HEWLETT hp PACKARD

HP-65

AVIATION PAC 1

CAUTION

At one time the FAA considered giving blanket approval for the use of calculators in aircraft. However, because of possible interference with ADF receivers, the FAA has elected to allow each carrier or owner to determine the appropriateness of in-flight calculator use.

While all calculators emit some extraneous radio noise, the level of radiation is generally very low. In recent laboratory tests, using the test set up specified in RTCA DO-119, the HP-65 had a maximum radiation emission of 2.5 microvolts in the range of 330 to 1700 KHz and less than 1.0 microvolt above 1700 KHz.

Tests have shown that ADF interference from Hewlett-Packard calculators is effectively eliminated when the calculator is at least five (5) feet from the ADF loop antenna. IF YOU SUSPECT INTERFERENCE WITH ANY INSTRUMENTATION WHILE IN-FLIGHT, TURN THE CALCULATOR OFF IMMEDIATELY.

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Introduction

The HP-65 Aviation Pac I is primarily intended for general aviation although many of the programs are equally applicable to commercial aviation. Programs for preflight, inflight and general aviation calculations are included. Some of the subjects are flight planning, aircraft weight and balance, wind calculations, unit conversions and navigation.

Included in Aviation Pac I are 31 pre-recorded magnetic cards, 9 blank magnetic cards, a card case, 20 pocket instruction cards, and an instruction booklet with program descriptions, formulas, example problems, user instructions and program listings.

We hope you find the HP-65 calculator and Aviation Pac I a useful addition to your aircraft instrumentation. Hewlett-Packard welcomes your comments and suggestions as these are our most important source of future, user-oriented programs.

Using the Aviation Pac I
Format of Instructions

The completed 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 number.

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

The INPUT DATA/UNITS column specifies the input data and the units of data if applicable. Data input keys consist of [0] to [9] and decimal point (the numeric keys), [EEX] (enter exponent), and [CHS] (change sign).

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

The OUTPUT DATA/UNITS column specifies intermediate and final outputs and their units where applicable.

The following illustrates the user instruction form for the *True Air Temperature and Density Altitude,* AV1-13A.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program		[ ]	[ ]	
2	Initialize		[RTN]	[R/S]	0.80
3	If you know the true air		[ ]	[ ]	
	temperature, go to step 7		[ ]	[ ]	
4	Input the following:		[ ]	[ ]	
	Mach number	M	[A]	[ ]	M
	Recovery coefficient (if differ-		[ ]	[ ]	
	ent from 0.8)	C_T	[B]	[ ]	C_T
5	Input indicated air temperature		[ ]	[ ]	
	and calculate true air temper-		[ ]	[ ]	
	ature	IT (°C)	[C]	[ ]	T (°C)
6	Go to step 8		[ ]	[ ]	
7	Input true air temperature	T (°C)	[D]	[ ]	T (K)
8	Input pressure altitude and		[ ]	[ ]	
	calculate density altitude	PALT	[E]	[ ]	DALT (ft)
9	For new case go to step 3		[ ]	[ ]	

STEP 1: Step 1 of the example is "Enter program." This calls for the entry of the prerecorded magnetic card into the HP-65.(Refer to *Entering a Program,* page 9) .

STEP 2: This step "initializes" or prepares the calculator for proper program execution. Pressing RTN then R/S performs the initialization. Note that after completion of this step, 0.80 would be in the display.

STEP 3: This step tells you to skip steps 4, 5, and 6 if you know the true air temperature. Steps 4, 5, and 6 must be executed if only indicated air temperature is known.

STEP 4: This step specifies two input values: Mach number (M) and Recovery coefficient (C_T). Since no order is specified, either value may be the first input. Note that the recovery coefficient need not be input at all if it equals 0.8.

STEP 5: Two things are accomplished during this step. The indicated air temperature (IT) is input in degrees Celsius and the calculator outputs the true air temperature in degrees Celsius.

STEP 6: This step, like step 3, tells you to skip to another step, in this case step 7.

STEP 7: This step is only executed if you came directly from step 3. Note that true air temperature is input in degrees Celsius and output in degrees Kelvin. (It is used in this form by the program.)

STEP 8: This step is both an input and a calculation step. Pressure altitude (PALT) is input. After the E key is pressed, density altitude (DALT) is displayed in feet.

STEP 9: This step tells how to proceed for a new case. For this program, starting at step 3 would assure proper program execution.

In addition to the user instruction form, each example problem has a set of keystrokes that show how it was solved. If you have trouble working the sample problems using the user instruction form, refer to the keystroke solution; however, do not attempt to use the keystroke solutions in place of the user instruction form. Many details of operation are not evident from the sample keystroke sequence.

The prerecorded magnetic cards supplied with Aviation Pac I will provide a considerable amount of prompting information by themselves. An asterisk on the left side of the card is a reminder to initialize by pressing RTN R/S. Arrows pointing to variables on the cards imply that the value is calculated by pressing the corresponding **A**, **B**, **C**, **D**, or **E** key. Sometimes values may be inputs or outputs. These values have arrows above them, pointing down. Usually, when values are both inputs and outputs they are associated with a calculate key labeled **CALC**. The calculate key must be pressed before the value can be calculated by pressing the key associated with it. *Flight Management,* AV1-2A, is an exception of this. In this program the machine considers an input of zero to be a calculate signal. All other values are stored.

In some cases, two values are input at once. Wind vectors are examples of this. A wind vector of 230 degrees and 7 knots would be input as 230.07 which is DDD.KK notation. The DDD stands for degrees, the KK stands for two decimal places of knots. Note that all places to the right of the decimal point, shown by letters, must be filled. In this case, the zero is inserted to hold the first decimal place since the wind speed is less than 10 knots.

Degrees, minutes, and seconds notation is used frequently in this pac. It is represented by DDD.MMSS, where DDD represents degrees, MM represents minutes, and SS represents seconds. H.MMSS is similar, but the H stands for hours.

SUPPLEMENTAL PROGRAMMING

As you have probably noticed, nine blank cards are supplied with your aviation pac. At least two of these cards will be needed for the "customized" programs. These are the *Customized Weight and Balance Program,* AV1-05A, and the *Customized Unit Conversions Program,* AV1-029A. Both of these programs allow you to store values on magnetic cards for easy access at some later time. After you have become more familiar with the use of Aviation Pac I, you may find other frequently used values that could be stored on a magnetic card for quick access. For instance, if you usually reference two particular VOR stations, you may want to write a program that will automatically store the distance and the heading between them in the appropriate registers for *Position By Two VOR's,* AV1-20A and *Navigation By Two VOR's,* AV1-21A. (Refer to the program listings at the back of the pac to find register usage.) You will probably be able to find other similar examples, and since pilots are tinkerers at heart, you will probably be writing complicated programs of your own in a short amount of time.

ENTERING A PROGRAM

From the card case supplied with this application pac, select a program card.

Set W/PRGM-RUN switch to RUN.

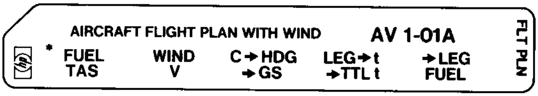
Turn the calculator ON. You should see 0.00

Gently insert the card (printed side up) in the right, lower slot as shown. When the card is part way in, the motor engages it and passes it out the left side of the calculator. Sometimes the motor engages but does not pull the card in. If this happens, push the card a little farther into the machine. Do not impede or force the card; let it move freely. (The display will flash if the card reads improperly. In this case, press [CLX] and reinsert the card.)

When the motor stops, remove the card from the left side of the calculator and insert it in the upper "window slot" on the right side of the calculator.

The program is now stored in the calculator. It remains stored until another program is entered or the calculator is turned off.

Aircraft Flight Plan with Wind



This program is used when making a flight plan which includes winds. It solves the wind triangle, giving correct values for airplane heading and ground speed. It works for multiple leg lengths, computing time for each leg, cumulative time, and fuel consumed for each leg. The program corrects reported winds from true heading to magnetic heading before using them in a calculation. The winds, true airspeed, fuel consumption, and magnetic variation can be altered on each leg of the flight. The equations used to compute the heading (HDG) and ground speed (GS) of the aircraft are

$$HDG = C + \sin^{-1} \frac{W}{TAS} \sin (D - C)$$

$$GS = TAS \cos (HDG - C) - W \cos (D - C)$$

where W is wind velocity, D is wind direction (magnetic), C is the aircraft course and TAS is the true airspeed.

Limits and Warnings

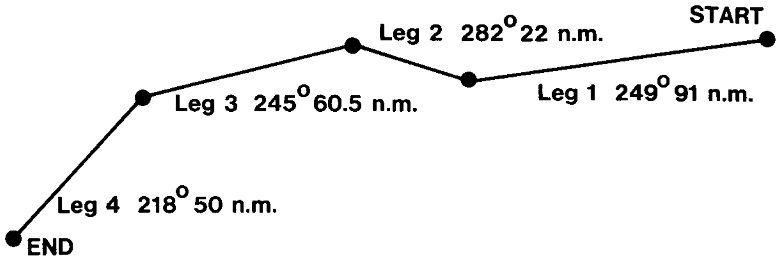
Wind must be less than 100 knots. Wind speed must not exceed true airspeed.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	
3	Input fuel consumption	FC (gal/hr)	A		FC
	then input true airspeed	TAS	A		TAS
4	Input wind*	DDD.KK	B		KK
	then magnetic variation				
	(+E, -W)	V	B		V
5	Input course and calculate				
	heading	C	C		HDG
	then calculate ground speed		C		GS
6	Input leg length and compute				
	leg time	leglength (n.m.)	D		H.MMSS**
	then display total time		D		H.MMSS
7	Calculate fuel used on leg		E		fuel (gal)
8	For next leg with same				
	fuel, TAS, wind, and				
	magnetic variation go to				
	step 5. To change fuel				
	go to step 3 and input new				
	value. To change wind go to				
	step 4 and input new value.				
	To change true air speed				
	go to step 3 input fuel				
	consumption then true air				
	speed. To change magnetic				
	variation go to step 4 input				
	wind then input magnetic				
	variation. For new case go				
	to step 2.				

*DDD.KK means direction, decimal point, wind speed. 325.08 means a direction of 325 degrees and a speed of 8 knots.

**H.MMSS means hours, decimal point, minutes, seconds. 2.0355 is 2 hours 3 minutes and 55 seconds.

Sample Problem



Winds for legs 1 and 2 – 230 degress @ 30 knots (true).
Winds for legs 3 and 4 – 300 degrees @ 20 knots (true).
Fuel consumption 8 gal/hr, TAS 105, magnetic variation 15 degrees E.

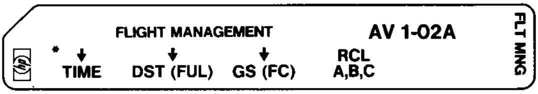
Solution

For the sketch above the following data table is completed (underlined values are input data).

Course/Steer	GS	Dist	Time/Total	Fuel
249/240	79	91	1:09:18/1:09:18	9.2
282/267	90	22	0:14:44/1:24:02	2.0
245/252	89	60.5	0:40:50/2:04:53	5.4
218/228	96	50	0:31:23/2:36:16	4.2

Keystrokes	**See Displayed**
RTN R/S 8 A 105 A 230.30 B 15 B 249 C	240
C	79
91 D	1.0918
D	1.0918
E	9.2
282 C	267
C	90
22 D	0.1444
D	1.2402
E	2.0
300.20 B 245 C	252
C	89
60.5 D	0.4050
D	2.0453
E	5.4
218 C	228
C	96
50 D	0.3123
D	2.3616
E	4.2

Flight Management



This program calculates either time flown, distance flown or ground speed using the other two variables as inputs. Since the equations are analogous, fuel consumed, fuel consumption or time flown can also be calculated if two of the values are known. The program is very useful in calculating ETA and fuel reserves from in-flight data.

TIME = DIST/GS
DIST = GS x TIME
GS = DIST/TIME
FUEL = FC x TIME
FC = FUEL/TIME
TIME = FUEL/FC

where

DIST is distance flown, GS is ground speed, and FC is fuel consumption

Limits and Warnings

Fuel consumption and fuel must be in compatible units; i.e., gal/hr and gal, or liters/hr and liters. GS and DIST must be in compatible units; i.e., knots and nautical miles, or miles/hr and miles.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	0.00
3	For time-distance calculations				
	go to step 6				
4	Input two of the following				
	time (H.MMSS)*	time	A		0.00
	fuel consumed	fuel	B		0.00
	fuel consumption per hr.	FC	C		0.00
5	Compute the remaining value **				
	time (H.MMSS)		A		time
	or fuel consumed		B		fuel
	or fuel consumption		C		FC

6	Input two of the following		[ ] [ ]	
	time (H.MMSS)	time	[A] [ ]	0.00
	distance	DIST	[B] [ ]	0.00
	ground speed	GS	[C] [ ]	0.00
7	Compute the remaining value **		[ ] [ ]	
	time (H.MMSS)		[A] [ ]	time
	or distance		[B] [ ]	DIST
	or ground speed		[C] [ ]	GS
8	For new case change		[ ] [ ]	
	appropriate inputs in step 4		[ ] [ ]	
	or 6.		[ ] [ ]	
9	To recall values in the order		[ ] [ ]	
	they appear on card		[D] [ ]	value

*H.MMSS means hours, decimal point, minutes, seconds. 2.0355 is 2 hours 3 minutes and 55 seconds.

**A zero must be in the display before step 5 or 7 can be performed.

Sample Problem

A 380 nautical mile flight will be made at an estimated ground speed of 105 knots. The fuel consumption is 8 gal/hr. Find the estimated time for the flight and fuel consumed.

Solution

Time = 3 hrs, 37 min, 8 seconds
Fuel Consumed = 28.95 gal

Keystrokes	See Displayed
RTN R/S 380 B 105 C A	3.3708
8 C B	28.95

Predicting Freezing Levels

The program computes the theoretical freezing level in feet above mean sea level, from altitude and temperatures in either fahrenheit or Celsius and computes the freezing level in both clouds (wet lapse rate of 1.5 degrees Celsius per 1000 feet) and in clear weather (dry lapse rate of 2 degrees Celsius per 1000 feet).

This program computes the freezing level from

$$FLD = Alt + 1000\,(T/2) \text{ (Freezing level dry)}$$
$$FLW = Alt + 1000\,(T/1.5) \text{ (freezing level wet)}$$

where temperature (T) is in degrees Celsius and altitude (Alt) is in feet or

$$FLD = Alt + 1000\left(\frac{T-32}{3.6}\right)$$

$$FLW = Alt + 1000\left(\frac{T-32}{2.7}\right)$$

where temperature (T) is in degrees fahrenheit.

Limits and Warnings

The actual lapse rate may differ from the standard lapse rate used in this program. This is especially true within 2000 feet of the ground where inversions are common. Also, the program does not give the correct answer when the atmosphere between you and the freezing level contains layers of clouds. When in doubt compute both wet and dry freezing levels and use the more pessimistic value.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	0.00
3	Input altitude	feet	[C] [ ]	
	and corresponding tempera-		[ ] [ ]	
	ture in °C	°C	[A] [ ]	
	or °F	°F	[B] [ ]	
4	Calculate either or both		[ ] [ ]	
	dry freezing level		[D] [ ]	feet
	or wet freezing level		[E] [ ]	feet
5	To recall input temperature		[R/S] [ ]	T
6	Go to step 3 for new case		[ ] [ ]	

Sample Probem

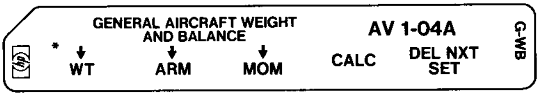
If the outside air temperature is –9 degrees centigrade at 8000 feet, how high is the wet freezing level?

Solution

Altitude = 2000 feet

Keystrokes	See Displayed
RTN R/S 9 CHS A 8000 C E	2000

General Aircraft Weight and Balance



The program calculates the final values of gross weight and moment or gross weight and center of gravity that are used to determine your position in the weight-balance envelope furnished with your aircraft. The program will accept either weights and moments or weights and moment arms for inputs. The program is written to accommodate changes in loading without restarting from the beginning.

The center of gravity is computed by dividing the sum of the moments by the gross weight.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	0.00
3	Input weight	weight	A		Sum Wt
4	Input either the moment arm	arm	B		Sum Mt
	or the moment	mom	C		Sum Mt
5	Repeat steps 3, 4 until all				
	weights and moments have				
	been input.				
6	Calculate the following				
	sum of weights		D	A	Sum Wt
	or center of gravity		D	B	c.g.
	or sum of moments		D	C	Sum Mt
7	To delete the last set of weight-				
	arm or weight-moment data				
	points		R/S		0.00
8	To delete any set of data points				
	press **E**, then perform		E		
	steps 3 and 4, inputing the				
	data which is to be deleted.				
	(**E** must be pressed before				
	each data pair to be deleted).				

Sample Problem

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

Item	Weight	Arm	Moment
Empty plane	1200		15000
Pilot	180	11.25	
Passenger	110	41	
Oil	15		–500
Fuel	120	25	

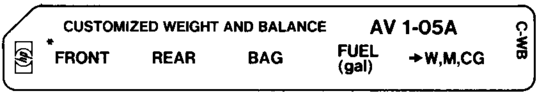
Find the gross weight, total moment and center of gravity.

Solution

Weight = 1625
Center Gravity = 14.79
Moment = 24,035

Keystrokes	See Displayed
RTN R/S 1200 A 15000 C 180 A 11.25 B	
110 A 41 B 15 A –500 C 120 A 25 B	
D A	1625
D B	14.79
D C	24,035

Customized Weight and Balance



The weight and balance of a two-or four-place light aircraft are easily calculated using this program and a constant card. This program is for aircraft with a maximum of four load-carrying compartments. An aircraft with a front and rear seat, one fuel tank, and one baggage compartment is the limit of complexity allowed. For larger aircraft use *General Aircraft Weight and Balance,* AV1-04A.

