HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions

Aeronautical Engineering

INTRODUCTION

In an effort to provide continued value to it's customers, Hewlett-Packard is introducing a unique service for the HP fully programmable calculator user. This service is designed to save you time and programming effort. As users are aware, Programmable Calculators are capable of delivering tremendous problem solving potential in terms of power and flexibility, but the real genie in the bottle is program solutions. HP's introduction of the first handheld programmable calculator in 1974 immediately led to a request for program **solutions** — hence the beginning of the HP-65 Users' Library. In order to save HP calculator customers time, users wrote their own programs and sent them to the Library for the benefit of other program users. In a short period of time over 5,000 programs were accepted and made available. This overwhelming response indicated the value of the program library and a Users' Library was then established for the HP-67/97 users.

To extend the value of the Users' Library, Hewlett-Packard is introducing a unique service—a service designed to save you time and money. The Users' Library has collected the best programs in the most popular categories from the HP-67/97 and HP-65 Libraries. These programs have been packaged into a series of low-cost books, resulting in substantial savings for our valued HP-67/97 users.

We feel this new software service will extend the capabilities of our programmable calculators and provide a great benefit to our HP-67/97 users.

A WORD ABOUT PROGRAM USAGE

Each program contained herein is reproduced on the standard forms used by the Users' Library. Magnetic cards are not included. The Program Description I page gives a basic description of the program. The Program Description II page provides a sample problem and the keystrokes used to solve it. The User Instructions page contains a description of the keystrokes used to solve problems in general and the options which are available to the user. The Program Listing I and Program Listing II pages list the program steps necessary to operate the calculator. The comments, listed next to the steps, describe the reason for a step or group of steps. Other pertinent information about data register contents, uses of labels and flags and the initial calculator status mode is also found on these pages. Following the directions in your HP-67 or HP-97 **Owners' Handbook and Programming Guide**, "Loading a Program" (page 134, HP-67; page 119, HP-97), key in the program from the Program Listing I and Program Listing II pages. A number at the top of the Program Listing indicates on which calculator the program was written (HP-67 or HP-97). If the calculator indicated differs from the calculator you will be using, consult Appendix E of your **Owner's Handbook** for the corresponding keycodes and keystrokes converting HP-67 to HP-97 keycodes and vice versa. No program conversion is necessary. The HP-67 and HP-97 are totally compatible, but some differences do occur in the keycodes used to represent some of the functions.

A program loaded into the HP-67 or HP-97 is not permanent—once the calculator is turned off, the program will not be retained. You can, however, permanently save any program by recording it on a blank magnetic card, several of which were provided in the Standard Pac that was shipped with your calculator. Consult your **Owner's Handbook** for full instructions. A few points to remember:

> The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.
>
> REMEMBER! To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

As a part of HP's continuing effort to provide value to our customers, we hope you will enjoy our newest concept.

TABLE OF CONTENTS

Program Description I

Program Title Properties of Air

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

This program computes properties of air at low pressures for a given temperature * in degrees Fahrenheit or Rankine.

The following properties are computed:

1. Specific heat ratio

   $k = 1/(1-R/J\ C_p)$

   where:

   R Universal gas constant

   J Mechanical equivalent of heat

2. Specific heat at constant pressure

   $C_p = 0.2478 - 4.2047 \times 10^{-5}T + 5.8 \times 10^{-8}T^2 - 1.49 \times 10^{-11}T^3$, Btu/lb. - °R

3. Specific heat at constant volume

   $C_v = C_p/k$, Btu/lb. - °R

4. Coefficient of viscosity

   $\mu = 7.4 \times 10^{-7}(T)^{1.5}/(T + 200)$, lbm./ft. - sec.

5. Absolute Rankine temperature

   $T = 459.7 + (T, °F)$, °R

* If temperature is in degrees Centigrade or Kelvin, use Temperature Conversion program (STD - 08A) from Standard Pac to convert to degrees Fahrenheit or Rankine.

Operating Limits and Warnings

Properties k, C_p, C_v and μ are good for temperature and pressure ranges of 300 - 2000 °R and 0 - 300 psia respectively.

Program Description II

Sketch(es)

Sample Problem(s)

Find the specific heat ratio, specific heat at constant pressure, specific heat at constant volume, coefficient of viscosity, and absolute Rankine temperature for air at a temperature of 300 degrees Fahrenheit.

k = 1.3930

C_p = 0.2428 Btu/lb. -°R

C_v = 0.1743 Btu/lb. -°R

μ = 1.6146 x 10^{-5} lbm./ft. -sec.

T = 759.70°R

Solution(s)

Keystrokes:		Outputs:
300[E] [A]	---------------------------->	1.3930
300[E] [B]	---------------------------->	0.2428
300[E] [C]	---------------------------->	0.1743
300[E] [D]	---------------------------->	1.6146 x 10^{-5}
300[E]	---------------------------------->	759.70

Reference(s)

Keenan and Kay, Gas Tables, fifth printing, John Wiley & Sons, Inc., March, 1956. Hall, Newman A., Thermodynamics of Fluid Flow, Prentice-Hall, Inc., 1951.

This program is a translation of the Users' Library program #01078A submitted by Paul. K. Shumpert.

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter Program			
2	Compute Specific heat ratio	T, °R *	A	k
		T, °F	E A	"
	or			
2	Compute specific heat at constant pressure	T, °R *	B	C_p, Btu/lb.-°R
		T, °F	E B	"
	or			
2	Compute specific heat at constant volume	T, °R *	C	C_v, Btu/lb. °R
		T, °F	E C	"
	or			
2	Compute coefficient of viscosity	T, °R *	D	μ, lbm./ft. - sec.
		T, °F	E D	"
	or			
2	Compute absolute Rankine temperature	T, °F	E	T, °R
3	For a new case, repeat step 2			
	* Temperature can be input as °R or °F as shown.			
	Note: having calculated one of the variables			
	k, C_p, C_v, or u, to calculate a second:			
	Recall the temperature	T, °R	RCL 1	T, °R
	Go to step 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	Compute k
002	FIX	-11	T, °R
003	DSP4	-63 04	
004	STO1	35 01	
005	ENT↑	-21	
006	×	-35	
007	5	05	
008	.	-62	
009	8	08	
010	EEX	-23	
011	CHS	-22	
012	8	08	
013	×	-35	
014	.	-62	
015	2	02	
016	4	04	
017	7	07	
018	8	08	
019	+	-55	
020	RCL1	36 01	
021	2	02	
022	3	03	
023	7	07	
024	8	08	
025	3	03	
026	÷	-24	
027	-	-45	
028	1	01	
029	4	04	
030	9	09	
031	EEX	-23	
032	CHS	-22	
033	1	01	
034	3	03	
035	RCL1	36 01	
036	3	03	
037	Y^x	31	
038	×	-35	
039	-	-45	
040	STO2	35 02	C_p
041	1	01	
042	ENT↑	-21	
043	1	01	
044	ENT↑	-21	
045	.	-62	
046	0	00	
047	6	06	
048	8	08	
049	5	05	
050	RCL2	36 02	
051	÷	-24	
052	-	-45	
053	÷	-24	
054	RTN	24	
055	*LBLB	21 12	
056	GSBA	23 11	Compute C_p

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	RCL2	36 02	
058	RTN	24	
059	*LBLC	21 13	Compute C_v
060	GSBA	23 11	
061	RCL2	36 02	
062	X⇄Y	-41	
063	÷	-24	
064	RTN	24	
065	*LBLD	21 14	Compute μ
066	STO1	35 01	
067	1	01	
068	.	-62	
069	5	05	
070	Y^x	31	
071	RCL1	36 01	
072	2	02	
073	0	00	
074	0	00	
075	+	-55	
076	÷	-24	
077	7	07	
078	.	-62	
079	4	04	
080	EEX	-23	
081	CHS	-22	
082	7	07	
083	×	-35	
084	SCI	-12	
085	RTN	24	
086	*LBLE	21 15	
087	ENT↑	-21	Compute T, °R
088	4	04	
089	5	05	
090	9	09	
091	.	-62	
092	7	07	
093	+	-55	
094	FIX	-11	
095	RTN	24	
100			
110			

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	4

REGISTERS

0	1	2	3	4	5	6	7	8	9
	Used	Used							

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Standard Atmosphere Below 35,322 Feet

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables This program computes the theoretical U.S. Standard Atmosphere temperature and pressure in English and Metric units at altitudes below 35,332 feet and 11,000 meters. Additionally, the actual mean sea level values, at a specific time, can be placed in the program for prediction of altitude temperature and pressure based on the following formulas:

$$P = \frac{P_o}{\left(\frac{T_o}{T_o - aZ}\right)^n} \qquad T = T_o - aZ \qquad t = T - T \text{ abs reference}$$

P = Pressure at altitude above/below mean sea level.

