HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions

Energy Conservation

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.

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Program calculates one of any four quantities in the design of an air cooling system for electronic equipment. Given the ambient temperature, the power dissipation in the enclosure, and the worst case maximum temperature, the program calculates the required blower rating in cubic feet per minute.

BLACK BODY THERMAL RADIATION 6

Calculates wave length of maximum emissive power, total emissive power, monochromatic emissive power, emissive power from zero to a specified wave length, for black radiating surfaces.

ECONOMIC INSULATION THICKNESS 14

Can be used to determine the economic thickness of insulation given the thermal properties of the insulation, the cost of energy, hours of operation, cost of insulation, and the temperature difference.

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TRANSIENT TEMPERATURE DISTRIBUTION IN A SEMI-INFINITE SOLID WITH CONVECTION BOUNDARY CONDITION 40
Computes factor enabling calculation of temperature in a semi-infinite solid for data including distance from surface, time, thermal conductivity, thermal diffusivity, and heat transfer coefficient.

CONSERVATION OF ENERGY. 44
This is a two card set which may be used to solve a variety of energy conservative flow problems (Bernoulli's equation). Card one accepts English units while card two is for metric units.

Program Description I

Program Title Air Cooling System Design

Contributor's Name Hewlett-Packard
Address 1000 N.E. Circle Blvd.
City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Define: H_i = Molal enthalpy of air at T_i and P_i (BTU/LB Mole)
P_i = Power in kilowatts (3413 kW-Hr/ BTU)
T_i = Temperature in degrees Rankine (°R)
$\dot{V}_i$ = Volumetric flow rate
$\dot{N}_i$ = Molal flow rate

i = 1 for outside enclosure

i = 2 for inside enclosure

p_i = pressure (in atmospheres)

C_p = specific heat at constant pressure = 6.953 (BTU/lb-mole °R)

- Molar volume for air at a temperature T and pressure p is V = (0.35905 (0.35905 x 10^3 Ft^3/lb-mole) (Atm/p)(T/491.7°R) = .7302
- Energy balance at steady state
  $H_1\dot{N}_1 + (P_1 - P_2) = H_2\dot{N}_2$
- Molal volume for an ideal gas has a flow rate $\dot{V}_1 = (\frac{p_2}{p_1})(\frac{T_2}{T_1})\dot{V}_2$
- Specific heat equation $H_2 - H_1 = C_p\ (T_2 - T_1)$
- Neglect pressure difference $p_i = p_2$

Continued on next page→

Operating Limits and Warnings

1. Calculation assumes steady state, treats air as an ideal gas, neglects humidity, etc.
2. The "E" key should not be used as it contains several values needed to cram the program into the limited memory.

Program Description I

Program Title Air Cooling System Design

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

Then $\dot{V}_2 = \frac{K(P_2-P_1)T_2}{T_2-T_1}$ = Ft^3/min = Req'd flow rate k = 5.974

or $P_2-P_1 = \frac{\dot{V}_2}{k}\left(\frac{T_2-T_1}{T_2}\right)$ = kW = Power Input

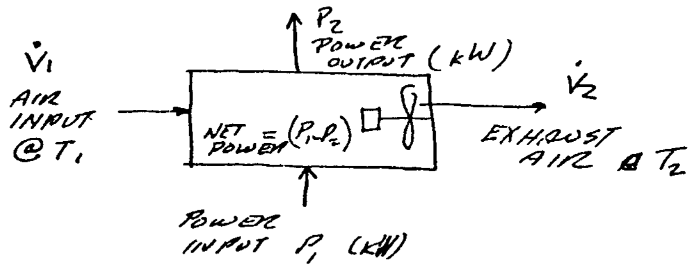
or $T_2 = \frac{\dot{V}_2 T_1}{\dot{V}_2-k(P_2-P_1)}$ = Max. Enclosure Temperature

or $T_1 = \frac{T_2}{\dot{V}_2}(V_2-k(P_2-P_1))$ = Ambient Temperature

Operating Limits and Warnings

Program Description II

Sketch(es)