The constant card is programmed by you, for your aircraft. It stores values relevant to your aircraft in the HP-65 for use by the *Customized Weight and Balance* program. Once the constant card is created, the only values which must be keyed into the HP-65 are the weights of the front seat passengers, the weights of the rear seat passengers, the weights of the baggage, and the gallons of fuel to be carried.

DIRECTIONS FOR THE CONSTANTS CARD

To start, please fill in the "value of item" column in Table I. The entries will be the constants for your airplane and will be stored in the registers shown. First, compute empty weight and empty moment for your airplane. This is the sum of the licensed empty weight plus oil, unusable fuel, manuals, etc. and the sum of their respective moments. It is *NOT* the "licensed empty weight and balance" found on your offical weight and balance form. The entry on Line 1 must include everything except the following: pilot and front passenger, rear passengers, baggage, and fuel. Normally, aircraft manuals list moment arms. If your airplane manual does not list the moment arms, they may be calculated from the aircraft loading diagram. An example of this calculation is included in the example problem.

TABLE I

Line	Item	Value of Item	Storage Register
1	Empty Weight (pounds)		STO 1
2	Empty moment (inch pounds)		STO 2
3	Length of front seat moment arm (inches)		STO 3
4	Length of rear seat moment arm (inches)*		STO 4
5	Length of baggage moment arm (inches)		STO 5
6	Length of fuel moment arm (inches)		STO 6

*If your aircraft does not have a rear seat input a zero in line 4.

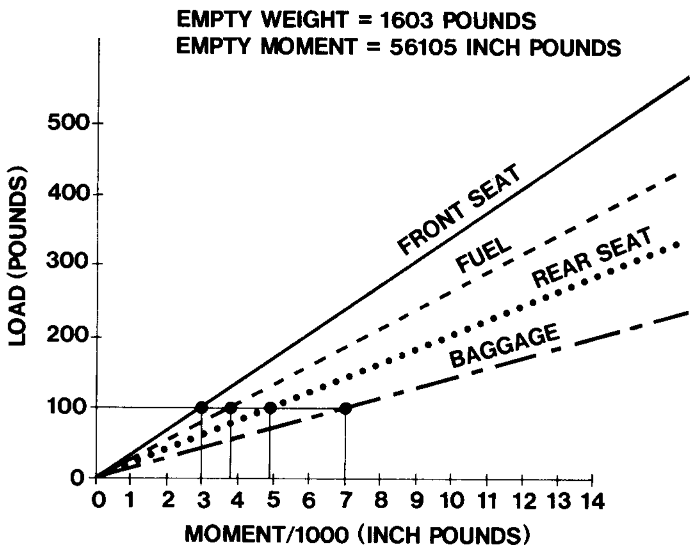
You are now ready to prepare your magnetic card.

1. Turn on the HP-65
2. Place the W/PRGM–RUN switch in W/PRGM position.
3. Press [f] [PRGM] to clear existing programs. (00 00 should appear in the display).
4. Press [LBL] [A] to associate your constants program with the [A] key.
5. Key in the sequence of numbers from the "value of item" column of Table I separated by the appropriate store command from the "storage register" column. (For example, if the first two lines were 1657, [STO] [1] and 18113 [STO] [2] you would key in [1] [6] [5] [7] [STO] [1] [1] [8] [1] [1] [3] [STO] [2] etc. The last two keys would be [STO] [6].)
6. Key in [RTN] to indicate the end of your program.
7. Take one of the blank magnetic cards in your card case and enter it into the lower slot. You have just recorded your constants for later use. The display should read 00 00 but the program is still in the HP-65.

8. Switch to RUN position.
9. Press **A**. Your constants are now stored in registers 1 through 6. Verify this by recalling and checking the numbers.
10. Try a sample loading of your aircraft using the constant card you have just made and the pre-recorded customized weight and balance card. Follow the User Instruction Form.
11. Until you clip the corner on the card you can change constants. When you are satisfied that everything is correct, clip the corner of the card.
12. Write the aircraft number on the card so that the card can be readily identified.

Sample Problem

Most aircraft manuals will include a table of moment arms and it will not be necessary to calculate them. However, this example shows how to calculate the moment arms from the loading diagram.



Assume a weight of 100 pounds. Find the intersections of the 100 pound line and the front seat, rear seat, fuel, and baggage lines. Look up the corresponding moments. In this case:

Front = 3000 inch pounds
Fuel = 3800 inch pounds

Rear = 4900 inch pounds
Baggage = 6900 inch pounds

Divide these values by 100 pounds and you have a complete Table I for the sample aircraft.

Line	Item	Value of Item	Storage Register
1	Empty weight (pounds)	1603	STO 1
2	Empty moment (inch pounds)	56105	STO 2
3	Length of front seat arm (inches)	30	STO 3
4	Length of rear seat arm (inches)	49	STO 4
5	Length of baggage moment arm (inches)	69	STO 5
6	Length of fuel moment arm (inches)	38	STO 6

Turn on the HP–65, switch to W/PRGM mode and put the tabulated values into the HP–65's memory using the following keystroke sequence:

[f] [PRGM] [LBL] [A] 1603 [STO] [1] 56105 [STO] [2] 30 [STO] [3]
49 [STO] [4] 69 [STO] [5] 38 [STO] [6] [RTN]

Now enter a blank card into the HP–65. The constants have been recorded for use in the following loading solution. Do *not* clip the corner of the card. It can be used over for a real case if the corner is not clipped. Switch back to RUN mode.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter constant card				
2	Store constants		A		
3	Enter *Customized Weight and*				
	Balance				
4	Initialize		RTN	R/S	Empty Wt
5	Input the following *				
	front seat weight(s)	pounds	A		pounds
	rear seat weight(s)	pounds	B		pounds
	baggage weight(s)	pounds	C		pounds
	fuel in gallons	gallons	D		pounds
6	Calculate total weight		E		pounds
7	Calculate total moment		E		in-lbs
8	Calculate center of gravity		E		inches
9	For new case go to step 1				

*The last input can be deleted by pressing R/S. To delete any input, key in weight (or gallons of fuel) as a negative value and go to step 5.

Part 1. The pilot of the sample aircraft weights 170 pounds, the front seat passenger 120 pounds, the rear seat passenger 200 pounds, the baggage 27 pounds, and thirty gallons of fuel are to be carried. What are the values of the weight, moment and center of gravity of the sample aircraft?

Weight = 2300.00 pounds
Moment = 83308.00 inch pounds
c.g. = 36.22 inches

Part 2. Assume the aircraft limits are:

Weight = 2400 pounds
Moment = 82,000 inch pounds
c.g. = 37 inches

The moment calculated is too large. This means that weight must be shifted forward. To determine how much must be moved take the difference in moments and divide by the difference in arms. In this case

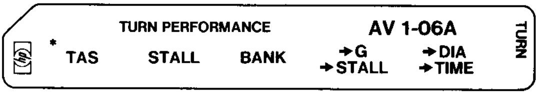
$$\frac{83{,}308 - 82{,}000}{69 - 30} = 33.54 \text{ pounds}$$

Since only 27 pounds of baggage are being carried, moving the baggage will not quite be enough. Additional shifts must also be done. Make sure by shifting the baggage using the program.

Weight = 2300.00 pounds
Moment = 82255.00 inch pounds
c.g. = 35.76 inches

Keystrokes	**See Displayed**
Enter sample card in RUN mode	
[A]	38
Enter *Customized Weight and Balance*	
[RTN] [R/S] 170 [A] 120 [A] 200 [B] 27 [C] 30 [D] [E]	2300
[E]	83308
[E]	36.22
83308 [ENTER↑] 82000 [−] 69 [ENTER↑] 30 [−] [÷]	33.54
27 [CHS] [C] [CHS] [A] [E]	2300.00
[E]	82255.00
[E]	35.76

Turn Performance



This program calculates the G-force, turn diameter, time required to complete a 360° turn, and stall speed for an airplane as a function of an aircraft's bank angle, airspeed and normal stall speed.

$$G = \frac{1}{\cos(\text{bank})}$$

$$\text{Diameter} = \frac{TAS^2}{34208 \tan(\text{bank})}$$

$$\text{time} = \frac{0.0055\ TAS}{\tan(\text{bank})}$$

$$\text{stall} \doteq (\text{normal stall})\sqrt{G}$$

Limits and Warnings

All values assume coordinated turns and no vertical accelerations. Gusty conditions will alter the calculated results significantly.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		RTN R/S	
3	Input all of the following			
	true airspeed	knots	A	knots
	normal stall speed	knots	B	knots
	degrees of bank	degrees	C	degrees
4	Calculate acceleration		D	G
	then turn stall speed		D	knots
	Calculate turn diameter		E	n.m.
	then time of turn		E	M.SS*
5	For new case go to step 3 and			
	change appropriate inputs			

*The display M.SS means minutes, decimal point, seconds. 2 minutes seven seconds is displayed 2.07.

Sample Problem

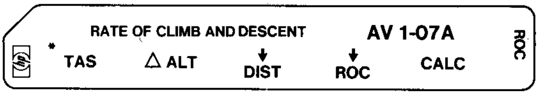
Calculate the G-force, diameter of turn, time required for a 360° turn, and stall speed for an aircraft in a 30° and 45° bank with a cruising speed of 115 knots and a stall speed of 60 knots.

Solution

Bank	G	stall	Diameter	time
30°	1.15	64.47 Knots	0.67 n.m.	1 min 5 sec
45°	1.41	71.35 Knots	0.39 n.m.	38 sec

Keystrokes	See Displayed
RTN R/S 115 A 60 B 30 C D	1.15
D	64.47
E	0.67
E	1.05
45 C D	1.41
D	71.35
E	0.39
E	0.38

Rate of Climb and Descent



The inputs of this program are true airspeed (TAS), elevation change (Δ ALT), and either rate-of-climb (ROC) or the distance (DIST) over which the elevation change is to occur. Outputs are rate-of-climb required to change elevation in the specified distance or, conversely, the distance required when the rate-of-climb is specified.

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

$$D = \frac{TAS\,\Delta\,ALT}{60\,ROC}$$

$$DIST = \sqrt{D^2 - (\Delta\,ALT)^2}$$

Limits and Warnings

Constant airspeed must be maintained throughout change of altitude. No correction is made for decreased aircraft performance at increased altitude. Inputs for ROC and TAS should be conservative, average values.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		RTN R/S	0.00
3	Input the following:			
	true airspeed	TAS (knots)	A	TAS
	and altitude change	ΔALT (ft)	B	ΔALT
	and either distance	DIST (n.m.)	C	DIST
	or rate-of-climb/descent	ROC (ft/min)	D	ROC
4	Calculate either distance		E C	DIST (n.m.)
	or rate-of-climb/descent		E D	ROC (ft/min)
5	Go to step 3 to change any			
	values for recomputation in			
	step 4.			

Sample Problems

1. 15 n.m. west of Las Vegas (El. 2600 ft) lies a mountain pass having an elevation of 6600 ft. Assuming a climbout TAS of 80 knots, what is the minimum ROC that you must maintain if you wish to clear the pass by 1000 ft?

2. Assume that a different aircraft climbs out at 800 ft/min. and maintains an airspeed of 120 knots. How far from the pass will it be when it is at 7600 ft?

Solutions

1. 443.79 ft/min
2. 2.47 n.m.

Keystrokes	See Displayed
1. [RTN] [R/S] 80 [A] 5000 [B] 15 [C] [E] [D]	443.78
2. [RTN] [R/S] 120 [A] 5000 [B] 800 [D] [E] [C]	12.47
[CHS] 15 [+]	2.53

Head Winds and Cross Winds

This program calculates both the head wind and cross wind components from the aircraft heading and reported winds. The program works both at altitude, where magnetic variation must be considered, and at landing and takeoff, where winds are reported in magnetic directions rather than true directions.

The head wind (HW) and right cross wind (RCW) components are computed from

$$HW = K \cos (D - HDG - V)$$

$$RCW = K \sin (D - HDG - V)$$

where

K = the reported wind velocity
D = the reported wind direction
HDG = the aircraft heading
V = the magnetic variation

Limits and Warnings

Reported winds must be less than 100 knots.

Wind directions reported by the control tower are magnetic and the variation need not be input when using the program for takeoff and landings. Other wind directions are reported in true directions and variation must be included to find the wind components.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	0.00
3	If winds are surface winds, go		[ ] [ ]	
	to step 4; if not, input		[ ] [ ]	
	variation (+E, –W)	V(deg)	[A] [ ]	V
4	Input both airplane heading	HDG (deg)	[B] [ ]	HDG
	and reported winds	DDD.KK*	[C] [ ]	DDD.KK
5	Calculate either or both of the		[ ] [ ]	
	following: headwind		[D] [ ]	knots
	right crosswind		[E] [ ]	knots
	NOTE: negative answers mean		[ ] [ ]	
	tailwind or left crosswind		[ ] [ ]	
6	To change any inputs go to		[ ] [ ]	
	step 3 and change only the		[ ] [ ]	
	variables affected.		[ ] [ ]	

*DDD.KK means direction, decimal point, wind speed. 325.08 means a direction of 325 degrees and a speed of 8 knots.

Sample Problems

1. At takeoff on runway 28 the winds are reported as 240° at 25 knots. What are the head wind and cross wind components?

2. At altitude the wind is reported as 160° and 40 knots. Your magnetic heading is 270°. What are the head wind and cross wind components if the magnetic variation is 15° east?

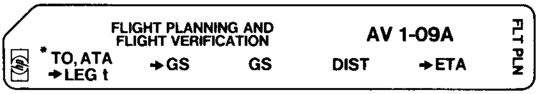
Solutions

1. 19.15 knots (head wind); – 16.07 knots (left cross wind)

2. –22.94 knots (tail wind); –32.77 knots (left cross wind)

Keystrokes	**See Displayed**
1. RTN R/S 280 B 240.25 C D	19.15
E	–16.07
2. RTN R/S 270 B 160.40 C 15 A D	–22.94
E	–32.77

Flight Planning and Flight Verification



This program can be used for flight planning and updating the flight plan as it is being flown. The program computes ETA's, ground speeds, cumulative distance flown, actual times for each leg and cumulative time flown. The ground speeds can be changed for each leg.

$$ETA = DIST/GS + TO$$
$$GS = DIST/(ATA - TO)$$

where

ETA = estimated time of arrival
DIST = distance
GS = ground speed
TO = take off time (or time over last checkpoint)
ATA = time over current checkpoint

Limits and Warnings

Distances and speeds must be in compatible units (knots and n.m., or mph and miles). Ground speeds are rounded in the display to the nearest whole unit. They are carried internally to full significance.

Flight planning and flight verification are identical except that: (1) flight planning usually assumes that the take-off time is 0.00, and (2) flight planning accepts the calculated ETA as the ATA at the checkpoint.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program		[ ]	[ ]	
2	Initialize		[RTN]	[R/S]	
3	Input take off time (usually 0		[ ]	[ ]	
	for flight planning)	H.MMSS*	[A]	[ ]	
4	Input ground speed	GS (knots)	[C]	[ ]	GS
5	Input leg length and read		[ ]	[ ]	
	cumulative distance	eg length (n.m.)	[D]	[ ]	total dist (n.m.)
6	Calculate ETA		[E]	[ ]	H.MMSS
7	Input ATA and read leg time.	H.MMSS	[A]	[ ]	H.MMSS
	(for flight planning do not		[ ]	[ ]	
	input ETA, just press [A]).		[ ]	[ ]	
8	To read out total elapsed time		[ ]	[ ]	
	to checkpoint press [R/S]		[R/S]	[ ]	H.MMSS
9	To calculate GS on the last leg		[B]	[ ]	GS (knots)
10	To use calculated GS for the		[ ]	[ ]	
	next leg press [C] and go		[ ]	[ ]	
	to step 5		[C]	[ ]	
11	If you wish to change the GS for		[ ]	[ ]	
	the next leg go to step 4.		[ ]	[ ]	
12	To use the same ground speed		[ ]	[ ]	
	for the next leg as you used		[ ]	[ ]	
	on the last leg, go to step 5		[ ]	[ ]	

***H.MMSS means hours, decimal point, minutes, seconds. 2.0355 is 2 hours 3 minutes and 55 seconds.**

Sample Problem

Part 1 – Flight Plan A flight consists of the following 3 legs:

	Ground speed	Distance
Leg 1	80K	20 n.m.
Leg 2	105K	53 n.m.
Leg 3	105K	41 n.m.

Make a flight plan showing the individual leg times, cumulative times, and distances at the end of each leg.

Solution	Total Distance	Total Time	Leg Time
Leg 1	20	:15:00	:15:00
Leg 2	73	:45:17	:30:17
Leg 3	114	1:08:43	:23:26

Part 2 – Flight Verification

Assume that the actual flight was flown with a take off time of 10:17:00. Assume that the actual times of arrival at the checkpoints were 10:31:10, 11:01:10 and 11:23:50. Find the ETA's at each checkpoint using 80 knots as the ground speed for the first leg. After finding the acutal ground speed for the first leg, assume that the difference between actual and estimated speeds is the wind velocity. Add the winds to the 105 knots assumed GS for leg 2. Use the GS calculated for leg 2 as the assumed GS for leg 3.

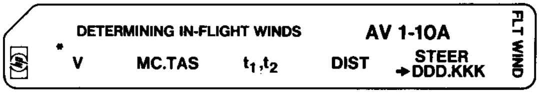
Compute ETA's for each checkpoint, actual leg times, cumulative time and actual ground speed for the flight.