P_o = Standard air pressure at mean sea level.

T_o = Standard absolute temperature at mean sea level in Rankine/Kelvin.

a = Temperature lapse rate per foot of altitude in ^oF/per meter ^oC.

Z = Altitude above/below mean sea level in feet/meters.

n = Constant G/aR = 5.2561

T = Temperature absolute at altitude in Rankine/Kelvin.

T abs ref. = 459.688 ^oR/ 273.16 ^oK.

t = Temperature at altitude in Fahrenheit/Centigrade

Operating Limits and Warnings 1. The program will accurately reproduce the theoretical U.S. Standard Atmosphere tables of temperature and pressure within the limits of -16,500 to 35,332 feet or -5,000 to 11,000 meters.

2. The correct temperature and pressure cannot be predicted under actual conditions when the temperature gradient is not linear, i.e. the lapse rate is not linear per foot of altitude.

Program Description II

Sketch(es)

Sample Problem(s)

1. What is the theoretical U.S. Standard Atmosphere pressure in inches of mercury, pounds per square foot, pounds per square inch, temperature in degrees Fahrenheit and degrees Rankine at an altitude of 30,000 feet?

2. What is the theoretical U.S. Standard Atmosphere pressure in millibars temperature in degrees centigrade and degrees Kelvin at an altitude of 11,000 meters?

1. Hg = 8.885413
   lbs/in^2 = 4.364107
   °F = -47.984800
   °R = 411.703200

2. mb = 226.319813
   °C = -56.500000
   °k = 216.660000

Solution(s)

Keystrokes:	Outputs:
1. [RTN] [f] [a] 30000[D] ----------------------------------->	8.885413
[E] --->	-47.984800
[RCL] [6] --->	411.703200
[f] [b] 3000[D] -->	4.364107
2. 1013.25[A] 288.16[B] .0065[C] 273.16[STO] [7]	
11000[D] -->	226.319813
[E] --->	-56.5000
[RCL] [6] --->	216.6600

Reference(s)

This program is a translation of the HP-65 Users' Library program #01148A submitted by William D. Staton.

User Instructions

STANDARD ATMOSPHERE BELOW 35,332 FEET

P_0	T_0	LR	ALT	t

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter Program				0.00
2	Initialize		RTN	R/S	0.000000
3	Automatic input of U.S. Standard Atmosphere		GTO	1	
	mean sea level values of Hg, temperature, lapse		R/S		459.688000
	rate plus reference temperature absolute.				
4	Input altitude and compute Hg.	Feet	D		Hg
5	Compute temperature °F at altitude.		E		°F
6	Recall °R at altitude.		RCL	6	°R
7	To recall input altitude in step 4		RCL	5	Feet
8	For new case change altitude input in step 4				
9	Convert program to compute LBS/IN^2 at altitude.		GTO	2	
			R/S		14.695949
10	Repeat steps 4 thru 8				
11	Convert program to compute LBS/FT^2 at altitude.	2116.216	A		2116.216
12	Repeat steps 4 thru 8				
13	To compute pressure and temperature based upon	Hg	A		Hg
	other than U.S. Standard Atmosphere, input				
	pressure reference at mean sea level.				
14	Input temperature reference at MSL.	°R	B		°R
15	Input temperature lapse rate per foot of	°F/FT.	C		°F/FT.
	altitude in °F.				
16	Repeat steps 4 thru 8.				
17	To compute the Standard Atmosphere in metric	1013.25	A		1013.25
	units, input millibars at MSL.				
18	Input temperature reference at MSL in °K.	288.16	B		288.16
19	Input lapse rate per meter in °C.	.0065	C		0.0065
20	Input temperature abs reference in °K	273.16	STO	7	273.16
21	Input altitude and compute pressure.	meters	D		mb
22	Compute temperature °C at altitude.		E		°C
23	Recall °K at altitude.		RCL	6	°K
24	For new case change altitude input in step 21.				

97 Program Listing I

Page of

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	2	02	Inputs U.S. Standards in program
003	9	09	
004	.	-62	
005	9	09	
006	2	02	
007	1	01	
008	2	02	
009	6	06	
010	STO1	35 01	Temperature at MSL in °R
011	5	05	
012	1	01	
013	8	08	
014	.	-62	
015	6	06	
016	8	08	
017	8	08	
018	STO2	35 02	
019	.	-62	Temperature lapse rate in °F per foot of H.
020	0	00	
021	0	00	
022	3	03	
023	5	05	
024	6	06	
025	6	06	
026	1	01	
027	6	06	
028	STO3	35 03	Temperature absolute at the melting point of ice under 29.92126 Hg minus 32 degrees.
029	4	04	
030	5	05	
031	9	09	
032	.	-62	
033	6	06	
034	8	08	
035	8	08	
036	STO7	35 07	
037	DSP6	-63 06	
038	RTN	24	
039	*LBLb	21 16 12	
040	1	01	Input lbs/in² for MSL reference pressure
041	4	04	
042	.	-62	
043	6	06	
044	9	09	
045	5	05	
046	9	09	
047	4	04	
048	8	08	
049	6	06	
050	1	01	
051	STO1	35 01	
052	RTN	24	
053	*LBLA	21 11	Input MSL ref. pressure.
054	STO1	35 01	
055	RTN	24	
056	*LBLB	21 12	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	STO2	35 02	Input MSL ref. temperature
058	RTN	24	
059	*LBLC	21 13	
060	STO3	35 03	Input temperature rate.
061	RTN	24	
062	*LBLD	21 14	
063	STO5	35 05	Input altitude for desired pressure and computes P_A.
064	RCL2	36 02	
065	ENT↑	-21	
066	ENT↑	-21	
067	RCL3	36 03	
068	RCL5	36 05	
069	×	-35	
070	-	-45	
071	STO6	35 06	
072	÷	-24	
073	5	05	
074	.	-62	
075	2	02	
076	5	05	
077	6	06	
078	1	01	
079	Y^x	31	
080	RCL1	36 01	
081	X⇄Y	-41	
082	÷	-24	
083	RTN	24	
084	*LBLE	21 15	
085	RCL6	36 06	Computes °F or °C at altitude.
086	RCL7	36 07	
087	-	-45	
088	RTN	24	
090			
100			
110			

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☒	SCI	☐
2	☐	☒	RAD	☒	ENG	☐
3	☐	☒			n	4

REGISTERS

0	1	2	3	4	5	6	7	8	9
	P_0 Ref.	T_0 Ref.	Lapse Rate		Alt.-H	Temp. at H °R/°K	T abs ref.		

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Aircraft Flyover Acoustic Tone Doppler Shift

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables Computes doppler shift of an aircraft fly-over acoustic source frequency observed on the ground. Also determines the 1/3 octave-band filter, and location within the filter, of the observed frequency. Inputs are flight path speed and angle, air temperature, source frequency, and aircraft elevation angle. Any input frequency can be located in the A.N.S.I.* 1/3 octave-band filters. Equations: See sketch on next page.

Doppler shift $f_0/f_s = 1/(1-M\cos\beta)$

Source angle $\beta = \theta + \alpha$

where
- f_0 is observed freq.
- f_s is source freq.
- M is Mach Number of source
- β=Source angle to observe

Mach number Mach = $V/(29.04\sqrt{t+459})$
- V=Flt. path speed, kts
- T=Air temp,°F

*Mid-frequency of 1/3 oct-band $f_m = 10^{N/10}$, N any integer

*Upper frequency of 1/3 oct-band $f_2 = 1.1225\ f_m$ (nominal band edge)

*American National Standards Institute

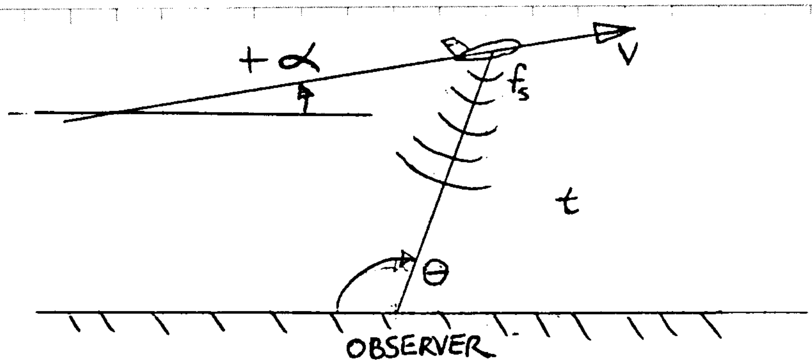
Operating Limits and Warnings 1/3 octave band filters start at f_m=50H_z which corresponds to N=17, ANSI convention. Minimum input frequency of 45 H_z.

f_m's are exact preferred frequencies, which are within 0.7% of nominal preferred frequencies.