Sample Problem(s)

t_1 = 72°F

t_2 = 85°F

$\dot{V}$ = 250 ft^3/min

Calculate: P_{1N} = 0.9982kW

Now assume you wish to change the ambient to 68°F with the same power and see what effect it has upon the blower rating. After having first pressed "D" just key in 68 in "A" and press "C". To use the calculated P_{1N} $\dot{V}$=191.1765

Now change $\dot{V}$ to 200 and P_{1N} to 1kW and resolve for t_1 = 68.7209°F. Now change t_1 to 65°F and calculate t_2 for the $\dot{V}$=200 and P_{1N} = 1 by entering 65° in "A" and pressing "B" to obtain t_2 = 81.1646

If you forget one of the other three variables in using the program for optimizing just look in R_1,R_2, R_3 or R_4 For T_1,T_2,V or P_{1N} as may be of interest.

Solution(s)

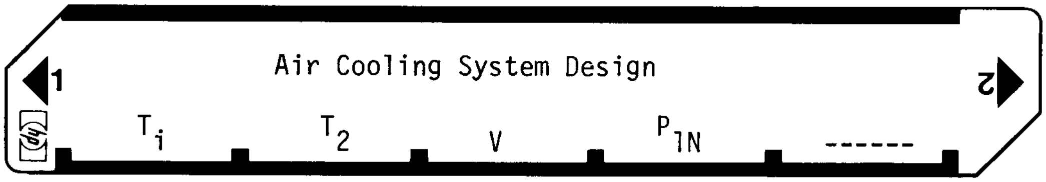
Keystrokes:	Outputs
72[A] 85[B] 250[C] [D]	0.9982
[D] 68[A] [C]	191.1765
200[C] 1[D] [A]	68.7209
65[A] [B]	81.1646

Reference(s)

V.M. Faires, Thermodynamics, 5th Edition, MacMillan Co., New York, 1970; page 453.

This program is a translation of the HP-65 User's Library program #02001A submitted by Todd A.C. Heard.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter any three of the four variables in any order using the designated keys.				
2.	Do not use the"E" key. If you do by mistake, just re-enter all the values again.				
3.	Enter ambient temperature.	T_1(°F)	A		°F
4.	Enter max temperature for the enclosure.	T_2(°F)	B		°F
5.	Enter volumetric flow rate of air cooling system.	V(Ft³/min)	C		Ft³/min
6.	Press and get max power (kW) that can be dissipated in the enclosure.		D		KW
	NOTE:				
	1) If you wish to change any of the input variable to see its affect on the calculation, key in the new value and press the key for the unknown.				
	2) As the variables may be keyed in in any order the result may be considered as an input and new values can be calculated with one of the input variables becoming the unknown.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO1	35 01	
003	0	00	
004	X≠Y?	16-32	
005	RTN	24	Calls constants,etc
006	GSBE	23 15	
007	RCL4	36 04	
008	RCL6	36 06	
009	CHS	-22	
010	RCL3	36 03	
011	+	-55	
012	RCL3	36 03	
013	÷	-24	
014	ENT↑	-21	
015	RCL8	36 08	Computed t_1(°F)
016	x	-35	
017	RCL7	36 07	
018	-	-45	
019	RTN	24	
020	*LBLB	21 12	
021	STO2	35 02	
022	0	00	
023	X≠Y?	16-32	
024	RTN	24	
025	GSBE	23 15	
026	RCL1	36 01	
027	RCL7	36 07	
028	+	-55	
029	RCL3	36 03	
030	x	-35	
031	ENT↑	-21	
032	RCL4	36 04	
033	RCL6	36 06	
034	x	-35	
035	CHS	-22	
036	RCL3	36 03	
037	+	-55	
038	÷	-24	Computed t_2(°F)
039	RCL7	36 07	
040	-	-45	
041	RTN	24	
042	*LBLC	21 13	
043	STO3	35 03	
044	0	00	
045	X≠Y?	16-32	
046	RTN	24	
047	GSBE	23 15	
048	RCL8	36 08	
049	RCL4	36 04	
050	x	-35	
051	RCL6	36 06	
052	x	-35	
053	ENT↑	-21	
054	RCL5	36 05	
055	÷	-24	Computed V (Ft^3/min)
056	RTN	24	
057	*LBLD	21 14	
058	STO4	35 04	
059	0	00	
060	X≠Y?	16-32	
061	RTN	24	
062	GSBE	23 15	
063	RCL5	36 05	
064	RCL3	36 03	
065	x	-35	
066	RCL6	36 06	
067	÷	-24	
068	ENT↑	-21	
069	RCL8	36 08	Computed P_{1N}(kW)
070	÷	-24	
071	RTN	24	
072	*LBLE	21 15	
073	5	05	
074	.	-62	Constant 5.974
075	9	09	
076	7	07	
077	4	04	
078	STO6	35 06	
079	4	04	Constant 460
080	6	06	
081	0	00	
082	STO7	35 07	
083	RCL2	36 02	
084	RCL1	36 01	
085	-	-45	(t_2-t_1)
086	STO5	35 05	
087	RCL2	36 02	
088	RCL7	36 07	
089	+	-55	T_2(°R)
090	STO8	35 08	
091	RTN	24	

