical outlet and plug the pack into the Calculator. After the above connections have been made the power switch may be turned ON.

Battery Operation

Disconnect the charger cord and push the power switch "ON". With Normal use a full battery charge can be expected to supply up to 2 hours of working time.

When the battery is low figures on display will dim. Do not continue battery operation, this indicates the need for a battery charge. Use of the calculator can be continued during the charge cycle.

Battery Charging

Simply follow the same procedure as in AC operation. But leave the power switch off. If a power cell has completely discharged, the calculator should not be operated on battery power until it has been recharged for at least 4-6 hours, unless otherwise instructed by a notice accompanying your machine. Batteries will reach full efficiency after 2 or 3 charge cycles.

Use proper Commodore/CBM adapter recharger for AC operation and recharging.

Adapter 640 or 707 North America.

Adapter 708 England.

Adapter 709 West Germany.

IMPORTANT — Low Power

If battery is low:

a. Display will appear erratic

b. Display will dim.

c. Display will fail to accept numbers.

If one or all of the above conditions occur, you may check for a low battery condition by entering a series of 8's. If 8's fail to appear, operations should not be continued on battery power. Unit may be operated on AC power. See battery charging explanation. If machine continues to be inoperative see guarantee section.

APPENDIX E

INTERNATIONAL SYSTEM OF UNITS (SI) CONVERSION FACTORS

Conversion to Metric Measures

Symbol	Given	Multiply by	To Obtain	Symbol
LENGTH				
in	inches	25.4*	millimeters	mm
ft	feet	30.48	centimeters	cm
yd	yards	0.9144*	meters	m
mi	miles (statute)	1.609	kilometers	km
nmi	miles (nautical)	1.852*	kilometers	km
	micron	1.0*	micrometers	μm
A°	angstrom	0.1*	nanometers	nm
AREA				
cmil	circular mils	0.0005067	sq.millimeters	mm^2
in^2	square inches	6.452	sq.centimeters	cm^2
ft^2	square feet	0.09290	sq.meters	m^2
yd^2	square yards	0.8361	sq.meters	m^2
mi^2	sq.miles (statute)	2.590	sq.kilo-meters	km^2
	acres	0.4047	hectares ($10^4 m^2$)	ha
VOLUME				
fl.oz.	fluid ounces (US)	29.57	cubic cm (millimeters)	cm^3 or ml
gal	gallons(US liq)	3.785	liters	l
gal	gallons (imp)	4.546	liters	l
in^3	cubic inches	16.39	cu centi-meters	cm^3
ft^3	cubic feet	0.02832	cubic meters	m^3
yd^3	cubic yard	0.7646	cubic meters	m^3
bbl	barrels(US petrbl)	0.1590	cubic meters	m^3
	acre feet	1233.5	cubic meters	m^3
SPEED				
ft/min	feet per minute	5.080*	millimeters per second	mm/s
mi/h	miles per hour	0.4470	meters per sec	m/s

Symbol	Given	Multiply by	To Obtain	Symbol
km/h	kilometers per hr	0.2778	meters per sec	m/s
kn	knots	0.5144	meters per sec	m/s
MASS				
oz	ounces(avdp)	28.35	grams	g
lb	pounds(avdp)	0.4536	kilograms	kg
ton	short tons (2000 lbs)	0.9072	metric tons (1000 kg)	t
DENSITY				
lb/ft^3	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3
FORCE				
oz,	ounces-force	0.2780	newtons	N
lb,	pounds-force	4.448	newtons	N
kg,	kilograms-force	9.807	newtons	N
dyn	dynes	10^{-5}	newtons	N
WORK, ENERGY—POWER				
ft-lb,	foot pounds -force	1.356	joules	J
cal	calorie (thermochem)	4.184*	joules	J
Btu	British thermal units(Intl)	1055	joules	J
hp	horsepower (elec)	746.*	watts	W
ft-lbs./s	foot pounds-force per second	1.356	watts	W
Btu/h	British thermal units per hour (Intl)	0.2931	watts	W
PRESSURE				
$lb./in^2$	pounds-force /inch²	6.898	kilopascals	kPa
$lb./ft^2$	pounds-force /foot²	47.88	pascals	Pa
$kg./m^2$	kilograms-force/meter²	9.807	pascals	Pa
mb	millibars	100.0*	pascals	Pa
mmHg	millimetrs of Hg	133.3	pascals	Pa
in H_2O	inches of water(39°F)	0.2491	kilopascals	kPa
ft H_2O	feet of water	2.989	kilopascals	kPa

LIGHT

fc	footcandles	10.76	lux	lx
fL	footlamberts	3.426	candelas per sq. meter	cd/m^2

Symbol	To Obtain	Divide by	Given	Symbol

Conversion FROM Metric Measures

TEMPERATURE

Symbol	Given	Compute by	To Obtain	Symbol
°F	°Fahrenheit	$(°F-32)\frac{5}{9}$	°Celsius	°C
°C	°Celsius	$°C\frac{9}{5}+32$	°Fahrenheit	°F

*Indicates exact value 5 omit when rounding

Symbols For Quantities

Quantity	Qty. Symbol	SI Unit	Unit Symbol	Identical Unit
length	l	meter	m	
mass	m	kilogram	kg	
time	t	second	s	
frequency	f, ν	hertz	Hz	1/s
angular frequency	ω	radian per sec	rad/s	
area	A, S	sq. meter	m^2	
volume	V	cubic meter	m^3	
velocity	v	meter per second	m/s	
acceleration (linear)	a	meter per sec^2	m/s^2	
force	F	newton	N	
torque	T, M	newton meter	N·m	
pressure	p	pascal	Pa	N/m^2
temperature (absolute)	T, Θ	kelvin	K	
temperature (customary)	t, θ	degree Celsius	°C	
attenuation coefficient	α	neper per mtr	Np/m	
phase coefficient	β	radian per meter	rad/m	
propagation coefficient $(\gamma = \alpha + j\beta)$	γ	reciprocal meter	m^{-1}	
radiant intensity	I	watt per steradian	W/sr	
radiant flux	P, ϕ	watt	W	
irradiance	E	watt per sq. meter	W/m^2	
luminous intensity	I	candela	cd	
luminous flux	ϕ	lumen	lm	
illuminance	E	lux	lx	lm/m^2

PHYSICAL CONSTANTS

electronic charge	e	1.602×10^{-19}	C
speed of light in vacuum....................	c	2.9979×10^{8}	m/s
permittivity of vacuum, elec const...	e	8.854×10^{-12}	F/m
permeability of vacuum, mag const .	m	$4\pi \times 10^{-7}$	H/m
Planck constant	h	6.626×10^{-34}	J*s
Boltzmann constant	k	1.38×10^{-23}	J/K
Faraday constant	F	9.649×10^{4}	C/mol
standard gravitational acceleration..	g	9.807	m/s²
normal atmospheric pressure	atm	101.3 kPa	

FACTOR UNIT PREFIX, SYMBOL								
10^{12}	tora	T	10^{1}	deka	da	10^{-6}	*micro*	μ
10^{9}	giga	G				10^{-9}	nano	n
10^{6}	mega	M	10^{-1}	deci	d	10^{-12}	pico	p
10^{3}	kilo	k	10^{-2}	centi	c	10^{-15}	femto	f
10^{2}	hecto	h	10^{-3}	milli	m	10^{-18}	atto	a