Solution	ETA	Actual leg time	Cumulative time	Calculated ground speed
Leg 1	10:32:00	14:10	14:10	85
Leg 2	11:00:04	30:00	44:10	106
Leg 3	11:24:22	22:40	1:06:50	109

Keystrokes	See Displayed
1. RTN R/S 0 A 80 C 20 D	20
E	0.1500
A	0.1500
105 C 53 D	73
E	0.4517
A	0.3017
105 C 41 D	114
E	1.0843
A	0.2326

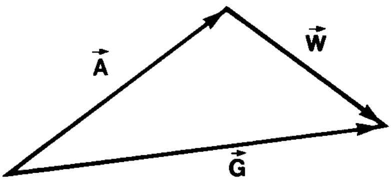
2.	RTN R/S 10.17 A 80 C 20 D E	10.32
	10.3110 A	0.1410
	R/S	0.1410
	B	85
	110 C 53 D	73
	E	11.0004
	11.0110 A	0.3000
	R/S	0.4410
	B	106
	C 41 D	114
	E	11.2422
	11.2350 A	0.2240
	R/S	1.0650
	B	109

Determing In-Flight Winds



This program computes the winds at altitude from TAS, course of aircraft, ground speed and heading. Ground speed is automatically calculated from time-distance inputs. Winds can be computed as either magnetic or true. The latter must be used when verifying wind forecasts by the weather bureau. The program allows continuous updating of winds.

This program solves the wind triangle shown below.



OR $\vec{A}+(\vec{W})=\vec{G}$

$\vec{W}=\vec{G}-\vec{A}$

$\vec{W}$, $\vec{A}$ and $\vec{G}$ are all vector quantities representing wind direction and speed; TAS and heading; and ground speed and course respectively.

Since both $\vec{A}$ and $\vec{G}$ use magnetic directions, $\vec{W}$ is computed as a magnetic direction. It must be corrected to true heading by adding the variation (V).

True wind direction = magnetic wind direction + V

Limits and Warnings

Winds must be less than 1000 mph.

Airspeeds less than 100 knots must be input with leading zeros—see step 4 on user instruction form.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	0.0000
3	To obtain true winds rather				
	than magnetic winds input				
	variation (+E, – W)	V(deg)	A		V
4	Input all of the following:				
	MAG course and TAS	DDD.KKK*	B		TAS
	and time at first checkpoint	t_1,(H.MMSS**)	C		H.MMSS
	and distance to next check-				
	point	n.m.	D		H.MMSS
	and time at 2nd checkpoint	t_2,(H.MMSS)	C		H.MMSS
5	To calculate wind, input head-				
	ing of airplane required to				
	fly course	steer(deg)	E		DDD.KKK
6	To change any variable except				
	time over first checkpoint				
	change the variable(s) and				
	go to step 5.				
7	To change time over first check-				
	point go to step 2.				

*DDD.KK means direction, decimal point, wind speed. 325.08 means a direction of 325 degrees and a speed of 8 knots.

**H.MMSS means hours, decimal point, minutes, seconds. 2.0355 is 2 hours 3 minutes and 55 seconds.

Sample Problem

After passing over a checkpoint at 3:05:20 a pilot flying a magnetic course of 150° finds that he must apply 15° right correction; i.e., steer 165° to maintain his ground course. He passes over his next checkpoint 70 n.m. away at 3:40:20. The TAS of his airplane is 110 knots and the variation is 7.5° east. If the local FSS asked him to report the winds, what would he tell them?

Solution

273° at 32 knots.

Keystrokes	See Displayed
RTN R/S 7.5 A 150.110 B 3.0520 C 70 D	
3.4020 C 165 E	273.032

Standard Atmosphere

STANDARD ATMOSPHERE (0-36089) AV 1-11A1 ATM 1
* PALT →T(°C) →a/a_0 →P/P_0 →ρ/ρ_0

STANDARD ATMOSPHERE (36089-82000) AV 1-11A2 ATM 2
* PALT →T(°C) →a/a_0 →P/P_0 →ρ/ρ_0

This two card program can be used to estimate atmospheric conditions from pressure altitude (PALT). It should be remembered that this is only an approximation based on average conditions.

The outputs, with the exception of temperature, are ratios of standard sea level conditions. For instance, if the pressure ratio (P/P_0) is found to be 0.7375 and standard conditions are 29.92 inches of mercury the pressure (P) is the product of 29.92 and 0.7375 or 22.07 inches of mercury. Some standard sea level condition commonly used by pilots are

Pressure→ P_0 = 29.92 in Hg = 14.696 psi

Speed of Sound→a_0 = 661.51 knots = 1116.4 ft/sec

Density→ ρ_0 = 0.002378 lb sec^2/ft^4

From 0 to 36089 feet the following relations hold

$$T(^\circ C) = 15\ 1.981 \times 10^{-3}\ h$$

$$a/a_0 = \sqrt{T/T_0}\ ;\ T_0 = 288.15\ K$$

$$P/P_0 = \left[\frac{T_0 - 1.981 \times 10^{-3}\ h}{T_0}\right]^{5.2563}$$

$$\rho/\rho_0 = \frac{P}{P_0}\ \frac{T_0}{T}$$

For altitudes between 36,089 feet and 82,000 feet, the following relations hold

$$T = -56.5\ ^\circ C$$

$$a/a_0 = 0.8671$$

$$P/P_0 = 0.2234\ e^{-\left(\frac{h-36089}{20804.9}\right)}$$

$$\rho/\rho_0 = \frac{P}{P_0}\ \frac{288.15}{216.65}$$

where

T is temperature in degrees centigrade
a is speed of sound
P is pressure
ρ is density
h is pressure altitude

Limits and Warnings

Card 1 is valid from 0 to 36089 feet, card two is valid from 36089 feet to 82,000 feet. There is disagreement among reference sources above 36,000 feet and below 2000 feet.

Reference:

Chemical Rubber Company Handbook, of Chemistry and Physics, 47th edition, 1966–1967, page F–120

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program (card 1 for		[ ] [ ]	
	pressure altitudes below		[ ] [ ]	
	36,089 feet and card 2 for		[ ] [ ]	
	pressure altitudes of 36,089		[ ] [ ]	
	feet and above)		[ ] [ ]	
2	Initialize		[RTN] [R/S]	
3	Input pressure altitude*	PALT	[A] [ ]	PALT
4	Compute any or all of the		[ ] [ ]	
	following: temperature		[B] [ ]	T (°C)
	speed of sound ratio		[C] [ ]	a/a_0
	pressure ratio		[D] [ ]	P/P_0
	density ratio		[E] [ ]	ρ/ρ_0
5	For new case in same altitude		[ ] [ ]	
	range go to step 3		[ ] [ ]	

*Flashing zeros indicate use of wrong card.

Sample Problems

1. What is the temperature and speed of sound at 27,000 feet assuming a standard atmosphere?

2. What is the density at 70,000 feet assuming a standard atmosphere?

Solutions

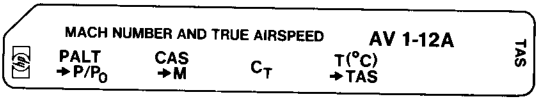
1. T = 38.49 °C

   a/a_0 = 0.90 which yields 596.97 knots for the speed of sound.

2. ρ/ρ_0 = 0.06 which yields a density of 1.38×10^{-4} lb sec^2/ft^4

Keystrokes		See Displayed
1.	(card 1)	
	RTN R/S 27000 A B	–38.49
	C	0.90
	661.51 ×	596.97
2.	(card 2)	
	RTN R/S 70000 A E	0.06
	.002377 × DSP 2	1.38×10^{-4}

Mach Number and True Airspeed



This program converts calibrated airspeed (CAS) to mach number and true airspeed (TAS). Pressure altitude (PALT) must be known to calculate mach number (M). Aircraft recovery coefficient (C_T) and indicated air temperature (IT) must also be known to calculate true airspeed. The recovery coefficient varies from 0.6 to 1.0 but is around 0.8 for most aircraft.

$$\text{Pressure ratio}\left(\frac{P}{P_0}\right) = \left[\frac{518.67 - 3.566 \times 10^{-3}\ \text{PALT}}{518.67}\right]^{5.2563}$$

$$M^2 = 5\left[\left(\frac{P_0}{P}\left\{\left[1 + 0.2\left(\frac{\text{CAS}}{661.5}\right)^2\right]^{3.5} - 1\right\} + 1\right)^{0.286} - 1\right]$$

$$\text{TAS} = 39M\sqrt{(\text{IT} + 273)\left[C_T\left(\frac{1}{(1 + 0.2\,M^2)} - 1\right) + 1\right]}$$

Limits and Warnings

Accuracy degenerates for mach numbers in excess of one.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program*				
2	Input pressure altitude	PALT	A		P/P_0
3	Input calibrated airspeed in				
	knots and calculate mach				
	number	CAS	B		M
4	Input recovery coefficient				
	(.8 for most aircraft)	C_T	C		C_T
5	Input indicated air temperature				
	and calculate true airspeed				
	in knots	IT (°C)	D		TAS
6	For same aircraft at same				
	PALT go to step 3 and skip				
	step 4. For different PALT go				
	to step 2 and skip step 4. For				
	totally new case go to step 2.				

*For pressure altitudes above 36089 feet, calculate P/P_0 using *Standard Atmosphere,* AV1-11A2 (Card 2) and skip step 2 of these instructions.

Sample Problems

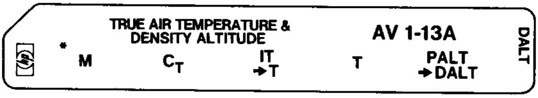
1. For a pressure altitude of 25,500 feet, a calibrated airspeed of 350 knots, a recovery factor of 0.8, and an indicated air temperature of 5 degrees Celsius, what is the flight mach number and the true airspeed?
2. For a pressure altitude of 40,000 feet with all other data unchanged, what is the mach number and the true airspeed?

Solutions

1. M = 0.84
   TAS = 515.76 knots
2. M = 1.10
   TAS = 657.42 knots

Keystrokes		See Displayed
1.	25500 **A** 350 **B**	0.84
	.8 **C** 5 **D**	515.76
2.	Enter *Standard Atmosphere* (Card 2)	
	40000 **A** **D**	0.19
	Enter *Mach Number and True Airspeed*	
	350 **B**	1.10
	.8 **C** 5 **D**	657.42

True Air Temperature and Density Altitude



This program accounts for the compressibility effects of high speed flight. Given the mach number (M) (which can be calculated using *Mach Number and True Airspeed*, AV1–12A) and the aircraft recovery coefficient (C_T = 0.8 for most aircraft), indicated air temperature (IT) is converted to true air temperature (T). True air temperature and pressure altitude are then converted to density altitude. For low flight mach numbers, compressibility effects are small. In such cases only temperature and pressure altitude (PALT) are needed to calculate density altitude (DALT).

$$T(K) = C_T \left(\frac{IT(K)}{0.205\ M^2 + 1} - IT \right) + IT(K)$$

$$DALT = 145366 \left[1 - \left(\frac{\rho}{\rho_0} \right)^{0.235} \right]$$

where

$$\frac{\rho}{\rho_0} = \frac{288.15}{T(K)} \left[1 - 6.876 \times 10^{-6}\ PALT \right]^{5.256}$$

Limits and Warnings

The program is limited to altitudes under 36089 feet.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	0.80
3	If you know the true air				
	temperature go to step 7				
4	Input the following:				
	mach number	M	A		M
	recovery coefficient (if				
	different from 0.8)	C_T	B		C_T
5	Input indicated air temperature				
	and calculate true air tempera-				
	ture	IT (°C)	C		T (°C)
6	Go to step 8				
7	Input true air temperature	T (°C)	D		T (K)
8	Input pressure altitude and				
	calculate density altitude	PALT	E		DALT (ft)
9	For new case go to step 3				

Sample Problems

1. M = 0.87
   C_T = 0.80
   IT = 8 °C
   PALT = 10,000 ft

2. For a low speed aircraft

   T = 12°C
   PALT = 9,000 ft

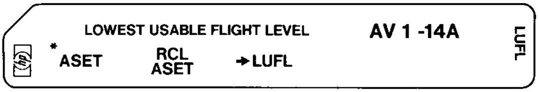
Solutions

1. T = –22.21 °C
   DALT = 7852.96 ft

2. DALT = 10,703.11 ft

Keystrokes	**See Displayed**
1. RTN R/S .87 A 8 C	–22.21
10000 E	7852.96
2. 12 D 9000 E	10703.11

Lowest Usable Flight Level



This program computes the lowest usable flight level for aircraft flying above 18,000 feet mean sea level (MSL) from the current altimeter setting.

For flights operating at altitudes in excess of 18,000 feet the altimeter is set at 29.92 and aircraft are assigned flight levels. In order to avoid overlapping flight levels with true altitude above sea level, the lowest usable flight level is found at which a setting of 29.92 will place the aircraft above 18,000 feet MSL.

The lowest usable flight level is 18,000 feet if the altimeter setting is greater than or equal to 29.92 inches of mercury (Hg).

For altimeter settings below 29.92

$$LUFL = 18{,}000 + 500 \times INT\,(60.82 - 2 \times ASET)$$

where

ASET = altimeter setting
INT = integer function

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		RTN R/S	0.00
3	Input altimeter setting	in Hg	A	in Hg
4	Calculate lowest usable flight			
	level		C	LUFL (ft)
5	For new case go to step 3			
6	To recall altimeter setting		B	in Hg

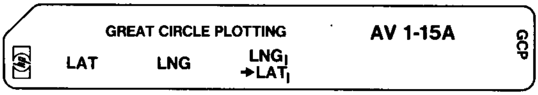
Sample Problem

For the following altimeter settings, find the lowest usable flight level.

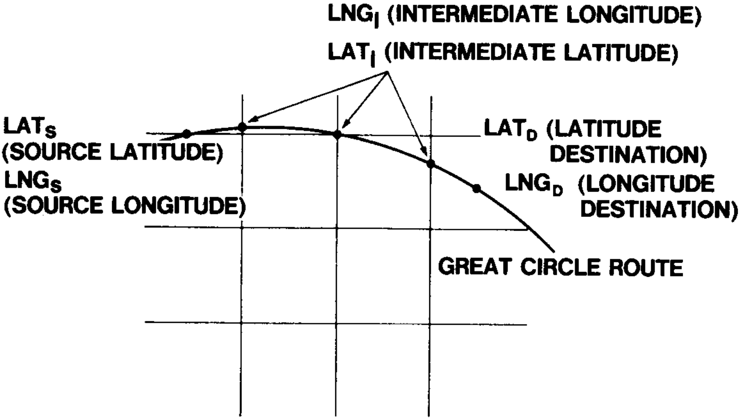
ASET	ANSWER
29.92	18,000
29.55	18,500
28.45	19,500

Keystrokes	See Displayed
RTN R/S 29.92 A C	18000
29.55 A C	18500
28.45 A C	19500

Great Circle Plotting



Given the latitude and longitude of two points on the globe and an intermediate longitude, this program calculates the latitude corresponding to the intersection of the great circle route and the intermediate longitude.



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

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

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

Limits and Warnings

No leg may pass exactly half way around the earth, and lines of longitude may not be plotted.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Input source latitude*	DDD.MMSS**	A		degrees
	and longitude	DDD.MMSS	B		degrees
3	Input destination latitude	DDD.MMSS	A		degrees
	and longitude	DDD.MMSS	B		degrees
4	Input an intermediate longitude				
	and calculate the corresponding				
	latitude	DDD.MMSS	C		LAT (degrees)
5	For new intermediate point go				
	to step 4, for new case go to				
	step 2.				

*Southern latitudes and eastern longitudes are expressed as negative values.

**DDD.MMSS means degrees, decimal point, minutes and seconds. 320.0713 is 320 degrees, 7 minutes and 13 seconds.

Sample Problem

On a flight from St. Helena to Bermuda, what is the latitude at 35° 17′ west longitude?

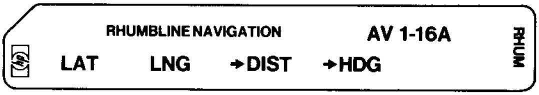
	LAT	LNG
St. Helena	15° 55′ S	5° 44′ W
Bermuda	32° 19′ N	64° 51′ W

Solution

$LAT_I = 11° 17' N$

Keystrokes	See Displayed
15.55 CHS A 5.44 B 32.19 A 64.51 B 35.17 C	11.17

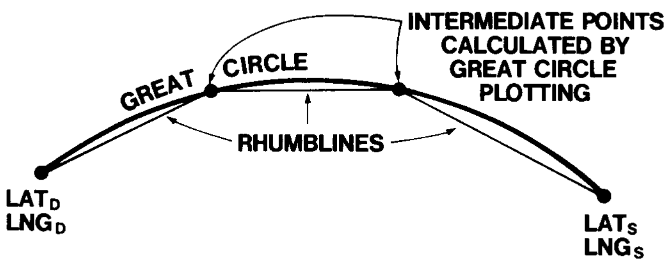
Rhumbline Navigation



This program accepts the coordinates of two points on the globe and calculates the rhumbline heading (HDG) and distance (DIST) between them. The program inputs are latitude and longitude of the source (LAT_S,LNG_S) and latitude and longitude of the destination (LAT_D, LNG_D) in degrees, minutes, and seconds. The program outputs are heading in degrees and distance in nautical miles.