The time required for filter band location is a function of the band no., 3 sec<time<34 sec for 17<N<40

Program Description II

Sketch(es)



Sample Problem(s) Air temperature t = 77°F

Given: Flight path angle α = -3°

Source tone frequency f_s = 687 H_z

Flight path speed V = 155 kts. (re to observer)

Calculate the Doppler shift, the observed frequency, the 1/3 oct. band filter position (f_0/f_m), the band number, and the filter mid-frequency for the following aircraft elevation angles.

θ_1 = 45 degrees

θ_2 = 90 degrees

θ_3 = 135 degrees

Aircraft Elev. Angle	θ_1 = 45°	θ_2 = 90°	θ_3 = 135°
f_0/f_s	1.21	1.01	0.87
f_0, H_z	829	695	595
f_0/f_m	1.04	1.10	0.94
Band No.	29	28	28
f_m, H_z	7.9×10^2 (nominal of 800)	6.3×10^2	6.3×10^2

Solutions:

Keystrokes: Output

77[ENT↑] 3[CHS] [A] 687[ENT↑] 155[B]

45[C] --->1.21[R/S] --->829.04[D] --->1.04[R/S] 29[R/S] 7.9 x 10^2

etc.

Reference(s)

1. Wood, A.B., A Textbook of Sound, pages 370B-372, G. Bell & Sons, London, 1957.
2. S1.11-1966, Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, page 12, American National Standards Institute, New York, 1966.

This program is a translation of the HP-65 Users' Library program #01291A submitted Edgar L. Zwieback.

User Instructions

FLYOVER ACOUSTIC DOPPLER

INPUT t,α	INPUT f_s,V	f_0/f_s	1/3 O-B	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1.	Enter program			
2.	Input air temperature	t,°F	↑	
3.	Input flight path angle (refer:Horz,+ is up)	α,Deg.	A	
4.	Input source (aircraft) tone freq.	f_s,H_z	↑	
5.	Input flight path speed (refer:observer)	V,kts	B	
6.	Input aircraft elevation angle (looking towards on-coming aircraft) and calculate Doppler shift freq. ratio	θ,Deg	C	f_0/f_s
7.	Calculate tone frequency received at OBS.		R/S	f_0,H_z
8.	Calculate 1/3 octave-band position of input freq.(ratio of input freq. to mid-freq. of appropriate band)	f,H_z	D	f/f_m
9.	Display filter band no.		R/S	N
10.	Display mid-freq. of band		R/S	f_m,H_z
	(For a set of θ's for a given flyover, it is only necessary to do steps 6 & 7, and steps 8-10 if desired)			
	(A change in t or α can be made without affecting f_s and V, and vice versa)			
	(The time required for step 8 is a function of of the value of f)			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	Input t,α
002	STO2	35 02	
003	X⇄Y	-41	
004	STO4	35 04	
005	X⇄Y	-41	
006	RTN	24	
007	*LBLB	21 12	Input f_s, V
008	STO3	35 03	
009	X⇄Y	-41	
010	STO6	35 06	
011	RTN	24	
012	*LBLC	21 13	
013	FIX	-11	Input & calc.
014	DSP2	-63 02	f_0/f_s
015	STO1	35 01	
016	RCL4	36 04	
017	4	04	
018	5	05	
019	9	09	
020	+	-55	
021	√X	54	
022	2	02	
023	9	09	
024	.	-62	
025	0	00	
026	4	04	
027	×	-35	
028	RCL3	36 03	
029	X⇄Y	-41	
030	÷	-24	
031	RCL1	36 01	
032	RCL2	36 02	
033	+	-55	
034	COS	42	
035	×	-35	
036	CHS	-22	
037	1	01	
038	+	-55	
039	1/X	52	
040	R/S	51	f_0/f_s Doppler shift
041	RCL6	36 06	
042	×	-35	
043	STO5	35 05	
044	RTN	24	
045	*LBLD	21 14	
046	STO5	35 05	
047	0	00	
048	STOI	35 46	
049	*LBL1	21 01	Calc. upper freq.
050	DSZI	16 25 46	f_z of 1/3 oct-
051	RCLI	36 46	ban filters
052	CHS	-22	
053	1	01	
054	6	06	
055	+	-55	
056	1	01	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	0	00	
058	÷	-24	
059	10^x	16 33	
060	STO7	35 07	
061	1	01	
062	.	-62	
063	1	01	
064	2	02	
065	2	02	
066	5	05	
067	×	-35	
068	RCL5	36 05	Compare f with f_z
069	X>Y?	16-34	
070	GTO1	22 01	
071	RCL7	36 07	
072	RCL5	36 05	
073	X⇄Y	-41	
074	÷	-24	f/f_m
075	R/S	51	
076	RCLI	36 46	
077	CHS	-22	
078	1	01	
079	6	06	
080	+	-55	Band no.
081	R/S	51	
082	RCL7	36 07	
083	SCI	-12	
084	DSP1	-63 01	f_m
085	RTN	24	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

REGISTERS

0	1	2	3	4	5	6	7	8	9
	θ,deg	α,deg	V,kts	t,°F	f_0/Hz	f_s,Hz	f_m,Hz	N	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title ISENTROPIC FLOW FOR IDEAL GASES

Contributor HEWLETT-PACKARD
Address 1000 N. E. Circle Blvd.
City Corvallis, Oregon **State** **Zip Code** 97330

Program Description, Equations, Variables

This card replaces isentropic flow tables for a specified specific heat ratio k. Inputs and outputs are interchangeable with the exception of k.

The following values are correlated:

- M is the Mach number;
- T/T_0 is the ratio of flow temperature T to stagnation or zero velocity temperature T_0;
- P/P_0 is the ratio of flow pressure P to stagnation pressure P_0;
- ρ/ρ_0 is the ratio of flow density ρ to stagnation density ρ_0;
- A/A^*_{sub} and A/A^*_{sup} are the ratios of flow area A to the throat area A* in converging—diverging passages. A/A^*_{sub} refers to subsonic flow while A/A^*_{sup} refers to supersonic flow.

Equations:

$$T/T_0 = \frac{2}{2 + (k - 1)\,M^2}$$

$$P/P_0 = (T/T_0)^{k/(k-1)}$$

$$\rho/\rho_0 = (T/T_0)^{1/(k-1)}$$

$$A/A^* = \frac{1}{M}\left[\left(\frac{2}{k+1}\right)\left(1 + \frac{k-1}{2}\,M^2\right)\right]^{\frac{k+1}{2(k-1)}}$$

In the last equation M^2 is determined using Newton's method. The initial guess used is as follows with a positive exponent for supersonic flow:

$$M_0^2 = (\sqrt{\text{Frac}\,(A/A^*)} + A/A^*)^{\pm 3}$$

Operating Limits and Warnings

Remarks:

After an input of A/A*, the program begins to iterate to find M^2 for future use. This iteration will normally take less than one minute, but may take longer on occasion. For extreme values of k (1.4 is optimum) the routine may fail to converge at all. An "Error" message will eventually halt the routine if it goes out of control.

Program Description I

Program Title

Contributor's Name

Address

City **State** **Zip Code**

Program Description, Equations, Variables

A/A* values of 1.00 are illegal inputs. Instead, input an M of 1.00.

The calculator uses flag 3 to decide whether to store or calculate a value. If you use the data input keys (setting flag 3) and then wish to calculate a parameter based on a prior input, clear flag 3 before pressing the appropriate user definable keys.

Registers R_0, R_5 and R_{S0}–R_I are available for user storage.

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Solution(s)

Example 1:

A pilot is flying at Mach 0.93 and reads on air temperature of 15 degrees Celsius (288 K) on a thermometer that reads stagnation temperature T_0. What is the true temperature assuming that k = 1.38?

Keystrokes:	Outputs:	
1.38 [f] [A] →	1.380	
.93 [A] →	0.930	
[B] →	0.859	(T/T_0)
288 [×] →	247.352	(T, K)
273 [−] →	−25.648	(T, °C)

If the same pilot reads a stagnation pressure P_0 of 700 millimeters of mercury, what is the true air pressure?

(Since the data input flag was set when 288 was keyed in, we must either clear it, or input 0.93 again.)

.93 [A] [C] →	0.575	(P/P_0)
700 [×] →	402.843	(mm Hg)

Example 2:

A converging, diverging passage has supersonic flow in the diverging section. At an area ratio A/A* of 1.60, what are the isentropic flow ratios for temperature, pressure and density? What is the Mach number? k = 1.74.