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
	t_1(°F)	t_2(°F)	V (FT^3/min)	P_{1N}(kW)	t_2-t_1	5.974	460	T_2(°R)	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Black Body Thermal Radiation

Contributor's Name Hewlett-Packard

Address 1000 N. E. Circle Blvd.

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

Program Description, Equations, Variables

Bodies with finite temperatures emit thermal radiation. The higher the absolute temperature, the more thermal radiation emitted. Bodies which emit the maximum possible amount of energy at every wavelength for a specified temperature are said to be black bodies. While black bodies do not actually exist in nature, many surfaces may be assumed to be black for engineering considerations.

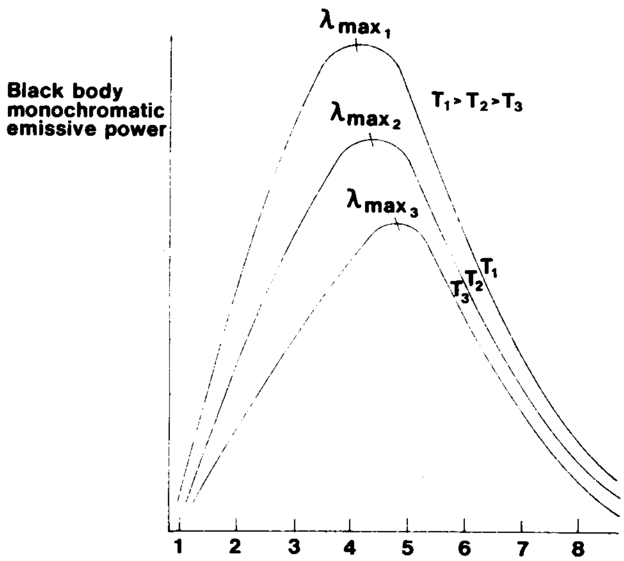


Figure 1.

(continued next page)

Operating Limits and Warnings

A minute or more may be required to obtain $E_{b(0-\lambda)}$ or $E_{b(\lambda_1-\lambda_2)}$ since the integration is numerical.

Sources differ on values for constants. This could yield small discrepancies between published tables and program outputs.

Figure 1 is a representation of black body thermal emission as a function of wavelength. Note that as temperature increases, the area under the curves (total emissive power $E_{b(0-\infty)}$) increases. Also note htat the wavelength of maximum emissive power λ_{max} shifts to the left as temperature increases.

This program calculates the wavelength of maximum emissive power for a given temperature, the temperature for which a given wavelength would be the wavelength of maximum emissive power, the total emissive power over all wavelengths, the emissive power at a particlular wavelength, the emissive power form zero to a specified wavelength, and the emissive power between specified wavelengths.

Equations:

$$\lambda_{max} \, T_{\lambda_{max}} = c_3$$

$$E_{b(0-\infty)} = \sigma T^4$$

$$E_{b\lambda} = \frac{2\pi c_1}{\lambda^5 (e^{c_2/\lambda T} - 1)}$$

$$E_{b(0-\lambda)} = \int_0^{\lambda} E_{b\lambda} \, d\lambda$$

$$= 2\pi c_1 \sum_{k=1}^{\infty} -T/kc_2 \; e^{-\frac{kc_2}{T\lambda}} \left[\left(\frac{1}{\lambda}\right)^3 + \frac{3T}{\lambda^2 kc_2} + \frac{6}{\lambda}\left(\frac{T}{kc_2}\right)^2 + 6\left(\frac{T}{kc_2}\right)^3 \right]$$

$$E_{b(\lambda_1 - \lambda_2)} = E_{b(0-\lambda_2)} - E_{b(0-\lambda_1)}$$

where

λ_{max} is the wavelength of maximum emissivity in microns;