Since the rhumbline is the constant heading path between points on the globe, it forms the basis of short distance navigation. In low and mid latitudes the rhumbline is sufficient for virtually all course and distance calculations which private pilots encounter. However, as distance increases or at high latitudes, the rhumbline ceases to be an efficient flight path since it is not the shortest distance between points.

The shortest distance between points is the great circle. However, in order to fly great circles, an infinite number of heading changes are necessary. Since it is impractical to calculate an infinite number of headings at an infinite number of points, several rhumblines may be used to approximate a great circle. The more rhumblines that are used the closer to the great circle distance the sum of the rhumbline distances will be. *Great Circle Plotting,* AV1-15A, may be used to calculate intermediate heading change points which can be linked by rhumblines.



$$HDG = \tan^{-1}\left[\frac{\pi\,(LNG_S - LNG_D)}{180(\ln\tan(45 + \tfrac{1}{2}LAT_D) - \ln\tan(45 + \tfrac{1}{2}LAT_S))}\right]$$

$$DIST = 60\,(LAT_D - LAT_S)/\cos(HDG)$$

or, if $\cos(HDG) = 0$

$$DIST = 60\,(LNG_D - LNG_S)\cos(LAT)$$

Limits and Warnings

No course should pass through either the south or north pole. Errors in distance calculations may be encountered as the cos (HDG) approaches zero.

Accuracy deteriorates for legs shorter than two or three miles.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Input source latitude*	DDD.MMSS**	[A] [ ]	degrees
	and source longitude	DDD.MMSS	[B] [ ]	degrees
3	Input destination latitude	DDD.MMSS	[A] [ ]	degrees
	and destination longitude	DDD.MMSS	[B] [ ]	degrees
4	Calculate distance		[C] [ ]	DIST(n.m.)
	and/or heading		[D] [ ]	HDG(deg)
5	If next leg starts at end of last		[ ] [ ]	
	leg go to step 3		[ ] [ ]	
6	For an entirely new case go to		[ ] [ ]	
	step 2.		[ ] [ ]	

*Southern latitudes and eastern longitudes are expressed as negative values.

**DDD.MMSS means degrees, decimal point, minutes and seconds. 320.0713 is 320 degrees, 7 minutes and 13 seconds.

Sample Problem

Find the leg lengths and headings for a flight from St. Helena to Bermuda using the intermediate point calculated in *Great Circle Plotting,* AV1-15A, as an intermediate point of heading change.

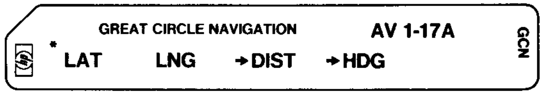
	LAT	LNG
St. Helena	15° 55′ S	5° 44′ W
Intermediate Point	11° 17′ N	35° 17′ W
Bermuda	32° 19′ N	64° 51′ W

Solution

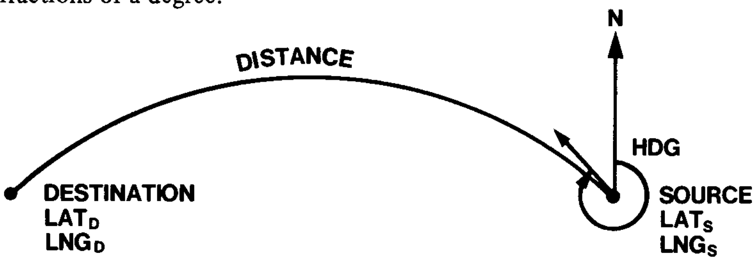
	DIST	HDG
LEG 1	2396.39 n.m.	312.92 Degrees
LEG 2	2065.29 n.m.	307.67 Degrees

Keystrokes	See Displayed
15.55 [CHS] [A] 5.44 [B] 11.17 [A] 35.17 [B] [C]	2396.39
[D]	312.92
32.19 [A] 64.51 [B] [C]	2065.29
[D]	307.67

Great Circle Navigation



This program computes the great circle distance between two points and computes the initial heading from the first point. Coordinates are input in degrees, minutes and seconds north or south of the equator and east or west of the prime meridian. Outputs are distances in nautical miles and headings in degrees and decimal fractions of a degree.



The great circle distance in nautical miles between two points is given by

$$\text{DIST} = 60 \cos^{-1}\left[\sin \text{LAT}_S \sin \text{LAT}_D + \cos \text{LAT}_S \cos \text{LAT}_D \cos(\text{LNG}_D - \text{LNG}_S)\right]$$

Where

LAT_S and LAT_D are the source and destination latitudes and LNG_S and LNG_D are the source and destination longitudes.

Correspondingly, the initial heading from the source to destination is

$$\text{HDG} = \cos^{-1}\left[\frac{\sin \text{LAT}_D - \sin \text{LAT}_S \cos(\text{DIST}/60)}{\sin(\text{DIST}/60) \cos \text{LAT}_S}\right]$$

NOTE: If $\sin(\text{LNG}_S - \text{LNG}_D) < 0$ then HDG = 360 – HDG

Limits and Warnings

Truncation and round off errors occur when the source and destination are very close together (1 mile or less). Input data is in degrees, minutes and seconds, not degrees, minutes and tenths of minutes. North latitudes and west longitudes are positive numbers, south latitudes and east longitudes are negative numbers.

Do not use coordinates located at diametrically opposite sides of the earth. Do not use latitudes at +90° or –90° (i.e., North and South Poles).

This program may give flashing zeros when trying to compute headings along lines of longitude.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	
3	Input source latitude*	DDD.MMSS**	[A] [ ]	LAT_S (deg)
	and source longitude	DDD.MMSS	[B] [ ]	LNG_S (deg)
4	Input destination latitude	DDD.MMSS	[A] [ ]	LAT_D (deg)
	and destination longitude	DDD.MMSS	[B] [ ]	LNG_D (deg)
5	Calculate leg distance		[C] [ ]	DIST (n.m.)
	and initial heading		[D] [ ]	HDG (deg)
6	If next leg starts at last leg		[ ] [ ]	
	end point go to step 4.		[ ] [ ]	
7	To restart for an entirely new		[ ] [ ]	
	leg go to step 2.		[ ] [ ]	

*Positive numbers indicate north latitudes and west longitudes. Negative numbers indicate south latitudes and east longitudes.

**DDD.MMSS means degrees, decimal point, minutes and seconds. 320.0713 is 320 degrees, 7 minutes and 13 seconds.

Sample Problem

Find the great circle distance from St. Helena to Bermuda.

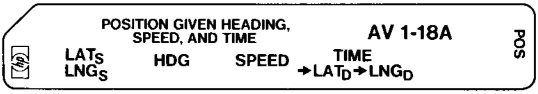
	LAT	LNG
St. Helena	15° 55′ S	5° 44′ W
Bermuda	32° 19′ N	64° 51′ W

Solution

4458.19 n.m. (note that this is only slightly shorter than the sum of the Rhumblines in *Rhumbline Navigation,* AV1-16A).

Keystrokes	See Displayed
RTN R/S 15.55 CHS A 5.44 B 32.19 A	
64.51 B C	4458.19
D	311.12

Position Given Heading, Speed, and Time



Given the starting position (LAT_S, LNG_S), the heading, the speed and the time of travel, the destination position (LAT_D, LNG_D) is calculated by a rhumbline.

$$LAT_D = \left(\frac{\text{Time x Speed x cos HDG}}{60}\right) + LAT_S$$

$$LNG_D = LNG_S - \frac{180}{\pi}\left[(\tan HDG) \times (\ln \tan(45 + \tfrac{1}{2} LAT_D) - \ln \tan(45 + \tfrac{1}{2} LAT_S))\right]$$

If HDG = 90° or 270° then.

$$LNG_D = \frac{DIST}{60 \cos LAT} + LNG_S$$

HDG = Heading

Speed = Speed in knots

Time = Time in hours

DIST = Speed x Time

Limits and Warnings

The path of flight may not cross a pole.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Input latitude of starting point	D.MMSS	[A] [ ]	LAT_S
	then longitude of starting		[ ] [ ]	
	point*	D.MMSS	[A] [ ]	LNG_S
3	Input both of the following		[ ] [ ]	
	true heading	HDG(deg)	[B] [ ]	HDG
	speed	speed(knots)	[C] [ ]	speed
4	Input time at speed and heading		[ ] [ ]	
	and calculate final longitude	H.MMSS**	[D] [ ]	LNG_D
	and latitude (both in degrees,		[ ] [ ]	
	minutes, seconds)		[D] [ ]	LAT_D
5	For new time go to step 4, for		[ ] [ ]	
	new heading or speed go to		[ ] [ ]	
	step 3, for new starting		[ ] [ ]	
	position go to step 2.		[ ] [ ]	

*Southern latitudes and eastern longitudes are expressed as negative values.

**H. MMSS means hours, decimal point, minutes, seconds. 2.0355 is 2 hours 3 minutes and 55 seconds.

Sample Problem

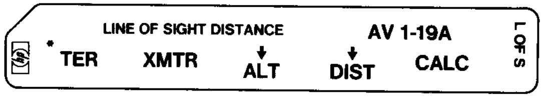
Starting at 30° N, 140° W, flying at 500 knots with a heading of 237 degrees what is the position after two hours?

Solution

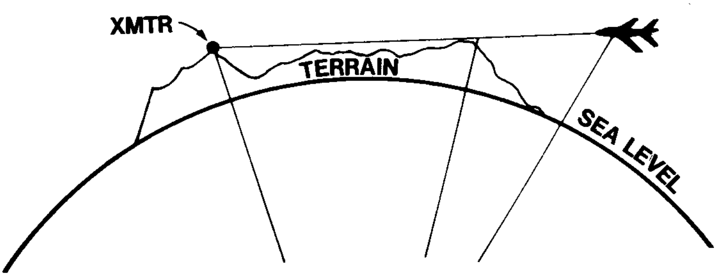
20° 55′ N, 155° 30′ W

Keystrokes	See Displayed
30 [A] 140 [A] 237 [B] 500 [C] 2 [D]	155.30
[D]	20.55

Line of Sight Distance



This program calculates either the aircraft altitude or the line-of-sight distance from an aircraft to a transmitting station. The inputs are the transmitter height (MSL), terrain height (MSL), and either the line-of-sight distance (n.m.) or the aircraft altitude in feet above MSL.



If

$$R_p = R + ALT$$
$$R_g = R + TER$$
$$R_t = R + XTMR$$

where

R = earth's radius = 3440 n.m.
ALT = aircraft altitude
TER = terrain altitude
XMTR = transmitter altitude

Since R_g is perpendicular to the line-of-sight

$$DIST = \sqrt{R_p^2 - R_g^2} + \sqrt{R_t^2 - R_g^2}$$

and

$$ALT = \sqrt{R_g^2 + \left(D - \sqrt{R_t^2 - R_g^2}\right)^2}$$

Limits and Warnings

Terrain input must not exceed either transmitter height or aircraft altitude. Any attempts to do so will result in a flashing display. This program does not account for refraction or radio waves.

The terrain input yields a worst case answer. If the terrain is close to either the station or the aircraft, the program will calculate a shorter distance or higher altitude than is actually necessary.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	1.00
3	Input the following:		[ ] [ ]	
	height of terrain between		[ ] [ ]	
	aircraft and transmitter	TER (feet)	[A] [ ]	TER
	and transmitter height	XMTR (feet)	[B] [ ]	XMTR
	and either airplane altitude	ALT (feet)	[C] [ ]	R_p^2 ($feet^2$)
	or line of sight distance	DIST (n.m.)	[D] [ ]	DIST (feet)
4	Calculate either		[ ] [ ]	
	aircraft altitude		[E] [C]	ALT (feet)
	or line of sight distance		[E] [D]	DIST (n.m.)
5	To change inputs go to step 3		[ ] [ ]	
	and change desired values. For		[ ] [ ]	
	a new case go to step 2.		[ ] [ ]	

Sample Problem

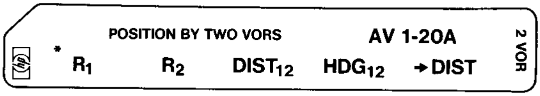
An omnidirectional antenna is 2000 feet high. The surrounding terrain is 1000 feet high. How high must you be to receive the transmission from a distance of 100 n.m?

Solution

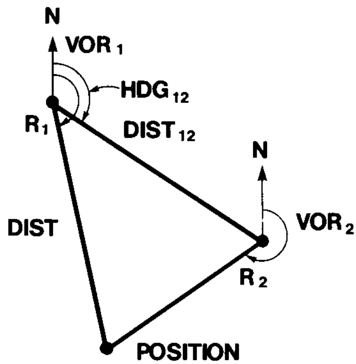
ALT = 4887.18 feet

Keystrokes	See Displayed
RTN R/S 1000 A 2000 B 100 D E C	4887.18

Position by Two VORs



This program finds the distance from one of two VOR's to an aircraft.



$$\text{DIST} = \left| \frac{\text{DIST}_{12} \sin(R_2 - \text{HDG}_{12})}{\sin(R_2 - R_1)} \right|$$

where

R_1 = Radial from VOR_1
R_2 = Radial from VOR_2
HDG_{12} = Heading between VORs
DIST_{12} = Distance between VORs
DIST = Distance from VOR_1 to aircraft

Limits and Warnings

The VORs must not be in a straight line through the aircraft.

Plane trigonometry is used so large distances or high latitudes will introduce error.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	
3	Input all of the following:		[ ] [ ]	
	Present position radial		[ ] [ ]	
	from VOR_1	R_1 (deg)	[A] [ ]	R_1
	Present position radial		[ ] [ ]	
	from VOR_2	R_2 (deg)	[B] [ ]	R_2
	Distance between VORs	$DIST_{12}$	[C] [ ]	$DIST_{12}$
	Heading between VORs	HDG_{12} (deg)	[D] [ ]	HDG_{12}
4	Calculate distance from VOR_1		[E] [ ]	DIST
5	For new case go to step 3 and		[ ] [ ]	
	change appropriate inputs.		[ ] [ ]	

Sample Problem

R_1 = 170 degrees
R_2 = 240 degrees
$DIST_{12}$ = 27 n.m.
HDG_{12} = 125 degrees

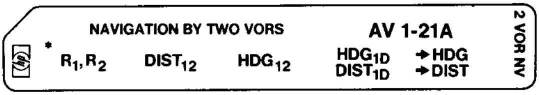
What is the distance from VOR_1?

Solution

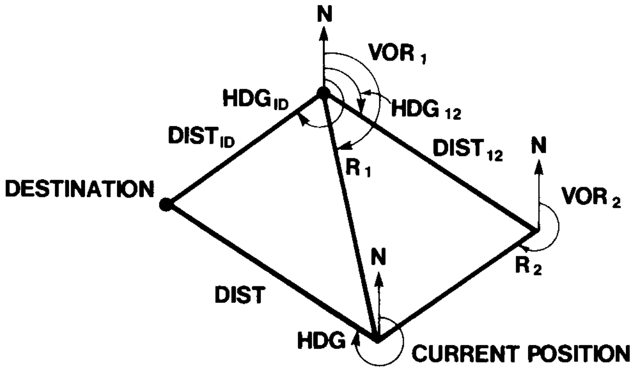
DIST = 26 n.m.

Keystrokes	**See Displayed**
RTN R/S 170 A 240 B 27 C 125 D E	26

Navigation by Two VORs



This program may be used to navigate between any two points provided signals can be received from two VOR stations.



$$D_1 = \left| \frac{DIST_{12} \sin(R_2 - HDG_{12})}{\sin(R_2 - R_1)} \right|$$

$$\overrightarrow{DIST} = \vec{D}_1 + \overrightarrow{DIST}_{1D}$$

where

- $DIST_{12}$ = Distance between VORs
- HDG_{12} = Heading between VORs
- R_1 = Radial from VOR_1
- R_2 = Radial from VOR_2
- D_1 = Distance from VOR_1 to aircraft
- $\vec{D}_1$ = Aircraft position vector with respect to VOR_1
- $\overrightarrow{DIST}_{1D}$ = Destination position vector with respect to VOR_1
- $\overrightarrow{DIST}$ = Required flight vector to destination

Limits and Warnings

The VORs must not be in a straight line from the aircraft.

Plane trigonometry is used so large distances or high latitudes will introduce error.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	
3	Input all of the following:		[ ] [ ]	
	Present position radial		[ ] [ ]	
	from VOR_1	R_1 (deg)	[A] [ ]	R_1
	then present position radial		[ ] [ ]	
	from VOR_2	R_2 (deg)	[A] [ ]	R_2
	Distance between VORs	$DIST_{12}$	[B] [ ]	$DIST_{12}$
	Heading of VOR_2 from VOR_1	HDG_{12} (deg)	[C] [ ]	HDG_{12}
	Heading from VOR_1 to		[ ] [ ]	
	destination	HDG_{1D} (deg)	[D] [ ]	HDG_{1D}
	then distance from VOR_1 to		[ ] [ ]	
	destination	$DIST_{1D}$	[D] [ ]	$DIST_{1D}$
4	Calculate magnetic heading		[E] [ ]	HDG
5	Calculate distance to destination		[E] [ ]	DIST
6	For new case go to step 2 and		[ ] [ ]	
	change appropriate inputs.		[ ] [ ]	

Sample Problem

R_1 = 170 degrees
R_2 = 250 degrees
$DIST_{12}$ = 13 n.m.
HDG_{12} = 145 degrees
HDG_{1D} = 255 degrees
$DIST_{1D}$ = 20 n.m.

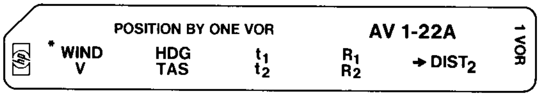
Find the heading and distance to the destination.