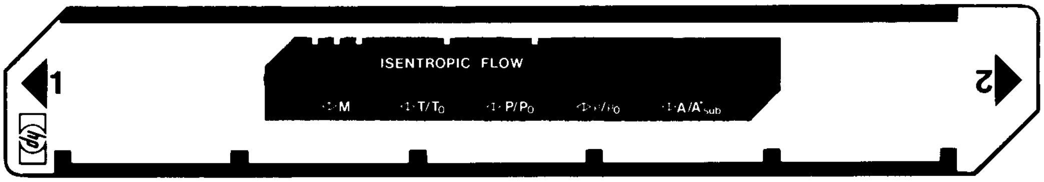
Keystrokes:	Outputs:	
1.74 [f] [A] →	1.740	
1.60 [f] [E] →	2.105	(M)
[B] →	0.379	(T/T_0)
[C] →	0.102	(P/P_0)
[D] →	0.269	(ρ/ρ_0)

or, alternatively, using automatic output.

[f] [B] →	1.740 ***	(k)
	2.105 ***	(M)
	0.379 ***	(T/T_0)
	0.102 ***	(P/P_0)
	0.269 ***	(ρ/ρ_0)
	1.600 ***	(A/A*)

Reference(s)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input specific heat ratio.	k	f A	k
3	Input one of the following:			
	Mach number	M	A	M
	Temperature ratio	T/T_0	B	M
	Pressure ratio	P/P_0	C	M
	Density ratio	ρ/ρ_0	D	M
	Subsonic area ratio	A/A^*_{sub}	E	M
	Supersonic area ratio	A/A^*_{sup}	f E	M
4	Calculate one of the following:			
	Mach number		A	M
	Temperature ratio		B	T/T_0
	Pressure ratio		C	P/P_0
	Density ratio		D	ρ/ρ_0
	Area ratio (subsonic or			
	supersonic)		E	A/A^*
4′	Calculate and output all			
	values automatically.		f B	$k, M, T/T_0, P/P_0$
				ρ/ρ_0, A/A^*
5	For another calculation based			
	on same input, go to step 4			
	(or 4′). For a new input, go to			
	step 3. For a new specific heat			
	ratio, go to step 2.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	Store k-1,1/(k-1)
002	STO2	35 02	
003	1	01	
004	-	-45	
005	STO3	35 03	
006	1/X	52	
007	STO4	35 04	
008	RCL2	36 02	
009	RTN	24	Output M.
010	*LBLA	21 11	
011	F3?	16 23 03	
012	GTO0	22 00	
013	RCL1	36 01	
014	√X	54	
015	RTN	24	
016	*LBL0	21 00	
017	X²	53	Store M^2.
018	STO1	35 01	
019	√X	54	
020	RTN	24	
021	*LBLB	21 12	
022	F3?	16 23 03	Output T/T_0.
023	GTO0	22 00	
024	2	02	
025	RCL1	36 01	
026	RCL3	36 03	
027	×	-35	
028	2	02	
029	+	-55	
030	÷	-24	
031	RTN	24	
032	*LBL0	21 00	Convert T/T_0 to M^2.
033	2	02	
034	X⇄Y	-41	
035	÷	-24	
036	2	02	
037	-	-45	
038	RCL3	36 03	
039	÷	-24	
040	STO1	35 01	
041	√X	54	
042	RTN	24	
043	*LBLC	21 13	
044	F3?	16 23 03	Output P/P_0.
045	GTO0	22 00	
046	GSBB	23 12	
047	RCL2	36 02	
048	RCL3	36 03	
049	÷	-24	
050	Yˣ	31	
051	RTN	24	
052	*LBL0	21 00	
053	RCL3	36 03	Convert P/P_0 to T/T_0 and GTO B.
054	RCL2	36 02	
055	÷	-24	
056	Yˣ	31	
057	SF3	16 21 03	
058	GTOB	22 12	
059	*LBLD	21 14	Output ρ/ρ_0.
060	F3?	16 23 03	
061	GTO0	22 00	
062	GSBB	23 12	
063	RCL4	36 04	
064	Yˣ	31	
065	RTN	24	
066	*LBL0	21 00	
067	SF3	16 21 03	Convert ρ/ρ_0 to T/T_0 and GTO B.
068	RCL3	36 03	
069	Yˣ	31	
070	GTOB	22 12	
071	*LBLE	21 15	
072	3	03	Set -3 in display for subsonic guess.
073	CHS	-22	
074	X⇄Y	-41	
075	F3?	16 23 03	
076	GTO1	22 01	
077	GTO3	22 03	
078	*LBL1	21 01	
079	ENT↑	-21	Make guess of M^2.
080	STO6	35 06	
081	FRC	16 44	
082	√X	54	
083	+	-55	
084	X⇄Y	-41	
085	Yˣ	31	
086	STO1	35 01	
087	*LBL2	21 02	
088	RCL6	36 06	Iterate by Newton's method to find M^2 Corresponding to A/A*.
089	GSB3	23 03	
090	÷	-24	
091	1	01	
092	-	-45	
093	.	-62	
094	5	05	
095	RCL8	36 08	
096	÷	-24	
097	.	-62	
098	5	05	
099	RCL1	36 01	
100	÷	-24	
101	-	-45	
102	÷	-24	
103	ST+1	35-55 01	
104	RCL1	36 01	
105	÷	-24	
106	ABS	16 31	
107	EEX	-23	
108	CHS	-22	
109	4	04	
110	X≤Y?	16-35	
111	GTO2	22 02	
112	RCL1	36 01	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	M^2	k	k-1	1/k-1		A/A*		Used	Used

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	√X	54	
114	RTN	24	
115	*LBLe	21 16 15	Set +3 in display for supersonic guess
116	3	03	
117	X⇄Y	-41	
118	F3?	16 23 03	
119	GTO1	22 01	
120	*LBL3	21 03	
121	2	02	Convert M^2 to A/A*
122	RCL2	36 02	
123	1	01	
124	+	-55	
125	÷	-24	
126	RCL3	36 03	
127	LSTX	16-63	
128	÷	-24	
129	STO7	35 07	
130	RCL1	36 01	
131	×	-35	
132	+	-55	
133	STO8	35 08	
134	RCL7	36 07	
135	2	02	
136	×	-35	
137	1/X	52	
138	Y^x	31	
139	RCL1	36 01	
140	√X	54	
141	÷	-24	
142	RTN	24	
143	*LBLb	21 16 12	
144	SPC	16-11	Output values
145	CF3	16 22 03	
146	RCL2	36 02	
147	PRTX	-14	
148	SPC	16-11	
149	GSBA	23 11	
150	PRTX	-14	
151	GSBB	23 12	
152	PRTX	-14	
153	GSBC	23 13	
154	PRTX	-14	
155	GSBD	23 14	
156	PRTX	-14	
157	GSBE	23 15	
158	PRTX	-14	
159	RTN	24	

LABELS

A $M \rightarrow M$	B $T/T_0 \rightarrow M$	C $P/P_0 \rightarrow M$	D $\rho/\rho_0 \rightarrow M$	E $A/A^*_{sub} \rightarrow M$
a k	b →k, M, T/T_0..	c	d	e $A/A^*_{sup} \rightarrow M$
0 Used	1 M^2 guess	2 M^2 iter	3 A/A	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	Data?

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	3

Program Description I

Program Title Normal and Oblique Shock Parameters for Compressible Flow

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Given the values for: free stream Mach number (M_1), the ratio of specific heats (γ), and the shock angle (θ); the program computes:

$$M_2 = \left[\frac{(\gamma+1)^2 M_1^4 \sin^2\theta - 4(M_1^2\sin^2\theta-1)(\gamma M_1^2\sin^2\theta+1)}{[2\gamma M_1^2\sin^2\theta-(\gamma-1)][(\gamma-1)M_1^2\sin^2\theta+2]}\right]^{1/2}$$ Mach No. behind shock

$$\frac{P_2}{P_1} = \frac{2\gamma M_1^2\sin^2\theta-(\gamma-1)}{\gamma+1}$$ Static pressure ratio

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma+1)M_1^2\sin^2\theta}{(\gamma-1)M_1^2\sin^2\theta+2}$$ Density ratio

$$\frac{T_2}{T_1} = \frac{[2\gamma M_1^2\sin^2\theta-(\gamma-1)][(\gamma-1)M_1^2\sin^2\theta+2]}{(\gamma+1)^2 M_1^2\sin^2\theta}$$ Temperature ratio

$$\frac{P_{T_2}}{P_{T_1}} = \left[\frac{(\gamma+1)M_1^2\sin^2\theta}{(\gamma-1)M_1^2\sin^2\theta+2}\right]^{\frac{\gamma}{\gamma-1}} \left[\frac{\gamma+1}{2\gamma M_1^2\sin^2\theta-(\gamma-1)}\right]^{\frac{1}{\gamma-1}}$$ Total pressure ratio

Where the 1 subscript denotes the value upstream of the shock, and the 2 subscript denotes the value downstream of the shock.