T is the absolute temperature in °R or K;

$E_{b(0-\infty)}$ is the total emissive power in Btu/hr-ft^2 or Watts/cm^2;

$E_{b\lambda}$ is the emissive power at λ in Btu/hr-ft^2-μm or Watts/cm^2-μm;

$E_{b(0-\lambda)}$ is the emissive power for wavelengths less than λ in Btu/hr-ft^2 or Watts/cm^2;

$E_{b(\lambda_1-\lambda_2)}$ is the emissive power for wavelengths between λ_1 and λ_2 in Btu/hr-ft^2 or Watts/cm^2.

$c_1 = 1.8887982 \times 10^7$ Btu-μm^4/hr-ft^2

$= 5.9544 \times 10^3$ Wμm^4/cm^2

$c_2 = 2.58984 \times 10^4$ μm-°R $= 1.4388 \times 10^4$ μm-K

$c_3 = 5.216 \times 10^3$ μm-°R $= 2.8978 \times 10^3$ μm-K

$\sigma = 1.713 \times 10^{-9}$ Btu/hr-ft^2-°R^4 $= 5.6693 \times 10^{-12}$ W/cm^2-K^4

$\sigma_{exp} = 1.731 \times 10^{-9}$ Btu/hr-ft^2-°R^4 $= 5.729 \times 10^{-12}$ W/cm^2-K^4

Program Description II

Sketch(es)

Sample Problem(s) Example 1:

What percentage of the radiant output of a lamp is in the visible range (0.4 to 0.7 microns) if the filament of the lamp is assumed to be a black body at 2400 K? What is the percentage at 2500 K?

Keystrokes:	Outputs:
[f] [B] →	5.669×10^{-12} W/cm^2-K^4
2400 [A] .4 [B] .7 [f] [E] [C] [÷] 100 [x] →	2.641%
2500 [A] .7 [f] [E] [C] [÷] 100 [x] →	3.337%

Example 2:

If the human eye was designed to work most efficinetly is sunlight and the visible spectrum runs from about 0.4 to 0.7 microns, what is the sun's temperature in degrees Rankine? Assume that the sun is a black body. Using the temperature calculated, find the fraction of the sun's total emissive power which falls in the visible range. Find the percentage of the sun's radiation which has a wavelength less than 0.4 microns.

Keystrokes:	Outputs:
[f] [A] →	1.713×10^{-9} Btu/hr-ft^2-°R^4
Compute mean of visible range.	
.4 [+] .7 [+] 2 [÷] →	550.0×10^{-3} μm
Compute temperature of sun.	
[B] →	9.484×10^3 °R

(continued)

Reference(s)

Robert Siegel and John R. Howell, *Thermal Radiation Heat Transfer*, Volume 1, National Aeronautics and Space Administration, 1968.

Compute percentage of power in visible range.

[A] .4 [B] .7 [f][E] [C] [÷] 100 [x]------------------→ 33.70 x 10^0 %

Compute percentage of power under 0.4 microns.