Solution

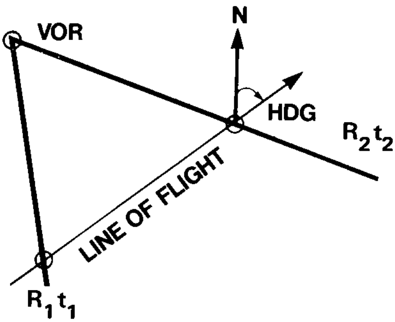
HDG = 289
DIST = 23 n.m.

Keystrokes	See Displayed
RTN R/S 170 A 250 A 13 B 145 C 255 D	
20 D E	289
E	23

Position by One VOR



This program computes the distance from a VOR station to an aircraft. The distance is found in a manner similar to the classical situation where one flies at right angles to the VOR radial and computes the time to the VOR from the time between bearings and the degrees of bearing change. This program offers a more complete solution in that it is unnecessary to fly at right angles to the VOR station and it includes the effect of winds.



The distance from the VOR station to the airplane is given by

$$S = \frac{(GS \times \Delta t)\sin(C - R_1)}{\sin(R_1 - R_2)} \qquad (1)$$

where
- GS = ground speed of aircraft
- Δt = time between readings = $t_2 - t_1$
- C = magnetic course of aircraft
- R_1 = first VOR radial to aircraft
- R_2 = second VOR radial to aircraft
- t_1 = time of the first VOR radial intercept.
- t_2 = time of the second VOR radial intercept.

Ground speed and course are found from the polar representation:

$$\frac{GS}{60} \angle C = TAS \angle HDG - W \angle D - V \qquad (2)$$

where
- V = magnetic variation
- TAS = true airspeed
- HDG = aircraft heading
- W = wind velocity
- D = wind direction (true)
- $\angle$ should be read as "at angle".

Although the ground speed vector is the true airspeed vector *plus* the wind vector, equation (2) is correct because the wind direction D indicates the direction the wind is coming from, not the direction it is blowing toward.

Limits and Warnings

Overall accuracy is limited by VOR receiver resolution. The difference in VOR readings should be at least 5° and preferably 10° to obtain accurate results. Times must be input to the nearest second.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	0.00
3	Optional: Input wind vector	DDD.KK	[A] [ ]	DDD.KK
	then magnetic variation		[ ] [ ]	
	(+E, −W)	V (deg)	[A] [ ]	V
4	Input all of the following:		[ ] [ ]	
	Aircraft heading	HDG (deg)	[B] [ ]	HDG
	then true airspeed	TAS (n.m.)	[B] [ ]	TAS
	Intersection time of first		[ ] [ ]	
	radial	t_1 (H.MMSS)*	[C] [ ]	t_1
	Heading of first VOR radial	R_1 (deg)	[D] [ ]	R_1
5	Input intersection time of		[ ] [ ]	
	second VOR radial	t_2 (H.MMSS)	[C] [ ]	t_2
	and heading of second		[ ] [ ]	
	VOR radial	R_2 (deg)	[D] [ ]	R_2
6	Calculate distance to		[ ] [ ]	
	second VOR		[E] [ ]	DIST (n.m.)
7	For a second fix using the same		[ ] [ ]	
	station go to step 5. For a new		[ ] [ ]	
	case go to step 3.		[ ] [ ]	

*H.MMSS means hours, decimal point, minutes, seconds. 2.0355 is 2 hours 3 minutes and 55 seconds.

Sample Problem

An airplane is flying at a heading of 35°. Its true airspeed is 150 knots. The reported winds are 240° at 19 knots. Magnetic variation is ±5° west. At 3:22:10 the OMNI indicates a heading of 330° to the station. At 3:34:30 the VOR reads 240° to the station. What is the distance to the station at the time of the second reading?

Solution

31.72 nautical miles.

Keystrokes	See Displayed
RTN R/S 240.19 A 15 CHS A 35 B 150 B	
3.2210 C 330 D 3.3430 C 240 D E	31.72

DME Speed Correction

The program calculate ground speed from the DME speed indicator when the airplane course is not directly to or from a DME station.

The DME speed indicator reads the component of velocity that is on a line between the plane and the DME station. The component V_1 is given by:

$$V_1 = GS \times |\cos(D - C)|$$

where

GS = The aircraft speed
D = Direction to (or from) the DME station
C = Aircraft ground course

solving for GS

$$GS = \frac{V_1}{|\cos(D - C)|}$$

The program will also correct for aircraft altitude

$$GS' = \frac{GS\sqrt{\Delta h^2 + DIST^2}}{DIST}$$

where

GS′ = Aircraft ground speed corrected for heading and elevation
Δh = Difference between aircraft and DME altitude.
DIST = Distance to DME

Limits and Warnings

The accuracy of the DME and the limits of measuring D and C cause errors when angles to DME radials approach 90 degrees. To obtain accurate values, you should only use data obtained when crossing DME radials at an angle less than 60°.

The program uses ground course as an input, not aircraft heading. Aircraft headings must be corrected by the wind correction angle to obtain ground course.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		[ ] [ ]	
2	Initialize		[RTN] [R/S]	
3	Input course (degrees)	course	[A] [ ]	course
	and radial (degrees)	radial	[B] [ ]	radial
4	Input DME speed and calculate		[ ] [ ]	
	ground speed	V_1 (knots)	[C] [ ]	GS (knots)
5	Optional:* Input distance to		[ ] [ ]	
	DME	DIST (n.m.)	[D] [ ]	DIST
	Input altitude *above* DME		[ ] [ ]	
	and calculate GS	Δh (ft)	[E] [ ]	GS (knots)
6	For new case with same course		[ ] [ ]	
	and radial go to step 4. Go to		[ ] [ ]	
	step 3 for new case.		[ ] [ ]	

*Step 5 corrects for elevation effects and is not necessary unless the aircraft is very high or very close to the DME station.

Sample Problem

An airplane flying a course of 265° intercepts the 220° to radial of a DME station. The indicated DME speed is 123 knots. What is the ground speed.

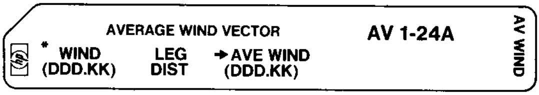
If you are 10,000 feet above the DME station and 7 n.m. away what is your ground speed?

Solution

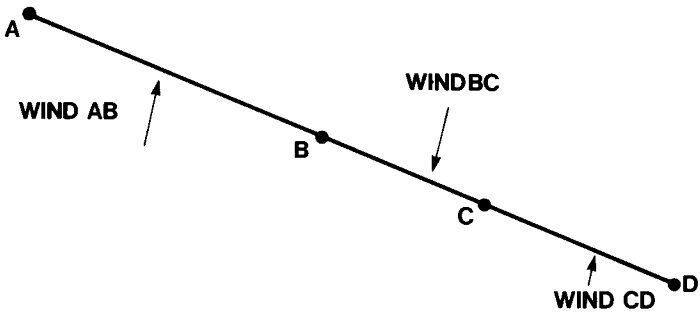
GS = 174 knots
GS′ = 179 knots

Keystrokes	See Displayed
RTN R/S 265 A 220 B 123 C	174
7 D 10000 E	179

Average Wind Vector



When planning a flight it may be helpful to reduce several reported wind vectors along the flight path to one average wind. By weighting each wind vector along the flight path according to the distance it acts, an approximate average wind vector can be found. For a flight from A to D with forecast winds as shown:



$$\overrightarrow{\text{Wind Ave}} = \frac{1}{\text{Dist}_{AD}}\left[(\text{Dist}_{AB})(\overrightarrow{\text{Wind}_{AB}}) + (\text{Dist}_{BC})(\overrightarrow{\text{Wind}_{BC}}) + (\text{Dist}_{CD})(\overrightarrow{\text{Wind}_{CD}})\right]$$

Limits and Warnings

The greater the aircraft velocity as compared to that of the wind, the closer the approximation is to the actual case.

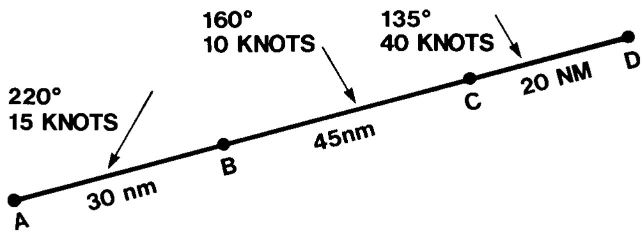
The velocity of input winds must be less than 100.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		RTN R/S	0.00
3	Input wind vector for a			
	particular flight segment	DDD.KK*	A	DDD.KK
	and input distance along			
	segment over which wind			
	vector acts	DIST	B	DIST
4	Repeat step 3 for each segment			
5	Calculate average wind		C	DDD.KK
6	For new case go to step 2			

*DDD.KK means direction, decimal point, wind speed. 325.08 means a direction of 325 degrees and a speed of 8 knots.

Sample Problem

Suppose a pilot wants to fly from A to D given the following wind pattern along his flight path. What is the approximate average wind?

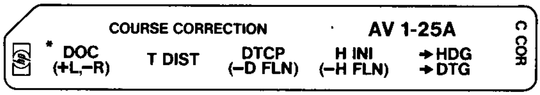


Solution

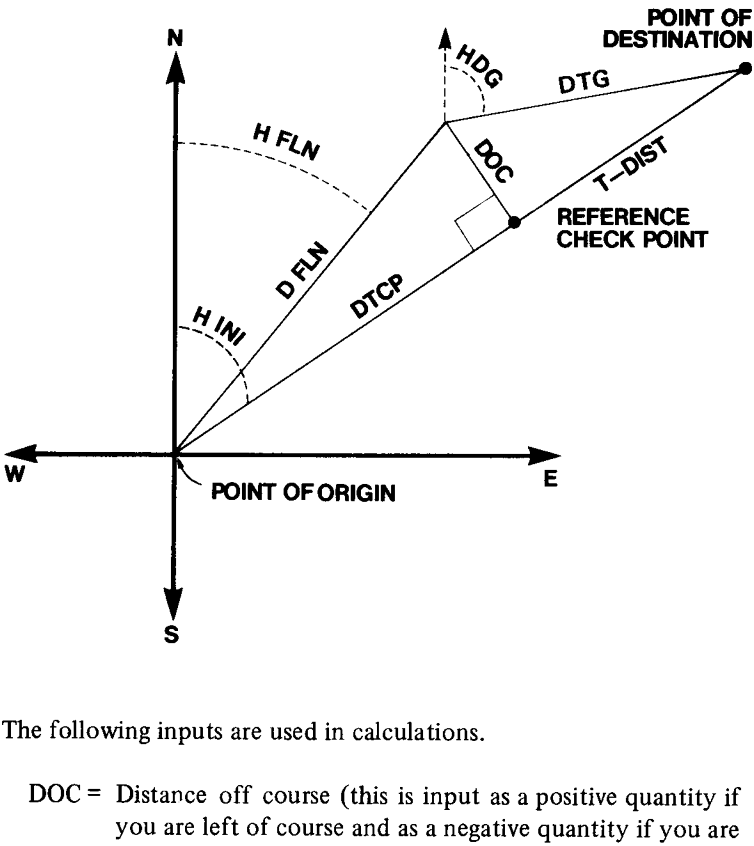
Wind Ave = 162.15 or a 15 knot wind at 162 degrees

Keystrokes	See Displayed
RTN R/S 220.15 A 30 B 160.10 A 45 B	
135.40 A 20 B C	162.15

Course Correction



The program calculates the new corrected heading and the distance to destination for an aircraft which has strayed a known distance off course.



The following inputs are used in calculations.

DOC = Distance off course (this is input as a positive quantity if you are left of course and as a negative quantity if you are to the right of course);

T DIST = Total distance from the point of origin to the point of destination;

DTCP = Distance to checkpoint from point of origin;

D FLN = Distance actually flown from origin to point of course correction calculation. This value may be used instead of DTCP. When it is used it is input as a negative quantity;

H INI = The initial heading that should have been flown to arrive at the point of destination;

H FLN = The heading actually flown to arrive at the point of calculation for course correction. It may be used instead of H INI. If it is, it is input as a negative value;

The outputs of calculation are:

HDG = The new heading to be flown to arrive at the point of destination;

DTG = The distance to go from the point of calculation;

$$DTCP = \sqrt{(-DF)^2 - (DOC)^2}$$

$$DTG = \sqrt{(DTCP - T\ DIST)^2 + (DOC)^2}$$

$$HDG = \sin^{-1}\left[\frac{DOC}{DTG}\right] + H\ INI$$

Limits and Warnings

This program assumes a flat earth. Large distances or calculations near the poles will yield inaccurate results.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	0.00
3	Input distance off course				
	(+left or −right)	DOC	A		DOC
	and total distance	T DIST	B		T DIST
	and distance from origin to				
	checkpoint	DTCP	C		DTCP
	or distance flown				
	(negative)	−D FLN	C		−D FLN
	and initial heading	H INI (deg)	D		H INI (deg)
	or heading flown				
	(negative)	−H FLN (deg)	D		-H FLN (deg)
4	Calculate new heading		E		HDG (deg)
5	Calculate distance to destination		E		DTG
	(Steps 4 and 5 may be repeated				
	alternately to display HDG				
	and DTG)				
6	To modify problem go to				
	step 3. For new case go to				
	step 2.				

Sample Problem

Suppose:

DOC = 15.6 (left)
T DIST = 180
H INI = 85.5 degrees
D FLN = 104 (input as – 104)

Find the heading which must be flown to reach the destination and the distance to destination.

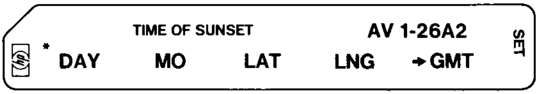
Solution

HDG = 96.93 degrees
DTG = 78.74 miles

Course Correction

Keystrokes	See Displayed
RTN R/S 15.6 A 180 B 85.5 D 104 CHS C E	96.93
E	78.74

Time of Sunrise/Sunset



Sunrise is computed from

$$S = [\theta_0 - \cos^{-1}(-\tan\phi_s \tan\phi_0)]/15 - E + 12 \qquad (1)$$

where

θ_0 = observer's longitude
θ_0 = observer's latitude
θ_s = subsolar latitude (declination of sun)
E = equation of time

θ_s and E are approximated by

$$\theta_s \doteq -23.5 \cos(t + 10) \qquad (2)$$
$$E \doteq 0.123 \cos(t + 87) - {}^1/_6 \sin(2t + 20) \qquad (3)$$
$$t \doteq 0.988 (D - 1 + 30.3 (m - 1)) \qquad (9)$$

where D and m are day and month respectively.

NOTE: Equation (1) computes the time at which the middle of the sun is on the horizon. Equation (1) does not account for atmopheric refractions. Refraction causes the sun to rise earlier than the value given by equation (1).

Sunset is computed from

$$S = [\theta_0 + \cos^{-1}(-\tan\phi_s \tan\phi_0)]/15 - E + 12 \qquad (1)$$

where:

θ_0 = observer's longitude
θ_0 = observer's longitude
ϕ_s = subsolar latitude (declination of sun)
E = equation of time

ϕ_s and E are approximated by

$$\phi_s \doteq -23.5 \cos(t + 10)$$
$$E \doteq 0.123 \cos(t + 87) - {}^1\!/_6 \sin(2t + 20)$$
$$t \doteq 0.988 (D - 1 + 30.3 (m - 1))$$

where D and m are day and month respectively.

NOTE: Equation (1) computes the time at which the middle of the sun is on the horizon. Equation (1) does not account for atmospheric refractions. Refraction causes the sun to rise earlier than the value given by equation (1).

Limits and Warnings

The approximate values of ϕ_s and E cause s to exhibit a maximum error of + 4.7 minutes and −0.6 minutes at 45° north latitude, based on 1973 ephemeris data. Refraction and secular changes in the ephemeris can result in errors as large as +8 minutes from observed data at 45° north. Errors decrease as latitudes approach 0°. Large errors exist above 65°.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program *Time Of Sunrise*				
	or *Time Of Sunset*				
2	Initialize		RTN	R/S	
3	Enter all of the following:				
	Day of month	Day	A		
	Month	Month	B		
	Observer Latitude**	DDD.MMSS*	C		
	Observer Longitude	DDD.MMSS	D		
4	Compute sunrise (or sunset)		E		HH.MM***
5	To change any variable go to				
	step 3 and change only those				
	affected.				

*DDD.MMSS means degrees, decimal point, minutes and seconds. 320.0713 is 320 degrees, 7 minutes and 13 seconds.

**Southern latitudes and eastern longitudes are expressed as negative values.

***HH.MM means hours, decimal point, minutes. 2.03 is 2 hours 3 minutes.

Sample Problems

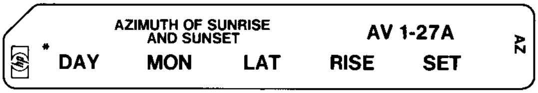
What time does the sun rise in San Francisco (37° 37′ N, 122° 23′ W) on Christmas Day? What time does the sun rise on June 25?

Solutions

15:27 GMT (07:27 AM Pacific Standard Time)
12:53 GMT (05:53 AM Pacific Daylight Time)

Keystrokes	See Displayed
RTN R/S 25 A 12 B 37.37 C 122.23 D	
E	15.27
6 B E	12.53

Azimuth of Sunrise and Sunset



This program computes the true heading (azimuth) of the sun as it rises or sets. Input data are day of the month, month of the year and latitude.