Operating Limits and Warnings

Assumes calorically perfect (Cp and Cv are constant) and thermally perfect ($P=\rho RT$) gas, and adiabatic flow. Only solutions where $M_2<M_1$; $\frac{P_2}{P_1}$, $\frac{\rho_2}{\rho_1}$, $\frac{T_2}{T_1} > 1$ and $P_{T_2}/P_{T_1} < 1$ are valid. If any one of these conditions is satisfied, the other four are satisfied.

Program Description II

Sketch(es)

Sample Problem(s)

1. Find the Mach number and static pressure behind an oblique shock where $M_1 = 2.5, \theta = 70°$, $\gamma = 1.4$ and $P_1 = 85$ psi. Also find the ratios across the shock for density, temperature and total pressure. (See Fig. 1)

2. Find the temperature, Mach number and total pressure behind a normal shock ($\theta = 90°$) where $M_1 = 6.23$, $= 1.4$, $P_{T_1} = 64$ psi and $T_1 = 624°R$ (See Fig. 2)

Solution(s)

```
1.  1.4[↑] 70[↑] 2.5[f] [a] [A] -----------    0.80 (M )
    [B] -----------------------------------    6.27 (P2/P1)
    85[X] ---------------------------------  533.12 (psi) (P2)
    [C] -----------------------------------    3.15 (P2/P1)
    [D] -----------------------------------    1.99 (T2/T1)
    [E] -----------------------------------    0.56 (PT2/PT1)
2.  6.23 [STO] [ ] 90 [STO] [2] [GTO] [0] [R/S] [D] -------------- 8.49 (T2/T1)
    624 [X] ------------------------------ 5296.40 (°R)(T2)
    [A] -----------------------------------    0.40 (M2)
    [E] -----------------------------------     .30 (PT2/PT1)
    64 [X] --------------------------------    1.62 (psi) (PT2)
```

Reference(s)

National Advisory Committee for Aeronautics, Report 1135, Equations, Tables and Charts for Compressible Flow, By Ames Research Staff, pgs. 7,8, U.S. Government Printing Office, 1953.

This program is a translation of the HP-65 Users' Library program #01303A submitted by Glenn D. Rambach.

User Instructions

NORMAL AND OBLIQUE SHOCK PARAMETERS
FOR COMPRESSIBLE FLOW

1 | M_2 | P_2/P_1 | ρ_2/ρ_1 | T_2/T_1 | P_{T_2}/P_{T_1} | 2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter program				
2.	Initialize		RTN		
3.	Input specific heat ratio	γ	↑		γ
4.	Input shock angle	θ (deg)	↑		θ
5.	Input freestream Mach No.	M_1			M_1
6.	Preliminary calculations		f	A	
7.	Compute any parameter:				
	Mach No. behind shock		A		M_2
	Static pressure ratio		B		P_2/P_1
	Density ratio		C		ρ_2/ρ_1
	Temperature ratio		D		T_2/T_1
	Total pressure ratio		E		P_{T_2}/P_{T_1}
8.	For calculations using new values for M_1	M_1	STO	1	M_1
	and/or θ	θ (deg)	STO	2	θ
9.	Reset for preliminaries		GTO	0	
10.	Perform new preliminaries		R/S		
11.	Perform step 7 for any of the new parameters				
	NOTE: To perform calculations for a new value				
	of γ, use steps 2 through 7.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	STO1	35 01	
003	R↓	-31	Store M_1 in R_1
004	STO2	35 02	Store θ in R_2
005	R↓	-31	
006	STO3	35 03	Store γ in R_3
007	1	01	
008	-	-45	
009	STO7	35 07	
010	2	02	
011	+	-55	
012	STO8	35 08	
013	*LBL0	21 00	Initial point for
014	RCL2	36 02	repeated operations
015	SIN	41	
016	RCL1	36 01	
017	×	-35	
018	X²	53	
019	STO4	35 04	
020	RCL8	36 08	
021	×	-35	
022	STO5	35 05	
023	RCL7	36 07	
024	RCL4	36 04	
025	×	-35	
026	STO6	35 06	
027	R/S	51	
028	*LBLA	21 11	Compute M_2
029	RCL5	36 05	
030	RCL8	36 08	
031	×	-35	
032	RCL1	36 01	
033	X²	53	
034	×	-35	
035	RCL4	36 04	
036	RCL3	36 03	
037	×	-35	
038	1	01	
039	+	-55	
040	4	04	
041	×	-35	
042	RCL4	36 04	
043	1	01	
044	-	-45	
045	×	-35	
046	-	-45	
047	GSBC	23 13	
048	×	-35	
049	GSBB	23 12	
050	÷	-24	
051	RCL8	36 08	
052	÷	-24	
053	RCL5	36 05	
054	÷	-24	
055	√X	54	
056	RTN	24	Display M_2
057	*LBLB	21 12	Compute P_2/P_1
058	RCL3	36 03	
059	RCL4	36 04	
060	×	-35	
061	2	02	
062	×	-35	
063	RCL7	36 07	
064	-	-45	
065	RCL8	36 08	
066	÷	-24	
067	RTN	24	Display P_2/P_1
068	*LBLC	21 13	Compute ρ_2/ρ_1
069	RCL5	36 05	
070	RCL6	36 06	
071	2	02	
072	+	-55	
073	÷	-24	
074	RTN	24	Display ρ_2/ρ_1
075	*LBLD	21 14	Compute T_2/T_1
076	GSBB	23 12	
077	GSBC	23 13	
078	÷	-24	
079	RTN	24	
080	*LBLE	21 15	Display T_2/T_1
081	GSBC	23 13	Compute P_{T_2}/P_{T_1}
082	GSBB	23 12	
083	÷	-24	
084	RCL7	36 07	
085	1/X	52	
086	Yˣ	31	
087	GSBC	23 13	
088	×	-35	Display P_{T_2}/P_{T_1}
089	RTN	24	
090			
100			
110			

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

REGISTERS

0	1	2	3	4	5	6	7	8	9
	M_1	θ	γ	$M_1^2 \sin^2\theta$	$(\gamma+1)M_1^2 \sin^2\theta$	$(\gamma-1)M_1^2 \sin^2\theta$	γ−1	γ+1	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Oblique Shock Angle for Wedge

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

When the upstream Mach number, the deflection angle and the specific heat ratio are given the compressible flow equation will give at most three values for the shock angle. This program calculates the weak oblique shock angle when it is possible.

The equation which must be solved is

$$\sin^6\sigma + b\sin^4\sigma + c\sin^2\sigma + d = 0$$

where

$$b = -\frac{M_1^2 + 2}{M_1^2} - k\sin^2\delta$$

$$c = \frac{2M_1^2 + 1}{M_1^4} + \left[\frac{(k+1)^2}{4} + \frac{k-1}{M_1^2}\right]\sin^2\delta$$

$$d = -\frac{\cos^2\delta}{M_1^4}$$

M_1 = Upstream Mach number > 1.0

δ = Deflection angle (deg)

k = Specific heat ratio

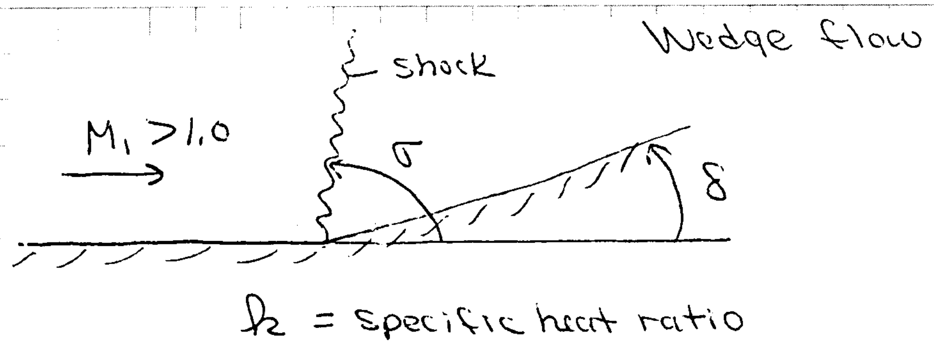
σ = Shock angle (D.M.S.)

Operating Limits and Warnings

If no shock condition is possible, i.e., if the shock must detach from the corner, then the first program card stops with a blinking display. If δ approaches δ_{max} for the flow the program takes some time (1 min or so) to converge. I have never had the program fail to converge, although it may be possible. Should convergence not occur, change the calculator to the DEG mode after the iteration is stopped.