[E] [C] [÷] 100 [x]--------------------------------→ 8.433%

User Instructions

Black Body Thermal Radiation

1					2
Eng	SI	Exp σ		$\lambda' \rightarrow E_{b(\lambda-\lambda')}$	
$T \rightarrow \lambda max$	$\lambda \rightarrow T(\lambda max)$	$\rightarrow E_b\ (0-\infty)$	$\rightarrow E_{b\lambda}$	$E_{b(0-\lambda)}$	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Load side 1 and side 2.				
2	Store constants:				
	For English units (Btu, μm, hr, ft, °R)		f	A	$1.713x10^{-9}$
	For SI units (W, μm, cm, K)		f	B	$5.669x10^{-12}$
3	For experimental Stefan-Boltzman constant				
	instead of theoretical value press		f	C	$1.731x10^{-9}$
					or $5.729x10^{-12}$
4	Calculate any or all of the following (T and				
	λ need only be input once):				
	Calculate λ_{max} for a given T;	T	A		λ_{max}
	Calculate T such that λ is λ_{max} for T;	λ			$T(\lambda_{max})$
	Calculate total emissive power;	T	A	C	$E_{b(0-\infty)}$
	Calculate the emissive power at λ;	T	A		λ_{max}
		λ	B	D	$E_{b\lambda}$
	Calculate the emissive power between zero				
	and λ;	T	A		λ_{max}
		λ	B	E	$E_{b(0-\lambda)}$
	Calculate the emissive power between λ				
	and λ'.	T	A		λ_{max}
		λ	B		$T(\lambda_{max})$
		λ'	f	E	$E_{b(\lambda-\lambda')}$
5	For a new case, go to steps 2, 3, or 4.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11		057	5	05	
002	1	01	Store English constants.	058	.	-62	
003	8	08		059	6	06	
004	8	08		060	6	06	
005	8	08		061	9	09	
006	7	07		062	3	03	
007	9	09		063	EEX	-23	
008	8	08		064	CHS	-22	
009	2	02		065	1	01	
010	STO1	35 01		066	2	02	
011	2	02		067	STO4	35 04	
012	5	05		068	RTN	24	
013	8	08		069	*LBLc	21 16 13	
014	9	09		070	1	01	Convert to experimental σ.
015	8	08		071	.	-62	
016	.	-62		072	0	00	
017	4	04		073	1	01	
018	STO2	35 02		074	0	00	
019	5	05		075	5	05	
020	2	02		076	ST×4	35-35 04	
021	1	01		077	RCL4	36 04	
022	6	06		078	RTN	24	
023	STO3	35 03		079	*LBLA	21 11	Store T and calculate λ_{max}.
024	.	-62		080	STO5	35 05	
025	1	01		081	RCL3	36 03	
026	7	07		082	X⇄Y	-41	
027	1	01		083	÷	-24	
028	3	03		084	RTN	24	
029	1	01		085	*LBLB	21 12	Store λ and calculate T for which λ would be λ_{max}.
030	2	02		086	STO6	35 06	
031	EEX	-23		087	RCL3	36 03	
032	CHS	-22		088	X⇄Y	-41	
033	8	08		089	÷	-24	
034	STO4	35 04		090	RTN	24	
035	RTN	24		091	*LBLC	21 13	Calculate $E_{b(0-\infty)}$.
036	*LBLb	21 16 12		092	RCL5	36 05	
037	5	05	Store SI constants.	093	X²	53	
038	9	09		094	X²	53	
039	5	05		095	RCL4	36 04	
040	4	04		096	×	-35	
041	.	-62		097	RTN	24	
042	4	04		098	*LBLD	21 14	Calculate $E_{b\lambda}$.
043	STO1	35 01		099	RCL1	36 01	
044	1	01		100	ENT↑	-21	
045	4	04		101	+	-55	
046	3	03		102	Pi	16-24	
047	8	08		103	×	-35	
048	8	08		104	RCL6	36 06	
049	STO2	35 02		105	5	05	
050	2	02		106	Yˣ	31	
051	8	08		107	÷	-24	
052	9	09		108	RCL2	36 02	
053	7	07		109	RCL6	36 06	
054	.	-62		110	÷	-24	
055	8	08		111	RCL5	36 05	
056	STO3	35 03		112	÷	-24	