The azimuth of the sun is given by

$$Az = \cos^{-1} \frac{\sin \phi_s}{\cos \phi_0}$$

ϕ_s is the latitude of the subsolar point
ϕ_o is the latitude of the observer

ϕ_s is approximated by

$\phi_s = 0.5 - 23.5 \cos(0.986 \text{ day} + 9.66)$ where day is the day of the year.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		RTN	R/S	
3	Input all of the following				
	Day of the month	Day	A		
	Month (Jan = 1, Dec = 12)	Month	B		
	Observer's latitude	DDD.MMSS*	C		
4	Calculate either or both				
	Azimuth of sunrise		D		degrees
	Azimuth of sunset		E		degrees
5	Go to step three to change any				
	input variable				
	Note: Azimuth is given as a				
	true azimuth, not magnetic.				

*DDD.MMSS means degrees, decimal point, minutes and seconds. 320.0713 is 320 degrees, 7 minutes and 13 seconds.

Limits and Warnings

The approximations used in this program limit the overall accuracy to ± 1%. Significant errors can occur at or above the arctic circles and their respective poles during certain times of the year.

Sample Problem

What is the azimuth of sunset on Christmas day for an observer in San Francisco (37° 37′ N)?

Solution

Answer: 240.51 degrees

Azimuth of Sunrise and Sunset

Keystrokes	See Displayed
RTN R/S 25 A 12 B 37.37 C E	240.51

Pilot Unit Conversions

This program performs unit conversions commonly encountered by pilots. Included are conversions between Fahrenheit and Celsius degrees, statute miles and nautical miles, liters and gallons, and gallons of gasoline and pounds of gasoline.

Equations:

$$°F = 1.8\,°C + 32$$
$$°C = (°F - 32)/1.8$$
$$\text{statute miles} = \text{nautical miles}/0.868978$$
$$\text{gallons} = \text{liters}/0.2642$$
$$\text{pounds gasoline} = \text{gallons gasoline} \times 6$$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		RTN R/S	0.00
3	Convert from			
	Fahrenheit to Celsius	°F	A	°C
	or statute miles to nautical miles	s.m.	B	n.m.
	or liters to gallons	liters	C	gallons
	or gallons gasoline to pounds	gal (gas)	D	lbs (gas)
4	Convert from			
	Celsius to Fahrenheit	°C	E A	°F
	or nautical miles to statute miles	n.m.	E B	s.m.
	or gallons to liters	gallons	E C	liters
	or pounds gasoline to gallons	lbs (gas)	E D	gal (gas)
5	For next conversion go to step			
	3 or 4			

Sample Problems

1. Convert 10 pounds of gasoline to gallons of gasoline.
2. Convert 40 gallons to liters.
3. Convert 100 statute miles to nautical miles.
4. Convert 212 degrees Fahrenheit to degrees Celsius.

Solutions

1. 1.67 gallons
2. 151.40 liters
3. 86.90 nautical miles
4. 100°C

Keystrokes	See Displayed
1. RTN R/S 10 E D	1.67
2. 40 E C	151.40
3. 100 B	86.90
4. 212 A	100.00

Customized Unit Conversions

Pilots encounter different conversion problems depending on where they fly and what type of aircraft they use. With this program, a pilot can permanently record his most used conversion factors and easily perform unit conversions. As an example, a pilot flying across national boundaries may want conversion factors for monetary exchange, while a crop duster may want the densities of chemicals.

Instructions: Select a conversion problem which you encounter frequently. Obtain the conversion factor for the problem and write it in equation form:

CONVERTED VALUE = CONVERSION FACTOR X VALUE

or

CON VAL = CF X VALUE

Where CON VAL is the answer in the units you desire, VALUE has the units you most often encounter, and CF is the constant factor that yields CON VAL when multiplied by VALUE.

Repeat this procedure for one, two or three other conversion problems which you encounter frequently. When you have the constants defined, follow the procedure below:

1. Turn the HP-65 on
2. Switch to RUN mode
3. Enter *Customized Unit Conversion,* AV1-29A
4. Press GTO A
5. Switch to W/PRGM mode (see 11 in display)
6. Key in your first conversion factor
7. Switch back to RUN mode
8. Press GTO B
9. Switch to W/PRGM mode (see 12 in display)
10. Key in your second conversion factor
11. Switch back to RUN mode
12. Press GTO C

13. Switch back to W/PRGM mode (see 13 in display)
14. Key in third conversion factor
15. Switch to RUN mode
16. Press GTO D
17. Switch to W/PRGM mode (see 14 in display)
18. Key in the last conversion factor
19. Enter one of the blank cards from your pac into the HP-65. You now have a program specifically for your unit conversions.
20. Switch back to RUN mode.
21. Check the card according to the general user instructions for known cases.

When you are certain that the card is correct you may wish to protect it from accidental erasure by clipping the corner. You can also label the card so that you can remember which keys correspond to which constants. For instance, if the constant associated with the A key (first conversion factor) converts pesos to dollars and the constant associated with the B key (second conversion factor) converts nautical miles to kilometers, the card might look like this

Note that the E key is associated with a "reverse arrow" if the key is pressed before one of the conversion keys (A through D) the reverse conversion will take place. For this card pressing E then A would convert dollars to pesos.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program (program must				
	already be customized)				
2	Initialize		RTN	R/S	0.00
3	For forward conversions input				
	value to be converted using				
	conversion 1	VALUE	A		CON VAL
	or conversion 2	VALUE	B		CON VAL
	or conversion 3	VALUE	C		CON VAL
	or conversion 4	VALUE	D		CON VAL
3′	For reverse conversions input				
	value to be converted using				
	conversion 1	CON VAL	E	A	VALUE
	or conversion 2	CON VAL	E	B	VALUE
	or conversion 3	CON VAL	E	C	VALUE
	or conversion 4	CON VAL	E	D	VALUE
4	For next conversion go to 3				
	or 3′				

Sample Problem

CON VAL A = 12 x VALUE A
CON VAL B = 144 x VALUE B
CON VAL C = 0.5 x VALUE C
CON VAL D = 0.333 x VALUE D

Keystrokes for sample customization

Enter *Customized Unit Conversion* in RUN mode.

Press GTO A, switch to W/PRGM, 12, switch to RUN, GTO B, switch to W/PRGM, 144, switch to RUN, GTO C, switch to W/PRGM, .5, switch to RUN, GTO D, switch to W/PRGM, .333, switch to RUN. Try the following conversions.

If

VALUE A = 10
VALUE B = 343
CON VAL C = 150
VALUE D = 300

Find

CON VALUE A
CON VALUE B
VALUE C
CON VALUE D

Solutions

CON VALUE A = 120.00
CON VALUE B = 49392.00
VALUE C = 300.00
CON VALUE D = 99.90

Keystrokes	See Displayed
RTN R/S 10 A	120.00
343 B	49392.00
150 E C	300.00
300 D	99.90

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AIRCRAFT FLIGHT PLAN WITH WIND

KEYS	CODE
f	31
REG	43
R/S	84
LBL	23
A	11
STO 1	33 01
RTN	24
LBL	23
A	11
STO 2	33 02
RTN	24
LBL	23
B	12
↑	41
f	31
INT	83
STO 3	33 03
−	51
EEX	43
2	02
x	71
STO 8	33 08
RTN	24
LBL	23
B	12
STO 4	33 04
RTN	24
LBL	23
C	13
DSP	21
•	83
0	00
STO 5	33 05
RCL 3	34 03
RCL 4	34 04

KEYS	CODE
−	51
g x⇄y	35 07
−	51
RCL 8	34 08
RCL 2	34 02
÷	81
f^{-1}	32
R→P	01
g R↓	35 08
f^{-1}	32
SIN	04
f	31
COS	05
g R↑	35 09
g LST X	35 00
RCL 5	34 05
+	61
1	01
f^{-1}	32
R→P	01
f	31
R→P	01
CLX	44
g x>y	35 24
3	03
6	06
0	00
+	61
RTN	24
LBL	23
C	13
g R↓	35 08
−	51
RCL 2	34 02
x	71

KEYS	CODE
RTN	24
LBL	23
D	14
g x⇄y	35 07
÷	81
STO 7	33 07
STO	33
+	61
6	06
DSP	21
•	83
4	04
f	31
→D.MS	03
RTN	24
LBL	23
D	14
RCL 6	34 06
f	31
→D.MS	03
RTN	24
LBL	23
E	15
RCL 7	34 07
RCL 1	34 01
x	71
DSP	21
•	83
1	01
RTN	24

R_1 Fuel	R_4 V	R_7 Leg Time
R_2 TAS	R_5 C	R_8 Wind
R_3 DDD	R_6 Total Time	R_9 Used

FLIGHT MANAGEMENT

KEYS	CODE
CLX	44
R/S	84
LBL	23
A	11
f^{-1}	32
→D.MS	03
STO 1	33 01
0	00
g x≠y	35 21
0	00
RTN	24
DSP	21
•	83
4	04
RCL 2	34 02
RCL 3	34 03
÷	81
STO 1	33 01
f	31
→D.MS	03
RTN	24
LBL	23
B	12
E	15
STO 2	33 02
0	00
g x≠y	35 21
0	00
RTN	24
RCL 1	34 01
RCL 3	34 03
x	71
STO 2	33 02
RTN	24
LBL	23

KEYS	CODE
C	13
E	15
STO 3	33 03
0	00
g x≠y	35 21
0	00
RTN	24
RCL 2	34 02
RCL 1	34 01
÷	81
STO 3	33 03
RTN	24
LBL	23
D	14
RCL 1	34 01
f	31
→D.MS	03
DSP	21
•	83
4	04
RTN	24
LBL	23
D	14
E	15
RCL 2	34 02
RTN	24
LBL	23
D	14
RCL 3	34 03
LBL	23
E	15
DSP	21
•	83
2	02
RTN	24

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
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g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 Time	R_4	R_7
R_2 Fuel or Dist	R_5	R_8
R_3 FC or GS	R_6	R_9 Used

PREDICTING FREEZING LEVELS

KEYS	CODE
f	31
STK	42
STO 7	33 07
STO 8	33 08
LBL	23
1	01
f^{-1}	32
SF 2	71
R/S	84
f	31
SF 2	71
LBL	23
A	11
f	31
TF 2	81
RCL 7	34 07
g NOP	35 01
STO 7	33 07
f^{-1}	32
SF 1	51
GTO	22
1	01
LBL	23
B	12
f	31
TF 2	81
RCL 7	34 07
g NOP	35 01
STO 7	33 07
f	31
SF 1	51
GTO	22
1	01
LBL	23
C	13

KEYS	CODE
f	31
TF 2	81
RCL 8	34 08
g NOP	35 01
STO 8	33 08
GTO	22
1	01
LBL	23
D	14
RCL 7	34 07
3	03
2	02
f^{-1}	32
TF 1	61
CLX	44
g NOP	35 01
−	51
3	03
•	83
6	06
f^{-1}	32
TF 1	61
CLX	44
2	02
GTO	22
0	00
LBL	23
E	15
RCL 7	34 07
3	03
2	02
f^{-1}	32
TF 1	61
CLX	44
g NOP	35 01

KEYS	CODE
−	51
2	02
•	83
7	07
f	31
TF 1	61
GTO	22
0	00
CLX	44
1	01
•	83
5	05
LBL	23
0	00
÷	81
EEX	43
3	03
x	71
RCL 8	34 08
+	61
GTO	22
1	01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1	R_4	R_7 Temp
R_2	R_5	R_8 ALT
R_3	R_6	R_9

GENERAL AIRCRAFT WEIGHT AND BALANCE

KEYS	CODE
f	31
REG	43
f^{-1}	32
SF 2	71
CLX	44
LBL	23
0	00
f^{-1}	32
SF 1	51
R/S	84
GTO	22
3	03
LBL	23
A	11
f	31
TF 1	61
RCL 1	34 01
GTO	22
0	00
+	61
f	31
TF 2	81
CHS	42
g NOP	35 01
STO	33
+	61
1	01
STO 3	33 03
RCL 1	34 01
GTO	22
0	00
LBL	23
C	13
f	31
TF 1	61

KEYS	CODE
RCL 2	34 02
GTO	22
0	00
+	61
f	31
TF 2	81
CHS	42
g NOP	35 01
LBL	23
1	01
STO	33
+	61
2	02
STO 4	33 04
f^{-1}	32
SF 2	71
RCL 2	34 02
GTO	22
0	00
LBL	23
D	14
f	31
SF 1	51
R/S	84
LBL	23
E	15
f	31
SF 2	71
R/S	84
LBL	23
B	12
f	31
TF 1	61
GTO	22
2	02

KEYS	CODE
RCL 3	34 03
x	71
GTO	22
1	01
LBL	23
2	02
RCL 2	34 02
RCL 1	34 01
÷	81
GTO	22
0	00
LBL	23
3	03
RCL 3	34 03
STO	33
−	51
1	01
RCL 4	34 04
STO	33
−	51
2	02
CLX	44
STO 3	33 03
STO 4	33 04
GTO	22
0	00
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 Σ Wt	R_4 Mt	R_7 0
R_2 Σ Mt	R_5 0	R_8 0
R_3 Wt	R_6 0	R_9 0

CUSTOMIZED WEIGHT AND BALANCE

KEYS	CODE
GTO	22
E	15
LBL	23
A	11
RCL 3	34 03
GTO	22
1	01
LBL	23
B	12
RCL 4	34 04
GTO	22
1	01
LBL	23
C	13
RCL 5	34 05
GTO	22
1	01
LBL	23
D	14
6	06
x	71
RCL 6	34 06
LBL	23
1	01
STO 8	33 08
g x⇄y	35 07
STO 7	33 07
STO	33
+	61
1	01
x	71
STO	33
+	61
2	02
RCL 7	34 07

KEYS	CODE
LBL	23
2	02
R/S	84
RCL 7	34 07
CHS	42
RCL 8	34 08
GTO	22
1	01
LBL	23
E	15
RCL 1	34 01
R/S	84
LBL	23
E	15
RCL 2	34 02
R/S	84
LBL	23
E	15
RCL 2	34 02
RCL 1	34 01
÷	81
GTO	22
2	02
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 Wt	R_4 Rear Arm	R_7 Last Wt
R_2 Total Mom	R_5 Baggage arm	R_8 Last arm
R_3 Front arm	R_6 Fuel arm	R_9

TURN PERFORMANCE

KEYS	CODE	KEYS	CODE	KEYS	CODE
g	35	E	15	g NOP	35 01
DEG	41	RCL 1	34 01	g NOP	35 01
DSP	21	↑	41	g NOP	35 01
•	83	x	71	g NOP	35 01
2	02	3	03	g NOP	35 01
R/S	84	4	04	g NOP	35 01
LBL	23	2	02	g NOP	35 01
A	11	0	00	g NOP	35 01
STO 1	33 01	8	08	g NOP	35 01
RTN	24	÷	81	g NOP	35 01
LBL	23	RCL 3	34 03	g NOP	35 01
B	12	f	31	g NOP	35 01
STO 2	33 02	TAN	06	g NOP	35 01
RTN	24	÷	81	g NOP	35 01
LBL	23	RTN	24	g NOP	35 01
C	13	LBL	23	g NOP	35 01
STO 3	33 03	E	15	g NOP	35 01
RTN	24	RCL 1	34 01	g NOP	35 01
LBL	23	•	83	g NOP	35 01
D	14	0	00	g NOP	35 01
RCL 3	34 03	0	00	g NOP	35 01
f	31	5	05	g NOP	35 01
COS	05	5	05	g NOP	35 01
g	35	x	71	g NOP	35 01
$1/x$	04	RCL 3	34 03	g NOP	35 01
RTN	24	f	31	g NOP	35 01
LBL	23	TAN	06	g NOP	35 01
D	14	÷	81	g NOP	35 01
D	14	f	31	g NOP	35 01
f	31	→D.MS	03	g NOP	35 01
$\sqrt{x}$	09	RTN	24		
RCL 2	34 02	g NOP	35 01		
x	71	g NOP	35 01		
RTN	24	g NOP	35 01		
LBL	23	g NOP	35 01		

R_1 TAS	R_4	R_7
R_2 stall	R_5	R_8
R_3 bank	R_6	R_9 Used

RATE OF CLIMB AND DESCENT

KEYS	CODE
CLX	44
STO 8	33 08
R/S	84
LBL	23
A	11
STO 6	33 06
RTN	24
LBL	23
B	12
STO 4	33 04
6	06
0	00
7	07
6	06
÷	81
STO 7	33 07
RCL 4	34 04
RTN	24
LBL	23
C	13
g	35
DSZ	83
STO 3	33 03
RTN	24
RCL 6	34 06
RCL 7	34 07
x	71
6	06
0	00
÷	81
RCL 5	34 05
÷	81
6	06
0	00
7	07

KEYS	CODE
6	06
x	71
↑	41
x	71
RCL 7	34 07
↑	41
x	71
–	51
f	31
$\sqrt{x}$	09
STO 3	33 03
RTN	24
LBL	23
D	14
g	35
DSZ	83
STO 5	33 05
RTN	24
RCL 6	34 06
RCL 7	34 07
x	71
6	06
0	00
÷	81
RCL 3	34 03
↑	41
x	71
RCL 7	34 07
↑	41
x	71
+	61
f	31
$\sqrt{x}$	09
÷	81
6	06

KEYS	CODE
0	00
7	07
6	06
x	71
STO 5	33 05
RTN	24
LBL	23
E	15
1	01
STO 8	33 08
g R↓	35 08
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1	R_4 Used	R_7 ΔALT (n.m.)
R_2	R_5 ROC	R_8 DSZ
R_3 DIST	R_6 TAS	R_9