Program Description II

Sketch(es)



Sample Problem(s) Given

$M_1 = 2.0$

$\delta = 10°$

$k = 1.4$

$\sigma = 39.3139$ Deg

Solution(s)

Keystrokes: Outputs:

2[x²] [STO] [1] 10 [STO] [2] 1.4 [STO] [3] [A] -----> 39.3139

Reference(s) 1. Introductory Gas Dynamics, A.J. Chapman and W.F. Walker, HRW Series in Mech. Engineering.

This program is a translation of the HP-65 Users' Library program #00630A submitted by Harry W. Townes.

User Instructions

OBLIQUE SHOCK ANGLE FOR WEDGE

1 | 2

σ

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter program card #1		RTN		
2.	Enter the Mach number M_1, square it and store				
	M_1^2 in R1	M_1^2	STO	1	
3.	Enter the deflection angle δ in deg, store in				
	R2	δ/deg	STO	2	
4.	Enter the specific heat ratio P_c store in R3	k	STO	3	
5.	Run the program			A	σ deg
	If program stops with a blinking display showing				
	zeros, the shock is detached and no solution				
	is possible for a weak shock angle.				
	NOTE: Some time is usually required for a solution,				
	especially as $\delta \to \delta_{max}$. The output will				
	be σ in D.MS in the X stack location.				
	Should the program not converge σ in RAD				
	is in the R8 register for as far as the				
	iteration ran.				
	The program stops when the residual is				
	$< 1 \times 10^{-6}$				
	A direct solution of the equation gives				
	only <1% accuracy for σ without any				
	iteration.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	RCL2	36 02	
003	SIN	41	
004	ENT↑	-21	
005	×	-35	
006	STO7	35 07	
007	RCL3	36 03	
008	×	-35	
009	RCL1	36 01	
010	2	02	
011	+	-55	
012	RCL1	36 01	
013	÷	-24	
014	+	-55	
015	CHS	-22	
016	3	03	
017	÷	-24	
018	STO4	35 04	b/3 R4
019	RCL3	36 03	
020	1	01	
021	+	-55	
022	ENT↑	-21	
023	×	-35	
024	4	04	
025	÷	-24	
026	RCL3	36 03	
027	1	01	
028	-	-45	
029	RCL1	36 01	
030	÷	-24	
031	+	-55	
032	RCL7	36 07	
033	×	-35	
034	RCL1	36 01	
035	2	02	
036	×	-35	
037	1	01	
038	+	-55	
039	RCL1	36 01	
040	ENT↑	-21	
041	×	-35	
042	÷	-24	
043	+	-55	
044	3	03	
045	÷	-24	
046	STO5	35 05	C/3 R5
047	RCL2	36 02	
048	COS	42	
049	RCL1	36 01	
050	ENT↑	-21	
051	×	-35	
052	÷	-24	
053	CHS	-22	d R6
054	STO6	35 06	
055	RCL5	36 05	
056	RCL4	36 04	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	ENT↑	-21	
058	×	-35	
059	-	-45	
060	STO7	35 07	
061	RCL4	36 04	
062	RCL5	36 05	
063	×	-35	
064	3	03	
065	×	-35	
066	RCL6	36 06	
067	-	-45	
068	2	02	
069	÷	-24	
070	RCL4	36 04	
071	ENT↑	-21	
072	ENT↑	-21	
073	×	-35	
074	×	-35	
075	-	-45	
076	STO8	35 08	
077	RCL7	36 07	
078	ENT↑	-21	
079	ENT↑	-21	
080	×	-35	
081	×	-35	
082	STO6	35 06	
083	RCL8	36 08	
084	ENT↑	-21	
085	×	-35	
086	+	-55	
087	0	00	
088	X≤Y?	16-35	Test for existance of weak shock
089	1/X	52	
090	RCL2	36 02	Blinking display for no solution possible
091	TAN	43	
092	STO2	35 02	
093	RAD	16-22	
094	RCL8	36 08	
095	RCL6	36 06	
096	CHS	-22	
097	√X	54	
098	÷	-24	
099	COS^{-1}	16 42	
100	Pi	16-24	
101	4	04	
102	×	-35	
103	+	-55	
104	3	03	
105	÷	-24	
106	COS	42	
107	RCL7	36 07	
108	CHS	-22	
109	√X	54	
110	×	-35	
111	2	02	
112	×	-35	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	$M_1{}^2$	δ and tan δ	k	Used	Used	Used	Used	σ in RAD	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCL4	36 04	
114	-	-45	
115	√X	54	
116	SIN⁻¹	16 41	
117	STO8	35 08	
118	.	-62	σ in RAD from direct solution of the equation. Iteration improves accuracy. A R/S in step 30 would eliminate iteration
119	0	00	
120	1	01	
121	STO6	35 06	
122	RCL8	36 08	
123	+	-55	
124	GSB0	23 00	
125	STO7	35 07	
126	RCL8	36 08	
127	GSB0	23 00	
128	RCL7	36 07	
129	X⇄Y	-41	
130	-	-45	
131	RCL6	36 06	
132	÷	-24	
133	STO7	35 07	
134	*LBL1	21 01	
135	RCL8	36 08	
136	GSB0	23 00	
137	RCL7	36 07	
138	÷	-24	
139	ST-8	35-45 08	
140	RCL8	36 08	
141	÷	-24	
142	ABS	16 31	
143	EEX	-23	
144	CHS	-22	
145	6	06	
146	X≤Y?	16-35	
147	GTO1	22 01	
148	RCL8	36 08	
149	R→D	16 46	σ in deg after convergence
150	RTN	24	
151	*LBL0	21 00	
152	STO5	35 05	
153	TAN	43	
154	1/X	52	
155	RCL2	36 02	
156	+	-55	
157	2	02	
158	x	-35	
159	RCL5	36 05	
160	2	02	
161	x	-35	
162	STO5	35 05	
163	COS	42	
164	RCL3	36 03	
165	+	-55	
166	RCL2	36 02	
167	x	-35	
168	RCL5	36 05	
169	SIN	41	
170	-	-45	
171	÷	-24	
172	CHS	-22	
173	RCL1	36 01	
174	-	-45	
175	RTN	24	
180			
190			
200			
210			
220			

LABELS

A σ	B	C	D	E
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☑	DEG	☑	FIX	☑
1	☐	☑	GRAD	☐	SCI	☐
2	☐	☑	RAD	☐	ENG	☐
3	☐	☑			n	4

Program Description I

Program Title Mach Number and True Airspeed

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables, etc.

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.

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

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

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

Operating Limits and Warnings

Accuracy degenerates for mach numbers in excess of one.

Program Description II

Sketch(es)

Sample Problem(s)

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?

Solution(s)

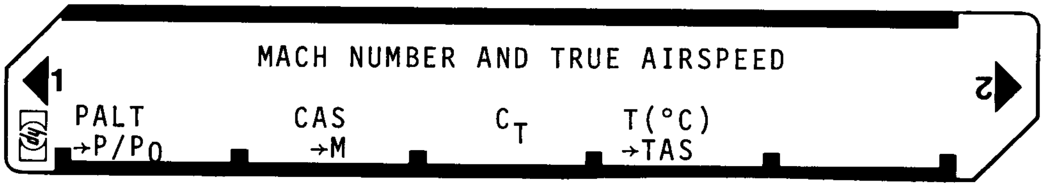
M = 0.84
TAS = 515.76 knots

Keystrokes	See Displayed
25500 A 350 B	0.84
.8 C 5 D	515.76

Reference(s)

This program is a translation of the HP-65 Users' Library program #00531B submitted by Hewlett-Packard.

User Instructions



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*.

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	3	03	
003	5	05	
004	6	06	
005	6	06	
006	EEX	-23	
007	CHS	-22	
008	6	06	
009	x	-35	
010	CHS	-22	Convert pressure
011	5	05	altitude to
012	1	01	pressure ratio
013	8	08	
014	.	-62	
015	6	06	
016	7	07	
017	+	-55	
018	LSTX	16-63	
019	÷	-24	
020	5	05	
021	.	-62	
022	2	02	
023	5	05	
024	6	06	
025	3	03	
026	Y^x	31	
027	STO6	35 06	
028	RTN	24	
029	*LBLB	21 12	
030	6	06	
031	6	06	
032	1	01	
033	.	-62	
034	5	05	Convert CAS to mach
035	÷	-24	number
036	GSBE	23 15	
037	3	03	
038	.	-62	
039	5	05	
040	Y^x	31	
041	1	01	
042	-	-45	
043	RCL6	36 06	
044	÷	-24	
045	1	01	
046	+	-55	
047	.	-62	
048	2	02	
049	8	08	
050	6	06	
051	Y^x	31	
052	1	01	
053	-	-45	
054	5	05	
055	x	-35	
056	√X	54	
057	STO4	35 04	
058	RTN	24	
059	*LBLC	21 13	
060	STO3	35 03	Input recovery
061	RTN	24	coefficient
062	*LBLD	21 14	
063	2	02	
064	7	07	Calculate TAS
065	3	03	
066	+	-55	
067	STO5	35 05	
068	RCL4	36 04	
069	GSBE	23 15	
070	÷	-24	
071	RCL5	36 05	
072	-	-45	
073	RCL3	36 03	
074	x	-35	
075	RCL5	36 05	
076	+	-55	
077	√X	54	
078	3	03	
079	9	09	
080	x	-35	
081	RCL4	36 04	
082	x	-35	
083	RTN	24	
084	*LBLE	21 15	
085	ENT↑	-21	
086	x	-35	
087	.	-62	
088	2	02	
089	x	-35	
090	1	01	
091	+	-55	
092	RTN	24	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n 2	

REGISTERS

0	1	2	3	4	5	6	7	8	9
			C_T	M	T	P/P_0			

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title TAKE-OFF RUN VS. DENSITY ALTITUDE

Contributor's Name Hewlett-Packard, Corvallis Division

Address 1000 N. E. Circle Blvd.