REGISTERS

0	1	2	3	4	5	6	7	8	9
λ	c_1	c_2	c_3	σ	T	λ, λ'	sum	kc_2/T	
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	e^x	33	
114	1	01	
115	-	-45	
116	÷	-24	
117	RTN	24	
118	*LBLE	21 15	Calculate $E_{b(0-\lambda)}$.
119	0	00	
120	STO8	35 08	
121	STO7	35 07	
122	*LBL1	21 01	
123	R↓	-31	
124	CLX	-51	
125	RCL8	36 08	
126	RCL2	36 02	
127	RCL5	36 05	
128	÷	-24	
129	-	-45	
130	STO8	35 08	
131	3	03	
132	X⇄Y	-41	
133	÷	-24	
134	RCL6	36 06	
135	X^2	53	
136	÷	-24	
137	LSTX	16-63	
138	1/X	52	
139	RCL6	36 06	
140	÷	-24	
141	-	-45	
142	6	06	
143	RCL6	36 06	
144	÷	-24	
145	RCL8	36 08	
146	X^2	53	
147	÷	-24	
148	-	-45	
149	6	06	
150	RCL8	36 08	
151	X^2	53	
152	÷	-24	
153	RCL8	36 08	
154	÷	-24	
155	+	-55	
156	RCL8	36 08	
157	RCL6	36 06	
158	÷	-24	
159	e^x	33	
160	×	-35	
161	RCL8	36 08	
162	÷	-24	
163	ST+7	35-55 07	
164	RCL7	36 07	
165	÷	-24	
166	EEX	-23	
167	CHS	-22	
168	5	05	

STEP	KEY ENTRY	KEY CODE	COMMENTS
169	X≤Y?	16-35	
170	GTO1	22 01	
171	R↓	-31	
172	CLX	-51	
173	RCL7	36 07	
174	ENT↑	-21	
175	+	-55	
176	Pi	16-24	
177	×	-35	
178	RCL1	36 01	
179	×	-35	
180	RTN	24	
181	*LBLe	21 16 15	Calculate $E_{b(\lambda-\lambda')}$.
182	ENT↑	-21	
183	ENT↑	-21	
184	GSBE	23 15	
185	X⇄Y	-41	
186	RCL6	36 06	
187	STO0	35 00	
188	R↓	-31	
189	STO6	35 06	
190	GSBE	23 15	
191	-	-45	
192	ABS	16 31	
193	RCL0	36 00	
194	STO6	35 06	
195	R↓	-31	
196	RTN	24	
200			
210			
220			

LABELS

A $T\to\lambda_{max}$	B $\lambda\to T(\lambda_{max})$	C $\to E_{b(0-\infty)}$	D $\to E_{b\ \lambda}$	E $\to E_{b(0-\lambda)}$
a Eng	b SI	c Exp σ	d	e $\lambda'\to E_{b(\lambda-\lambda')}$
0	1 $E_{b(0-\lambda)}$	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	3

Program Description I

Program Title Economic Insulation Thickness

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

$$I = 3.46 \times 10^{-3} \sqrt{Y(\Delta T)\, M\, k/b} - 6k$$

Where:

I = thickness of insulation in inches

Y = hours per year

k = conductivity of insulation $BTU/ft^2 {}^\circ F/ft.$

ΔT = temperature difference, °F

M = cost of energy \$ per 10^6 BTU

b = cost of insulation \$ per ft^2 per in. thickness

Operating Limits and Warnings

Insulation is assumed to be protected from moisture saturation possibilities.

Program Description II

Sketch(es)

Sample Problem(s)

A. What thickness of insulation is economic for a prefab wall used in a structure with the following conditions?

$k = 0.15$, $\Delta T = 72° - 32°F$

Y = 24 hrs per day per year(8760),

M = $1.00 per 10^6 BTU

b = $0.20 per sq. ft. per inch thickness

B. What if the energy price is $2.50/million BTU?

Solution(s)

0.15 [↑] 8760[B] 40[C] 1[D] 0.2[E] [A] [R/S] --------------> 0.87 inches

A Ans. 0.87 inches

2.5[D] [A] [R/S] ---> 1.90

B Ans. 1.90 inches

Reference(s) Mechanical Engineers Handbook, L. Marks, McGraw-Hill 1941, pg 404.

This program is a translation of the HP-65 Users' Program #01621A submitted by John R. Feemster.