HEAD WINDS AND CROSS WINDS

KEYS	CODE
CLX	44
f^{-1}	32
SF 1	51
DSP	21
•	83
2	02
g	35
DEG	41
LBL	23
A	11
STO 1	33 01
R/S	84
LBL	23
B	12
STO 2	33 02
R/S	84
LBL	23
C	13
STO 3	33 03
R/S	84
LBL	23
D	14
RCL 3	34 03
f	31
INT	83
RCL 1	34 01
RCL 2	34 02
+	61
–	51
RCL 3	34 03
f^{-1}	32
INT	83
EEX	43
2	02
x	71

KEYS	CODE
f^{-1}	32
R→P	01
f	31
TF 1	61
g x⇄y	35 07
g NOP	35 01
f^{-1}	32
SF 1	51
DSP	21
•	83
2	02
R/S	84
LBL	23
E	15
f	31
SF 1	51
D	14
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 V	R_4	R_7
R_2 HDG	R_5	R_8
R_3 DDD.KK	R_6	R_9 Used

FLIGHT PLANNING AND FLIGHT VERIFICATION

KEYS	CODE
f	31
REG	43
f	31
SF 1	51
LBL	23
0	00
DSP	21
•	83
0	00
R/S	84
GTO	22
0	00
LBL	23
A	11
RCL 1	34 01
STO 2	33 02
g x⇄y	35 07
STO 1	33 01
f	31
TF 1	61
GTO	22
4	04
g x⇄y	35 07
f^{-1}	32
D.MS+	02
↑	41
CLX	44
g x>y	35 24
2	02
4	04
f	31
D.MS+	02
RCL 5	34 05
g x⇄y	35 07
f	31

KEYS	CODE
D.MS+	02
STO 5	33 05
g LST X	35 00
LBL	23
4	04
f^{-1}	32
SF 1	51
DSP	21
•	83
4	04
R/S	84
RCL 5	34 05
GTO	22
4	04
LBL	23
C	13
STO 3	33 03
GTO	22
0	00
LBL	23
D	14
STO 4	33 04
STO	33
+	61
6	06
RCL 6	34 06
GTO	22
0	00
LBL	23
E	15
RCL 4	34 04
RCL 3	34 03
÷	81
f	31
→D.MS	03

KEYS	CODE
RCL	34 01
f	31
D.MS+	02
2	02
4	04
g x>y	35 24
CLX	44
g NOP	35 01
f^{-1}	32
D.MS+	02
GTO	22
4	04
LBL	23
B	12
RCL 4	34 04
RCL 1	34 01
RCL 2	34 02
f^{-1}	32
D.MS+	02
f^{-1}	32
→D.MS	03
↑	41
CLX	44
g x>y	35 24
2	02
4	04
+	61
÷	81
GTO	22
0	00

R_1 t_{new}	R_4 DIST	R_7
R_2 t_{old}	R_5 Total time	R_8
R_3 GS	R_6 Total DIST	R_9 Used

DETERMINING IN-FLIGHT WINDS

KEYS	CODE	KEYS	CODE	KEYS	CODE
f	31	R/S	84	3	03
REG	43	LBL	23	÷	81
f^{-1}	32	D	14	g x⇄y	35 07
SF 1	51	STO 6	33 06	RCL 1	34 01
DSP	21	R/S	84	+	61
•	83	LBL	23	↑	41
4	04	E	15	CLX	44
CLX	44	RCL 3	34 03	g x>y	35 24
R/S	84	f^{-1}	32	3	03
LBL	23	R→P	01	6	06
A	11	STO 7	33 07	0	00
STO 1	33 01	g x⇄y	35 07	+	61
R/S	84	STO 8	33 08	•	83
LBL	23	RCL 2	34 02	5	05
B	12	RCL 6	34 06	+	61
f	31	RCL 5	34 05	f	31
INT	83	RCL 4	34 04	INT	83
STO 2	33 02	f^{-1}	32	+	61
g LST X	35 00	D.MS+	02	DSP	21
f^{-1}	32	f^{-1}	32	•	83
INT	83	→D.MS	03	3	03
EEX	43	÷	81	R/S	84
3	03	f^{-1}	32	g NOP	35 01
x	71	R→P	01	g NOP	35 01
STO 3	33 03	STO	33	g NOP	35 01
R/S	84	–	51	g NOP	35 01
LBL	23	7	07	g NOP	35 01
C	13	CLX	44	g NOP	35 01
STO 5	33 05	RCL 8	34 08	g NOP	35 01
f^{-1}	32	–	51	g NOP	35 01
TF 1	61	CHS	42		
STO 4	33 04	RCL 7	34 07		
g NOP	35 01	f	31		
f	31	R→P	01		
SF 1	51	EEX	43		

R_1 Variation	R_4 t_1	R_7 E_x
R_2 MAG course	R_5 t_2	R_8 E_y
R_3 TAS	R_6 DIST	R_9 Used

STANDARD ATMOSPHERE (0 –36089 FEET)

KEYS	CODE
R/S	84
LBL	23
A	11
3	03
6	06
0	00
8	08
9	09
g x≤y	35 22
0	00
÷	81
g R↓	35 08
STO 1	33 01
2	02
8	08
8	08
•	83
1	01
5	05
STO 3	33 03
RCL 1	34 01
RTN	24
LBL	23
B	12
1	01
5	05
RCL 1	34 01
1	01
9	09
8	08
1	01
EEX	43
CHS	42
6	06
x	71

KEYS	CODE
–	51
RTN	24
LBL	23
C	13
B	12
2	02
7	07
3	03
•	83
1	01
5	05
+	61
RCL 3	34 03
÷	81
f	31
$\sqrt{x}$	09
RTN	24
LBL	23
D	14
RCL 3	34 03
RCL 1	34 01
1	01
9	09
8	08
1	01
EEX	43
CHS	42
6	06
x	71
–	51
STO 4	33 04
RCL 3	34 03
÷	81
5	05
•	83

KEYS	CODE
2	02
5	05
6	06
3	03
g	35
y^x	05
STO 6	33 06
RTN	24
LBL	23
E	15
D	14
RCL 3	34 03
x	71
RCL 4	34 04
÷	81
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 h	R_4 T(K)	R_7
R_2	R_5	R_8
R_3 288.15	R_6 P/P_0	R_9 Used

STANDARD ATMOSPHERE (36089 – 82,000 FEET)

KEYS	CODE
R/S	84
LBL	23
A	11
3	03
6	06
0	00
8	08
9	09
STO 5	33 05
g x>y	35 24
0	00
÷	81
g R↓	35 08
STO 1	33 01
2	02
8	08
8	08
•	83
1	01
5	05
STO 3	33 03
RCL 1	34 01
RTN	24
LBL	23
B	12
5	05
6	06
•	83
5	05
CHS	42
RTN	24
LBL	23
C	13
•	83
8	08

KEYS	CODE
6	06
7	07
1	01
RTN	24
LBL	23
D	14
RCL 1	34 01
RCL 5	34 05
–	51
2	02
0	00
8	08
0	00
4	04
•	83
9	09
÷	81
CHS	42
f^{-1}	32
LN	07
•	83
2	02
2	02
3	03
4	04
x	71
STO 6	33 06
RTN	24
LBL	23
E	15
D	14
RCL 3	34 03
x	71
2	02
1	01

KEYS	CODE
6	06
•	83
6	06
5	05
÷	81
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

$\mathbf{R_1}$ h	$\mathbf{R_4}$	$\mathbf{R_7}$
$\mathbf{R_2}$	$\mathbf{R_5}$ 36089	$\mathbf{R_8}$
$\mathbf{R_3}$ 288.15	$\mathbf{R_6}$ P/P_0	$\mathbf{R_9}$ Used

MACH NUMBER AND TRUE AIRSPEED

KEYS	CODE
3	03
5	05
6	06
6	06
EEX	43
CHS	42
6	06
x	71
CHS	42
5	05
1	01
8	08
•	83
6	06
7	07
+	61
g LST X	35 00
÷	81
5	05
•	83
2	02
5	05
6	06
3	03
g	35
y^x	05
STO 6	33 06
RTN	24
LBL	23
B	12
6	06
6	06
1	01
•	83
5	05

KEYS	CODE
÷	81
E	15
3	03
•	83
5	05
g	35
y^x	05
1	01
−	51
RCL 6	34 06
÷	81
1	01
+	61
•	83
2	02
8	08
6	06
g	35
y^x	05
1	01
−	51
5	05
x	71
f	31
$\sqrt{x}$	09
STO 4	33 04
RTN	24
LBL	23
C	13
STO 3	33 03
RTN	24
LBL	23
D	14
2	02
7	07

KEYS	CODE
3	03
+	61
STO 5	33 05
RCL 4	34 04
E	15
÷	81
RCL 5	34 05
−	51
RCL 3	34 03
x	71
RCL 5	34 05
+	61
f	31
$\sqrt{x}$	09
3	03
9	09
x	71
RCL 4	34 04
x	71
RTN	24
LBL	23
E	15
↑	41
x	71
•	83
2	02
x	71
1	01
+	61
RTN	24

R_1	R_4 M	R_7
R_2	R_5 IT (K)	R_8
R_3 C_T	R_6 P/P_0	R_9

TRUE AIR TEMPERATURE AND DENSITY ALTITUDE

KEYS	CODE	KEYS	CODE	KEYS	CODE
•	83	RTN	24	1	01
8	08	LBL	23	5	05
STO 3	33 03	D	14	+	61
R/S	84	2	02	x	71
LBL	23	7	07	RCL 5	34 05
A	11	3	03	÷	81
STO 4	33 04	•	83	•	83
RTN	24	1	01	2	02
LBL	23	5	05	3	03
B	12	STO 6	33 06	5	05
STO 3	33 03	+	61	g	35
RTN	24	STO 5	33 05	y^x	05
LBL	23	RTN	24	CHS	42
C	13	LBL	23	1	01
D	14	E	15	+	61
RCL 4	34 04	6	06	1	01
↑	41	•	83	4	04
x	71	8	08	5	05
•	83	7	07	3	03
2	02	9	09	6	06
0	00	EEX	43	6	06
5	05	CHS	42	x	71
x	71	6	06	RTN	24
1	01	x	71	g NOP	35 01
+	61	CHS	42	g NOP	35 01
÷	81	1	01	g NOP	35 01
RCL 5	34 05	+	61	g NOP	35 01
−	51	5	05	g NOP	35 01
RCL 3	34 03	•	83	g NOP	35 01
x	71	2	02	g NOP	35 01
RCL 5	34 05	5	05		
+	61	6	06		
STO 5	33 05	g	35		
RCL 6	34 06	y^x	05		
−	51	RCL 6	34 06		

R_1	R_4 M	R_7
R_2	R_5 T(k)	R_8
R_3 C_T	R_6 273.15	R_9

LOWEST USABLE FLIGHT LEVEL

KEYS	CODE
f	31
STK	42
STO 8	33 08
R/S	84
LBL	23
A	11
STO 8	33 08
R/S	84
LBL	23
B	12
RCL 8	34 08
R/S	84
LBL	23
C	13
2	02
9	09
•	83
9	09
2	02
RCL 8	34 08
g x>y	35 24
g x⇄y	35 07
g NOP	35 01
↑	41
+	61
6	06
0	00
•	83
8	08
2	02
g x⇄y	35 07
—	51
f	31
INT	83
5	05

KEYS	CODE
0	00
0	00
x	71
1	01
8	08
EEX	43
3	03
+	61
R/S	84
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
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g NOP	35 01
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g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
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g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1	R_4	R_7
R_2	R_5	R_8 ALT Set
R_3	R_6	R_9 Used

GREAT CIRCLE PLOTTING

KEYS	CODE
f^{-1}	32
→D.MS	03
RCL 1	34 01
STO 2	33 02
g $x \rightleftarrows y$	35 07
STO 1	33 01
RTN	24
LBL	23
B	12
f^{-1}	32
→D.MS	03
RCL 3	34 03
STO 4	33 04
g $x \rightleftarrows y$	35 07
STO 3	33 03
RTN	24
LBL	23
C	13
f^{-1}	32
→D.MS	03
STO 7	33 07
RCL 4	34 04
RCL 1	34 01
E	15
RCL 7	34 07
RCL 3	34 03
RCL 2	34 02
E	15
−	51
RCL 4	34 04
RCL 7	34 07
RCL 1	34 01
E	15
−	51
RCL 3	34 03

KEYS	CODE
RCL 7	34 07
RCL 2	34 02
E	15
+	61
RCL 3	34 03
RCL 4	34 04
−	51
f	31
SIN	04
÷	81
f^{-1}	32
TAN	06
STO 8	33 08
f	31
→D.MS	03
RTN	24
LBL	23
E	15
f	31
TAN	06
g $x \rightleftarrows y$	35 07
f	31
COS	05
x	71
g $x \rightleftarrows y$	35 07
f	31
SIN	04
x	71
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1	LAT_D	**R_4**	LNG_S	**R_7**	LNG_I
R_2	LAT_S	**R_5**		**R_8**	Used LAT_I
R_3	LNG_D	**R_6**		**R_9**	Used

RHUMBLINE NAVIGATION

KEYS	CODE
f^{-1}	32
→D.MS	03
RCL 1	34 01
STO 2	33 02
g x⇄y	35 07
STO 1	33 01
2	02
÷	81
4	04
5	05
+	61
f	31
TAN	06
f	31
LN	07
RCL 5	34 05
STO 6	33 06
g x⇄y	35 07
STO 5	33 05
RCL 1	34 01
RTN	24
LBL	23
B	12
f^{-1}	32
→D.MS	03
RCL 3	34 03
STO 4	33 04
g x⇄y	35 07
STO 3	33 03
RTN	24
LBL	23
D	14
RCL 4	34 04
RCL 3	34 03
–	51

KEYS	CODE
STO 7	33 07
2	02
÷	81
f	31
SIN	04
f^{-1}	32
SIN	04
9	09
0	00
÷	81
g	35
π	02
x	71
RCL 5	34 05
RCL 6	34 06
–	51
f	31
R→P	01
g R↓	35 08
STO 8	33 08
RCL 7	34 07
f	31
SIN	04
f^{-1}	32
SIN	04
0	00
g x>y	35 24
3	03
6	06
0	00
RCL 8	34 08
g	35
ABS	06
–	51
g	35

KEYS	CODE
ABS	06
RTN	24
LBL	23
C	13
D	14
RCL 7	34 07
RCL 1	34 01
f	31
COS	05
x	71
RCL 1	34 01
RCL 2	34 02
–	51
RCL 8	34 08
f	31
COS	05
0	00
g x≠y	35 21
g R↓	35 08
÷	81
g x=y	35 23
g R↑	35 09
g NOP	35 01
6	06
0	00
x	71
g	35
ABS	06
RTN	24
g NOP	35 01

R_1 LAT_D	R_4 LNG_S	R_7 LNG_S LNG_D
R_2 LAT_S	R_5 Used	R_8 HDG
R_3 LNG_D	R_6 Used	R_9 Used

GREAT CIRCLE NAVIGATION

KEYS	CODE
f^{-1}	32
SF 1	51
f	31
REG	43
CLX	44
g	35
DEG	41
R/S	84
LBL	23
A	11
f^{-1}	32
→D.MS	03
RCL 1	34 01
STO 2	33 02
g x⇄y	35 07
STO 1	33 01
R/S	84
LBL	23
B	12
f^{-1}	32
→D.MS	03
RCL 3	34 03
STO 4	33 04
g x⇄y	35 07
STO 3	33 03
R/S	84
LBL	23
C	13
RCL 4	34 04
RCL 3	34 03
−	51
↑	41
f	31
SIN	04
0	00

KEYS	CODE
g x>y	35 24
f	31
SF 1	51
+	61
CLX	44
+	61
f	31
COS	05
RCL 2	34 02
f	31
COS	05
STO 6	33 06
x	71
RCL 1	34 01
f	31
COS	05
x	71
RCL 1	34 01
f	31
SIN	04
STO 7	33 07
RCL 2	34 02
f	31
SIN	04
STO 8	33 08
x	71
+	61
f^{-1}	32
COS	05
↑	41
↑	41
6	06
0	00
x	71
RTN	24

KEYS	CODE
LBL	23
D	14
3	03
6	06
0	00
C	13
g R↓	35 08
↑	41
f	31
COS	05
RCL 8	34 08
x	71
RCL 7	34 07
g x⇄y	35 07
−	51
g x⇄y	35 07
f	31
SIN	04
÷	81
RCL 6	34 06
÷	81
f^{-1}	32
COS	05
f	31
TF 1	61
−	51
g NOP	35 01
f^{-1}	32
SF 1	51
R/S	84

R_1 LAT_D	R_4 LNG_S	R_7 Used
R_2 LAT_S	R_5 0	R_8 Used
R_3 LNG_D	R_6 Used	R_9 Used

POSITION GIVEN HEADING, SPEED AND TIME

KEYS	CODE
f^{-1}	32
→D.MS	03
RCL 4	34 04
STO 2	33 02
g x⇄y	35 07
STO 4	33 04
RTN	24
LBL	23
B	12
STO 5	33 05
RTN	24
LBL	23
C	13
STO 6	33 06
RTN	24
LBL	23
D	14
f^{-1}	32
→D.MS	03
RCL 6	34 06
x	71
STO 7	33 07
RCL 5	34 05
f	31
COS	05
x	71
6	06
0	00
÷	81
RCL 2	34 02
+	61
f	31
SIN	04
f^{-1}	32
SIN	04

KEYS	CODE
STO 1	33 01
E	15
RCL 2	34 02
E	15
g x=y	35 23
GTO	22
1	01
−	51
RCL 5	34 05
f	31
TAN	06
x	71
g	35
π	02
÷	81
1	01
8	08
0	00
x	71
GTO	22
2	02
LBL	23
1	01
RCL 7	34 07
RCL 2	34 02
f	31
COS	05
÷	81
6	06
0	00
÷	81
LBL	23
2	02
CHS	42
RCL 4	34 04