City Corvallis **State** OR **Zip Code** 97330

Program Description, Equations, Variables

$A_D = 145366\ [1 - (\frac{\rho}{\rho o})^{0.235}]$ Density altitude

$\rho/\rho o = (288/T_{°K})(1-6.87 \times 10^{-6}\ Ap)^{5.256}$

where A_ρ = Pressure altitude (Ft)

$F = 1 + 2.18 \times 10^{-5}\ A_D + 2.032 \times 10^{-8}\ A_D^2$

$D_A = (D_{STD}/W_G) \cdot W_A \cdot F$

where

D_A = Actual take-off run (Ft)

D_{STD} = Sea level take-off run at 15°C and full gross weight

W_G = Gross weight

W_A = Actual take-off weight

Operating Limits and Warnings Computed value of D_A is an approximation to be tempered by caution and good sense. It depends on runway surface condition, aircraft condition, pilot skill; assumes zero wind. No provision for obstructions.

Program Description II

Sketch(es)

Sample Problem(s) Land performance of a popular twin engine amphibian is a ground run of 965 feet (sea level) at 15°C at full gross weight of 6,000 lbs.

How much runway will it require at Laramie, Wyoming (elev, 7300 ft.) on a summer day when outside air temperature is 35°C (95°F) and plane is loaded to 5750 lbs?

Solution(s) 965/6000 = .1608 - Aircraft parameter to be inserted in program at LBL 1.

A_D (density altitude) = 11094 ft

D_A (actual take-off distance) = 3461 ft

Outpoints:

Keystrokes: 965[ENT ↑] 6000[÷][STD][0] 35[ENT ↑] 7300[ENT ↑] 5750[A] → 11094

[B] → 3461

Reference(s)

1) HP-65 Users' Library Program #532A

2) "AOPA Handbook for Pilots - 1974", page 15 (F VS A_D)

3) "Aerodynamics of the airplane", Millikan, John Wiley & Sons, 1941, page 132.

User Instructions

TAKE-OFF RUN/DENSITY ALTITUDE

1 ◀ ▶ 2

DENS. ALT. | T OFF RUN

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load program				
2.	Adjust aircraft constant as required	G.R.Height	↑		Height
		F.G.Weight	÷		
			STO	ϕ	
3.	Input T_A	°C	↑		
4.	Input A_P	Ft.	↑		
5.	Input W_A	lbs.	A		
	Display A_D				Ft.
6.	Compute and Display D_A		B		Ft.

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	DSP0	-63 00	
003	STO1	35 01	W_A (Take off Wt.)
004	R↓	-31	A_P (Pressure Alt.)
005	STO2	35 02	
006	R↓	-31	
007	2	02	
008	7	07	
009	3	03	
010	STO3	35 03	
011	+	-55	
012	STO4	35 04	Temp. °k
013	6	06	
014	.	-62	
015	8	08	
016	7	07	
017	6	06	
018	EEX	-23	
019	CHS	-22	
020	6	06	
021	RCL2	36 02	
022	×	-35	
023	CHS	-22	
024	1	01	
025	+	-55	
026	5	05	
027	.	-62	
028	2	02	
029	5	05	
030	6	06	
031	Y^x	31	
032	RCL3	36 03	
033	1	01	
034	5	05	
035	+	-55	
036	×	-35	
037	RCL4	36 04	
038	÷	-24	
039	.	-62	
040	2	02	
041	3	03	
042	5	05	
043	Y^x	31	
044	CHS	-22	
045	1	01	
046	+	-55	
047	1	01	
048	4	04	
049	5	05	
050	3	03	
051	6	06	
052	6	06	
053	×	-35	A_D
054	RTN	24	
055	*LBLB	21 12	
056	ENT↑	-21	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	ENT↑	-21	
058	2	02	
059	.	-62	
060	1	01	
061	8	08	
062	EEX	-23	
063	CHS	-22	
064	5	05	
065	×	-35	
066	1	01	
067	+	-55	
068	X⇄Y	-41	
069	ENT↑	-21	
070	×	-35	A_D^2
071	2	02	
072	.	-62	
073	0	00	
074	3	03	
075	2	02	
076	EEX	-23	
077	CHS	-22	
078	8	08	
079	×	-35	
080	+	-55	
081	RCL0	36 00	
082	×	-35	
083	RCL1	36 01	
084	×	-35	D_A (Actual Take-Off Distance, Ft.)
085	RTN	24	
086	R/S	51	
090			
100			
110			

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	0

REGISTERS

0	1	2	3	4	5	6	7	8	9
	W_A	A_P	273	T°k					

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title TRUE AIR TEMPERATURE AND DENSITY ALTITUDE

Contributor's Name Hewlett-Packard, Corvallis Division

Address 1000 N. E. Circle Blvd.

City Corvallis **State** OR **Zip Code** 97330

Program Description, Equations, Variables This program accounts for the compressibility effects of high speed flight. Given the mach number (M) 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).

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

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

where

$$\frac{\rho}{\rho o} = \frac{288.15}{T(K)} \left[1 - 6.879 \times 10^{-6} PALT\right]^{5.256}$$

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

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

Solution(s)

1. T =-22.21°C

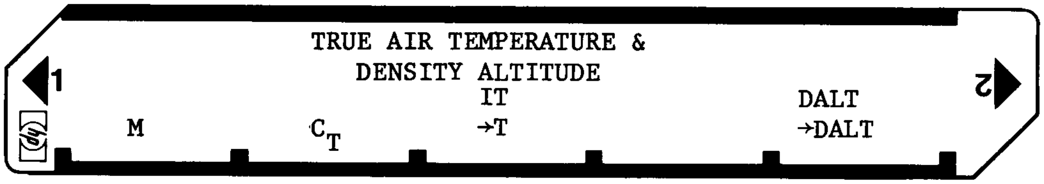
   DALT = 7852.96 ft

2. DALT = 10,703.11 ft

Keystrokes [f][a]	See Displayed
1. .87[A]8[C]	-22.21
10000[E]	7852.96
2. 12[D]9000[E]	10703.11

Reference(s) This program is a translation of the HP-65 Users' Library Program #00532A Submitted by User's Library.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program		A a	
2	Initialize			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 temperature	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			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	.	-62	
003	8	08	Initialize
004	STO3	35 03	
005	RTN	24	
006	*LBLA	21 11	
007	STO4	35 04	Input mach number
008	RTN	24	
009	*LBLB	21 12	
010	STO3	35 03	
011	RTN	24	Input recovery
012	*LBLC	21 13	factor
013	GSBD	23 14	
014	RCL4	36 04	
015	ENT↑	-21	
016	×	-35	
017	.	-62	Calculate true
018	2	02	temperature
019	0	00	
020	5	05	
021	×	-35	
022	1	01	
023	+	-55	
024	÷	-24	
025	RCL5	36 05	
026	-	-45	
027	RCL3	36 03	
028	×	-35	
029	RCL5	36 05	
030	+	-55	
031	STO5	35 05	
032	RCL6	36 06	
033	-	-45	
034	RTN	24	
035	*LBLD	21 14	
036	2	02	
037	7	07	Convert T(°C) to
038	3	03	T(K) and store it.
039	.	-62	
040	1	01	
041	5	05	
042	STO6	35 06	
043	+	-55	
044	STO5	35 05	
045	RTN	24	
046	*LBLE	21 15	
047	6	06	
048	.	-62	
049	8	08	
050	7	07	
051	9	09	
052	EEX	-23	
053	CHS	-22	Calculate density
054	6	06	ratio
055	×	-35	
056	CHS	-22	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	1	01	
058	+	-55	
059	5	05	
060	.	-62	
061	2	02	
062	5	05	
063	6	06	
064	Y^x	31	
065	RCL6	36 06	
066	1	01	
067	5	05	
068	+	-55	
069	×	-35	
070	RCL5	36 05	
071	÷	-24	
072	.	-62	
073	2	02	
074	3	03	Calculate density
075	5	05	altitude
076	Y^x	31	
077	CHS	-22	
078	1	01	
079	+	-55	
080	1	01	
081	4	04	
082	5	05	
083	3	03	
084	6	06	
085	6	06	
086	×	-35	
087	RTN	24	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

REGISTERS

0	1	2	3	4	5	6	7	8	9
			C_T	M	T(K)	273.15			

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Aircraft Climb

Contributor's Name Carroll F. Lam

Address 4411 Random Ct.