User Instructions

Economic Insulation Thickness

1					2
I in.	k↑ Y hr/yr	ΔT°F	$/10^6 BTU	$/Inch Ins	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Input program				
2.	Input data				
	K	BTU/hr°F/ft	↑		k
	Y	hr/yr	B		k
	ΔT	°F	C		°F
3.	Any two of the following are entered				
	I	inches	A		inches
	$/10^6 BTU	$	D		$
	$/inch ins.	$	E		$
4.	Calculate				
	I		A	R/S	inches
	$/10^6 BTU		D	R/S	$
	$/inch ins.		E	R/S	$
5.	To begin new problem begin at step 2				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO1	35 01	
003	3	03	
004	.	-62	
005	4	04	Const. 3.46×10^{-3}
006	6	06	
007	EEX	-23	
008	3	03	
009	CHS	-22	
010	STO6	35 06	
011	RCL1	36 01	
012	R/S	51	Calculate I
013	RCL2	36 02	
014	RCL3	36 03	
015	×	-35	
016	RCL4	36 04	
017	×	-35	
018	RCL5	36 05	
019	×	-35	
020	RCL7	36 07	
021	÷	-24	
022	√X	54	
023	RCL6	36 06	
024	×	-35	
025	6	06	
026	RCL5	36 05	
027	×	-35	
028	-	-45	
029	STO1	35 01	
030	RTN	24	
031	*LBLB	21 12	
032	STO2	35 02	
033	R↓	-31	
034	STO5	35 05	
035	RTN	24	
036	*LBLC	21 13	
037	STO3	35 03	
038	RTN	24	
039	*LBLD	21 14	
040	STO4	35 04	
041	R/S	51	Calculate M
042	RCL1	36 01	
043	RCL5	36 05	
044	6	06	
045	×	-35	
046	+	-55	
047	RCL6	36 06	
048	÷	-24	
049	X²	53	
050	RCL2	36 02	
051	RCL5	36 05	
052	×	-35	
053	RCL3	36 03	
054	×	-35	
055	RCL7	36 07	
056	÷	-24	
057	÷	-24	
058	STO4	35 04	
059	RTN	24	
060	*LBLE	21 15	
061	STO7	35 07	Calculate b
062	R/S	51	
063	RCL2	36 02	
064	RCL5	36 05	
065	×	-35	
066	RCL4	36 04	
067	×	-35	
068	RCL3	36 03	
069	×	-35	
070	RCL1	36 01	
071	RCL5	36 05	
072	6	06	
073	×	-35	
074	+	-55	
075	RCL6	36 06	
076	÷	-24	
077	X²	53	
078	÷	-24	
079	STO7	35 07	
080	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
	Ins.	hrs/yr	ΔT	M	k	Const	b		

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Heat Transfer Through Composite Cylinders and Walls

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

This program can be used to calculate the overall heat transfer coefficient for composite tubes and walls from individual section conductances and surface coefficients.

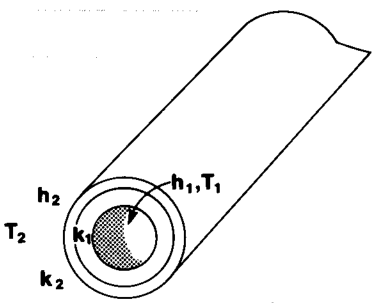


Figure 1.—Composite tube

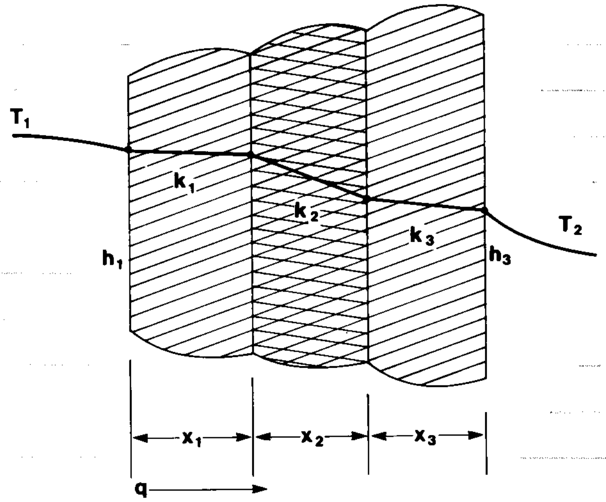


Figure 2. —Composite wall

Operating Limits and Warnings

These equations are for steady state heat transfer through materials with constant properties in all directions.

Inputs must start with the inside convective coefficient and work out in the case of composite cylinders.

Zero is an invalid input for D, k, and h.

Dimensional consistency must be maintained.

Program Description I

Program Title Heat Transfer Through Composite Cylinders and Walls

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

The overall heat transfer coefficient U is defined by:

$$q/L = U\,\Delta T$$

or

$$q/A = U\,\Delta T$$

where ΔT is the total temperature difference $(T_2 - T_1)$, q/L is the heat transfer per unit length of pipe, and q/A is the heat transfer per unit area of wall.