KEYS	CODE
+	61
1	01
f^{-1}	32
R→P	01
f	31
R→P	01
g R↓	35 08
STO 3	33 03
f	31
→D.MS	03
RTN	24
LBL	23
D	14
RCL 1	34 01
f	31
→D.MS	03
RTN	24
LBL	23
E	15
2	02
÷	81
4	04
5	05
+	61
f	31
TAN	06
f	31
LN	07
RTN	24
g NOP	35 01

R_1 LAT_D	R_4 LNG_S	R_7 DIST
R_2 LAT_S	R_5 HDG	R_8
R_3 LNG_D	R_6 Speed	R_9 Used

LINE OF SIGHT DISTANCE

KEYS	CODE
f	31
REG	43
f^{-1}	32
SF 1	51
6	06
0	00
7	07
6	06
STO 6	33 06
3	03
4	04
4	04
0	00
x	71
STO 7	33 07
1	01
R/S	84
LBL	23
A	11
STO 1	33 01
RCL 7	34 07
+	61
↑	41
x	71
STO 8	33 08
RCL 1	34 01
R/S	84
LBL	23
B	12
STO 2	33 02
RCL 7	34 07
+	61
↑	41
x	71
STO 4	33 04

KEYS	CODE
RCL 2	34 02
R/S	84
LBL	23
E	15
f	31
SF 1	51
R/S	84
LBL	23
C	13
RCL 7	34 07
+	61
↑	41
x	71
f^{-1}	32
TF 1	61
STO 3	33 03
R/S	84
RCL 4	34 04
RCL 8	34 08
−	51
f	31
$\sqrt{x}$	09
RCL 5	34 05
−	51
RCL 8	34 08
f	31
$\sqrt{x}$	09
f	31
R→P	01
RCL 7	34 07
−	51
f^{-1}	32
SF 1	51
R/S	84
LBL	23

KEYS	CODE
D	14
RCL 6	34 06
x	71
f^{-1}	32
TF 1	61
STO 5	33 05
R/S	84
RCL 4	34 04
RCL 8	34 08
−	51
f	31
$\sqrt{x}$	09
RCL 3	34 03
RCL 8	34 08
−	51
f	31
$\sqrt{x}$	09
+	61
RCL 6	34 06
÷	81
f^{-1}	32
SF 1	51
R/S	84
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 TER	R_4 $(XTMR + R)^2$	R_7 R = 20901440
R_2 XTMR	R_5 DIST(ft)	R_8 $(TER + R)^2$
R_3 $(ALT + R)^2$	R_6 6076	R_9 Used

POSITION BY TWO VORS

KEYS	CODE
DSP	21
•	83
0	00
R/S	84
LBL	23
A	11
STO 1	33 01
RTN	24
LBL	23
B	12
STO 2	33 02
RTN	24
LBL	23
C	13
STO 3	33 03
RTN	24
LBL	23
D	14
STO 4	33 04
RTN	24
LBL	23
E	15
RCL 2	34 02
RCL 4	34 04
−	51
f	31
SIN	04
RCL 3	34 03
x	71
RCL 2	34 02
RCL 1	34 01
−	51
f	31
SIN	04
÷	81

KEYS	CODE
g	35
ABS	06
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 R_1	R_4 HDG_{12}	R_7
R_2 R_2	R_5	R_8
R_3 $DIST_{12}$	R_6	R_9 Used

NAVIGATION BY TWO VORS

KEYS	CODE
DSP	21
•	83
0	00
R/S	84
LBL	23
A	11
STO 1	33 01
RTN	24
LBL	23
A	11
STO 2	33 02
RTN	24
LBL	23
B	12
STO 3	33 03
RTN	24
LBL	23
C	13
STO 4	33 04
RTN	24
LBL	23
D	14
STO 5	33 05
RTN	24
LBL	23
D	14
STO 6	33 06
RTN	24
LBL	23
E	15
RCL 3	34 03
RCL 1	34 01
RCL 2	34 02
–	51
f	31

KEYS	CODE
SIN	04
÷	81
RCL 2	34 02
RCL 4	34 04
–	51
f	31
SIN	04
x	71
g	35
ABS	06
2	02
7	07
0	00
RCL 1	34 01
–	51
g x⇄y	35 07
f^{-1}	32
R→P	01
STO 7	33 07
g x⇄y	35 07
STO 8	33 08
9	09
0	00
RCL 5	34 05
–	51
RCL 6	34 06
f^{-1}	32
R→P	01
STO	33
+	61
7	07
g x⇄y	35 07
STO	33
+	61
8	08

KEYS	CODE
RCL 8	34 08
RCL 7	34 07
f	31
R→P	01
g x⇄y	35 07
9	09
0	00
g x⇄y	35 07
–	51
0	00
g x⇄y	35 07
g x≤y	35 22
3	03
6	06
0	00
+	61
STO 7	33 07
g R↓	35 08
g R↓	35 08
STO 8	33 08
RCL 7	34 07
RTN	24
LBL	23
E	15
RCL 8	34 08
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 R_1	R_4 HDG_{12}	R_7 Σx, HDG
R_2 R_2	R_5 HDG_{1D}	R_8 Σy, DIST
R_3 $DIST_{12}$	R_6 $DIST_{1D}$	R_9 Used

POSITION BY ONE VOR

KEYS	CODE
CLX	44
STO 1	33 01
STO 2	33 02
g	35
DEG	41
R/S	84
LBL	23
A	11
STO 2	33 02
RTN	24
LBL	23
A	11
STO 1	33 01
RTN	24
LBL	23
B	12
STO 4	33 04
RTN	24
LBL	23
B	12
STO 3	33 03
RTN	24
LBL	23
C	13
RCL 6	34 06
STO 5	33 05
g x⇄y	35 07
STO 6	33 06
RTN	24
LBL	23
D	14
RCL 8	34 08
STO 7	33 07
g x⇄y	35 07
STO 8	33 08

KEYS	CODE
RTN	24
LBL	23
E	15
RCL 2	34 02
f	31
INT	83
RCL 1	34 01
−	51
RCL 2	34 02
f^{-1}	32
INT	83
EEX	43
2	02
x	71
CHS	42
f^{-1}	32
R→P	01
RCL 4	34 04
RCL 3	34 03
f^{-1}	32
R→P	01
g x⇄y	35 07
g R↑	35 09
+	61
g R↓	35 08
+	61
g R↑	35 09
g x⇄y	35 07
f	31
R→P	01
RCL 6	34 06
RCL 5	34 05
f^{-1}	32
D.MS+	02
f^{-1}	32

KEYS	CODE
→D.MS	03
↑	41
CLX	44
g x>y	35 24
2	02
4	04
+	61
x	71
g x⇄y	35 07
RCL 7	34 07
−	51
f	31
SIN	04
x	71
RCL 7	34 07
RCL 8	34 08
−	51
f	31
SIN	04
÷	81
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 V	R_4 HDG	R_7 R_1
R_2 DDD.KK	R_5 t_1	R_8 R_2
R_3 TAS	R_6 t_2	R_9 Used

DME SPEED CORRECTION

KEYS	CODE
DSP	21
•	83
0	00
R/S	84
LBL	23
A	11
STO 1	33 01
RTN	24
LBL	23
B	12
STO 2	33 02
RTN	24
LBL	23
C	13
RCL 2	34 02
RCL 1	34 01
–	51
f	31
COS	05
÷	81
g	35
ABS	06
STO 3	33 03
RTN	24
LBL	23
D	14
STO 4	33 04
RTN	24
LBL	23
E	15
↑	41
6	06
0	00
7	07
6	06

KEYS	CODE
÷	81
↑	41
x	71
RCL 4	34 04
↑	41
x	71
+	61
f	31
$\sqrt{x}$	09
RCL 4	34 04
÷	81
RCL 3	34 03
x	71
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
gNOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 C	R_4 DIST	R_7
R_2 D	R_5	R_8
R_3 GS	R_6	R_9 Used

AVERAGE WIND VECTOR

KEYS	CODE
DSP	21
•	83
2	02
f	31
REG	43
CLX	44
R/S	84
LBL	23
A	11
STO 7	33 07
↑	41
f^{-1}	32
INT	83
STO 2	33 02
–	51
STO 3	33 03
RCL 7	34 07
RTN	24
LBL	23
B	12
STO 7	33 07
STO	33
+	61
1	01
RCL 2	34 02
x	71
RCL 3	34 03
g x⇄y	35 07
f^{-1}	32
R→P	01
STO	33
+	61
4	04
g x⇄y	35 07
STO	33

KEYS	CODE
+	61
5	05
RCL 7	34 07
RTN	24
LBL	23
C	13
RCL 5	34 05
RCL 1	34 01
÷	81
RCL 4	34 04
RCL 1	34 01
÷	81
f	31
R→P	01
STO 6	33 06
g R↓	35 08
STO 7	33 07
↑	41
CLX	44
g x>y	35 24
3	03
6	06
0	00
+	61
•	83
5	05
+	61
f	31
INT	83
RCL 6	34 06
+	61
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 Sum D	R_4 E_x	R_7 Used
R_2 v/100	R_5 E_y	R_8 0
R_3 0	R_6 Ave. v/100	R_9 Used

COURSE CORRECTION

KEYS	CODE
f	31
REG	43
f	31
STK	42
R/S	84
LBL	23
A	11
STO 1	33 01
RTN	24
LBL	23
B	12
STO 4	33 04
RTN	24
LBL	23
C	13
STO 2	33 02
RTN	24
LBL	23
D	14
STO 3	33 03
RTN	24
LBL	23
E	15
RCL 2	34 02
0	00
g x⩽y	35 22
GTO	22
3	03
RCL 2	34 02
↑	41
x	71
RCL 1	34 01
↑	41
x	71
−	51

KEYS	CODE
f	31
$\sqrt{x}$	09
↑	41
LBL	23
3	03
g R↓	35 08
STO 5	33 05
RCL 4	34 04
−	51
↑	41
x	71
RCL 1	34 01
↑	41
x	71
+	61
f	31
$\sqrt{x}$	09
STO 6	33 06
RCL 1	34 01
g x⇄y	35 07
÷	81
f	32
SIN	04
STO 7	33 07
0	00
RCL 3	34 03
g x>y	35 24
GTO	22
1	01
CHS	42
RCL 1	34 01
RCL 5	34 05
÷	81
f^{-1}	32
TAN	06

KEYS	CODE
+	61
LBL	23
1	01
RCL 7	34 07
+	61
STO 8	35 08
3	03
6	06
0	00
g x⩽y	35 22
−	51
STO 8	33 08
0	00
RCL 8	34 08
g x⩽y	35 22
3	03
6	06
0	00
+	61
STO 8	33 08
RTN	24
LBL	23
E	15
RCL 8	34 06
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 DOC	R_4 T-DIST	R_7 Correction
R_2 −D FLN or DTCP	R_5 DTCP	R_8 HDG
R_3 −H FLN or H INI	R_6 DTG	R_9 Used

TIME OF SUNRISE (CARD 1)

KEYS	CODE
LBL	23
A	11
STO 1	33 01
R/S	84
LBL	23
B	12
STO 2	33 02
R/S	84
LBL	23
C	13
STO 3	33 03
R/S	84
LBL	23
D	14
STO 4	33 04
R/S	84
LBL	23
E	15
3	03
0	00
•	83
3	03
RCL 2	34 02
1	01
–	51
x	71
RCL 1	34 01
+	61
1	01
–	51
•	83
9	09
8	08
8	08
x	71

KEYS	CODE
STO 5	33 05
8	08
7	07
+	61
f	31
COS	05
•	83
1	01
2	02
3	03
x	71
RCL 5	34 05
↑	41
+	61
2	02
0	00
+	61
f	31
SIN	04
6	06
÷	81
–	51
CHS	42
RCL 5	34 05
1	01
0	00
+	61
f	31
COS	05
2	02
3	03
•	83
5	05
x	71
f	31

KEYS	CODE
TAN	06
RCL 3	34 03
f^{-1}	32
→D.MS	03
f	31
TAN	06
x	71
f^{-1}	32
COS	05
CHS	42
RCL 4	34 04
f^{-1}	32
→D.MS	03
+	61
1	01
5	05
÷	81
+	61
1	01
2	02
+	61
↑	41
CLX	44
g $x>y$	35 24
2	02
4	04
+	61
f	31
→D.MS	03
R/S	84

R_1 Day	R_4 LNG	R_7
R_2 Month	R_5 t	R_8
R_3 LAT	R_6	R_9 Used

TIME OF SUNSET (CARD 2)

KEYS	CODE
LBL	23
A	11
STO 1	33 01
R/S	84
LBL	23
B	12
STO 2	33 02
R/S	84
LBL	23
C	13
STO 3	33 03
R/S	84
LBL	23
D	14
STO 4	33 04
R/S	84
LBL	23
E	15
3	03
0	00
•	83
3	03
RCL 2	34 02
1	01
–	51
x	71
RCL 1	34 01
+	61
1	01
–	51
•	83
9	09
8	08
8	08
x	71

KEYS	CODE
STO 5	33 05
8	08
7	07
+	61
f	31
COS	05
•	83
1	01
2	02
3	03
x	71
RCL 5	34 05
↑	41
+	61
2	02
0	00
+	61
f	31
SIN	04
6	06
÷	81
–	51
CHS	42
RCL 5	34 05
1	01
0	00
+	61
f	31
COS	05
2	02
3	03
•	83
5	05
x	71
f	31

KEYS	CODE
TAN	06
RCL 3	34 03
f^{-1}	32
→D.MS	03
f	31
TAN	06
x	71
f^{-1}	32
COS	05
RCL 4	34 04
f^{-1}	32
→D.MS	03
+	61
1	01
5	05
÷	81
+	61
1	01
2	02
+	61
2	02
4	04
g x>y	35 24
↑	41
–	51
–	51
f	31
→D.MS	03
R/S	84
g NOP	35 01

R_1 Day	R_4 LNG	R_7
R_2 Month	R_5 t	R_8
R_3 LAT	R_6	R_9 Used

AZIMUTH OF SUNRISE AND SUNSET

KEYS	CODE
f^{-1}	32
SF 1	51
STO 1	33 01
R/S	84
LBL	23
B	12
STO 2	33 02
R/S	84
LBL	23
C	13
STO 3	33 03
R/S	84
LBL	23
D	14
RCL 2	34 02
•	83
4	04
x	71
2	02
•	83
3	03
+	61
f	31
INT	83
STO 8	33 08
2	02
RCL 2	34 02
g x≤y	35 22
CLX	44
STO 8	33 08
RCL 1	34 01
RCL 8	34 08
–	51
RCL 2	34 02
1	01

KEYS	CODE
–	51
3	03
1	01
x	71
+	61
•	83
9	09
8	08
6	06
x	71
9	09
•	83
6	06
6	06
+	61
f	31
COS	05
2	02
3	03
•	83
5	05
x	71
CHS	42
•	83
5	05
+	61
f	31
SIN	04
RCL 3	34 03
f^{-1}	32
→D.MS	03
f	31
COS	05
÷	81
f^{-1}	32

KEYS	CODE
COS	05
3	03
6	06
0	00
g x⇄y	35 07
f	31
TF 1	61
–	51
g NOP	35 01
f^{-1}	32
SF 1	51
R/S	84
LBL	23
E	15
f	31
SF 1	51
GTO	22
D	14
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1 Day	R_4	R_7
R_2 Month	R_5	R_8 0.4 m+ 2.3
R_3 LAT	R_6	R_9 Used

PILOT UNIT CONVERSIONS

KEYS	CODE
f^{-1}	32
SF 1	51
f	31
STK	42
R/S	84
LBL	23
A	11
↑	41
f	31
TF 1	61
GTO	22
1	01
3	03
2	02
—	51
1	01
•	83
8	08
÷	81
RTN	24
LBL	23
1	01
1	01
•	83
8	08
x	71
3	03
2	02
+	61
f^{-1}	32
SF 1	51
RTN	24
LBL	23
B	12
↑	41

KEYS	CODE
•	83
8	08
6	06
8	08
9	09
7	07
8	08
f^{-1}	32
TF 1	61
x	71
RTN	24
÷	81
f^{-1}	32
SF 1	51
RTN	24
LBL	23
C	13
↑	41
•	83
2	02
6	06
4	04
2	02
f^{-1}	32
TF 1	61
x	71
RTN	24
÷	81
f^{-1}	32
SF 1	51
RTN	24
LBL	23
D	14
↑	41
6	06

KEYS	CODE
f^{-1}	32
TF 1	61
x	71
RTN	24
÷	81
f^{-1}	32
SF 1	51
RTN	24
LBL	23
E	15
f	31
SF 1	51
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1	R_4	R_7
R_2	R_5	R_8
R_3	R_6	R_9

CUSTOMIZED UNIT CONVERSION

KEYS	CODE
0	00
STO 8	33 08
R/S	84
LBL	23
A	11
g	35
DSZ	83
g	35
$^1/x$	04
÷	81
RTN	24
LBL	23
B	12
g	35
DSZ	83
g	35
$^1/x$	04
÷	81
RTN	24
LBL	23
C	13
g	35
DSZ	83
g	35
$^1/x$	04
÷	81
RTN	24
LBL	23
D	14
g	35
DSZ	83
g	35
$^1/x$	04
÷	81
RTN	24

KEYS	CODE
LBL	23
E	15
1	01
STO 8	33 08
g R↓	35 08
RTN	24
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

KEYS	CODE
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01
g NOP	35 01

R_1	R_4	R_7
R_2	R_5	R_8 Used
R_3	R_6	R_9

HEWLETT PACKARD

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