City Annadale **State** VA **Zip Code** 22003

Program Description, Equations, Variables

Given current and new higher altitudes, A_1 and A_z, and associated headwinds at these altitudes, W_1 and W_z, this program will compute the following:

1. $D_{min} = [(V_{cr} - V_{cl}) + (\frac{W_1 - W_2}{2})] (\frac{V_{cr} - W_1}{W_1 - W_2})$ TC

where: V_{cr} = cruise air speed
V_{cc} = climb air speed
T_c = time to climb, A_1 to A_2

2. $T_{climb} = \frac{A_m}{ROC_{max}} \ln (\frac{A_m - A_1}{A_m - A_2})$

where: A_m = aircraft celing
ROC_{max} = sea level rate-of-climb

3. $T_{act} = \frac{D_{act} - [V_{cl} - (\frac{W_1 + W_2}{2})] T_c}{V_{cr} - W_2} + T_c$

4. $T_{save} = \frac{D_{act}}{V_{cr} - W_1} - T_{act}$

Operating Limits and Warnings

$W_1, W_2 \geq 0$

$A_2 > A_1$

$D_{act} > D_{min}$ if steps 9,10,11 are to be used.

Program Description I

Program Title Aircraft Climb

Contributor's Name Carroll F. Lam
Address 4411 Random Ct.
City Annandale State VA Zip Code 22003

Program Description, Equations, Variables (con't)

The equation for D_{min} is derived by setting up an equation for the two time possibilites for traveling between points A and B_1 and solving for the D that assures that the travel time based on climbing to a higher altitude with a smaller headwind component is less than the travel time that would result from remaining at altitude A_1.

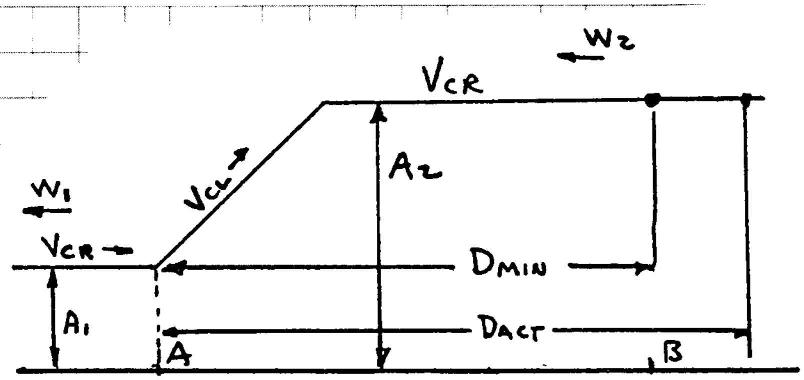
Although the program doesn't incorporate it, there would in general be an additional benefit in climbing to a higher altitude, namely a higher true airspeed will generally result.

Operating Limits and Warnings

See previous page.

Program Description II

Sketch(es)



Sample Problem(s)

Assumed aircraft parameters: V_{cr} = 150 mph
V_{cl} = 85 mph
ROC_{max} = 850 ft/min
A_{max} = 18.5 kft

Given: Current Altitude (A_1) = 3.5 kft
Current Headwind Component (W_1) = 38 mph
Potential Altitude (A_z) = 11.5 kft
Headwind Component at A_z (W_z) = 10 mph
Distance Remaining (D_{act}) = 185 miles

Find:
1. Distance required for climb to breakeven
2. Time to fly distance remaining if climb is made
3. Time saved by climbing to higher altitude
4. Time to climb to new altitude

Solution(s) 150[STO] [1] 85[STO] [2] [850] [STO] [3] 18.5 [STO] [4]

	11.5	[ENTER]	------------	Store A_z	11.50
	10	[ENTER]	------------	Store W_z	10.50
	3.5	[ENTER]	------------	Store A_1	3.50
	38	[A]	---------------	Store W_1	11.50
1.		[B]	---------------	Compute D_{min}	87.54
2.	185	[C]	---------------	Compute T_{act} for 185 miles	1.28 (1 hr, 28 mins)
3.		[R/S]	---------------	Compute T_{saved}	0.10 (10 mins)
4.		[D]	---------------	Compute T_{climb}	0.16 (16 mins)

Reference(s) Equations (1),(2), and (4) are submitter's own derivations based on the geometry of the problem.

Equation (3) is based on an assumption that ROC varies lineary with altitude [$ROC(A) = A_{max}(1-\frac{A}{A_{max}})$] and straight forward integration. See any good aeronautical engineering text.

This program is a translation of the HP-65 Users Library program # 01815A submitted by Carroll F. Lam.

User Instructions

AIRCRAFT CLIMB 1

DATA

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter program card 1				
2.	Input specific aircraft parameters				
	Cruise airspeed V_{cr} (miles/hr)	V_{cr}	STO	1	V_{cr}
	Climb airspeed V_{cl} (miles/hr)	V_{cl}	STO	2	V_{cl}
	Sea-level rate of climb (ft/min)	R_oC	STO	3	R_oC
	Ceiling (kft)	A_{max}	STO	4	A_{max}
3.	Enter program card 2				
4.	Input higher altitude	A_z(kft)	ENTER		
5.	Input wind at higher altitude	W_z	ENTER		
6.	Input lower altitude	A_l(kft)	ENTER		
7.	Input wind at lower altitude	W_l	A		
8.	Compute minimum remaining distance		B		D_{min}
	If actual distance remaining is greater than D_{min}k go to step 9; otherwise stop, or go to 12.				
9.	Key in actual stage length	D_{act}			
10.	Compute actual remaining time with climb		C		T_{act}(H.MM)
11.	Compute time saved by climbing		R/S		T_{save}(H.MM)
12.	Compute climb time		D		T_{climb}(H.MM)
	Repeat steps 4-7 to enter new data.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO5	35 05	
003	R↓	-31	Store Data
004	STO6	35 06	
005	R↓	-31	
006	STO7	35 07	
007	R↓	-31	
008	STO8	35 08	
009	RTN	24	
010	*LBLD	21 14	
011	RCL4	36 04	
012	RCL8	36 08	
013	-	-45	
014	RCL4	36 04	
015	RCL6	36 06	
016	-	-45	
017	÷	-24	
018	LN	32	Compute Climb Time
019	RCL3	36 03	
020	÷	-24	
021	RCL4	36 04	
022	x	-35	
023	CHS	-22	
024	1	01	
025	6	06	
026	.	-62	
027	7	07	
028	x	-35	
029	STO9	35 09	
030	→HMS	16 35	
031	RTN	24	
032	*LBLB	21 12	
033	RCL1	36 01	Compute Minimum
034	RCL5	36 05	State Length
035	-	-45	
036	RCL5	36 05	
037	RCL7	36 07	
038	-	-45	
039	÷	-24	
040	LSTX	16-63	
041	2	02	
042	÷	-24	
043	RCL1	36 01	
044	RCL2	36 02	
045	-	-45	
046	+	-55	
047	x	-35	
048	GSBD	23 14	
049	HMS→	16 36	
050	x	-35	
051	RTN	24	
052	*LBLC	21 13	
053	ENT↑	-21	
054	ENT↑	-21	
055	RCL5	36 05	
056	RCL7	36 07	
057	+	-55	Compute Actual Stage Time
058	2	02	
059	÷	-24	
060	CHS	-22	
061	RCL2	36 02	
062	+	-55	
063	RCL9	36 09	
064	x	-35	
065	-	-45	
066	RCL1	36 01	
067	RCL7	36 07	
068	-	-45	
069	÷	-24	
070	RCL9	36 09	
071	+	-55	
072	→HMS	16 35	
073	R/S	51	
074	X⇄Y	-41	Compute Time Savings
075	RCL1	36 01	
076	RCL5	36 05	
077	-	-45	
078	÷	-24	
079	→HMS	16 35	
080	CHS	-22	
081	HMS+	16-55	
082	CHS	-22	
083	RTN	24	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

REGISTERS

0	1	2	3	4	5	6	7	8	9
	V_{cruise}	V_{climb}	$R.O.C_{max}$	A_{max}	W_1	A_1	W_2	A_z	T_{climb}
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

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