For cylinders

$$U = \frac{2\pi}{\frac{2}{h_1 D_1} + \frac{\ln D_2/D_1}{k_1} + \frac{\ln D_3/D_2}{k_2} + \ldots + \frac{2}{h_n D_n}}$$

For walls

$$U = \frac{1}{\frac{1}{h_1} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots + \frac{1}{h_n}}$$

where

h is the convective surface coefficient;

D_n is the outside diameter of the annulus;

k is the conductive coefficient;

x is the thickness of a wall section.

Program Description II

Sketch(es)

Sample Problem(s)

Example 1:

A steel pipe with an inside diameter of 4 inches and a thickness of 0.5 inches has a conductivity of 25 Btu/ft-hr-°F. Two inches of asbestos (k = 0.1 Btu/hr-ft-°F) enclose the pipe bringing the total diameter to 9 inches. If the inside convective coefficient is 1000 Btu/hr-ft²-°F and the outside coefficient is 5 Btu/hr-ft²-°F, what is the overall heat transfer coefficient? What is the heat loss for 100 feet of pipe if ΔT is 115°F?

Keystrokes	See Displayed
4 [↑] 12 [÷] 1000 [A] 5 [↑] 12 [÷] 25 [B] 9 [↑] 12 [÷] 0.1 [B] 9 [↑] 12 [÷] 5 [A] [C] →	0.98 Btu/hr-ft-°F
115 [×] →	112.44 Btu/hr-ft
100 [×] →	11244.20 Btu/hr

Solution(s)

Example 2:

A wall is composed of 1 foot of brick (k = 0.4 Btu/hr-ft-°F), and 1 inch of wood (k = 0.12 Btu/hr-ft-°F). The convective coefficient on one side is 23 Btu/hr-ft²-°F. The convective coefficient of the other side is 5 Btu/hr-ft²-°F. What is the overall coefficient? What is the heat flux if the temperature difference is 70°F?

Keystrokes	See Displayed
[RTN] 1 [↑] 0.4 [E] 1 [↑] 12 [÷] .12 [E] 23 [D] 5 [D] [C] →	0.29 Btu/ft²-hr-°F
70 [×] →	20.36 Btu/ft²-hr

Reference(s)

User Instructions

COMPOSITE CYLINDERS AND WALLS
RTN=START D↑h | D↑k | →U | h | x↑k

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	For a composite wall go to			
	step 9.			
3	Input the inner diameter	D_{in}	↑	D_{in}
4	Input the inner convective			
	coefficient	h_{in}	A	2/hD
5	Input next diameter value	D	↑	D
	and corresponding coefficient	k or h	B	
6	Go to step 5 for next surface			
	or go to step 3 for outside			
	surface*			
7	Calculate overall heat transfer			
	coefficient		C	U
8	To calculate another overall			
	coefficient, go to step 2			
9	Input the coefficients for each			
	section of the wall:			
	Convective coefficient	h	D	1/h
	or length of conductive path	x	↑	
	and conductive coefficient	k	E	x/k
10	Go to step 9 for next input*			
11	Calculate overall heat transfer			
	coefficient		C	U
12	To calculate another overall			
	coefficient, go to step 2			

* Press RTN to restart a calculation.

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	Pi	16-24	Initialize
003	STO6	35 06	
004	CLX	-51	
005	STO8	35 08	
006	R↓	-31	
007	X⇄Y	-41	
008	STO7	35 07	
009	X⇄Y	-41	
010	GTOA	22 11	
011	*LBL1	21 01	Idle
012	RTN	24	
013	*LBLA	21 11	
014	×	-35	Add convective
015	1/X	52	factor
016	ST+8	35-55 08	
017	RTN	24	
018	*LBLB	21 12	
019	1/X	52	
020	X⇄Y	-41	
021	RCL7	36 07	
022	X⇄Y	-41	Add conductive
023	STO7	35 07	factor
024	÷	-24	
025	LN	32	
026	×	-35	
027	2	02	
028	÷	-24	
029	ST-8	35-45 08	
030	GTO1	22 01	
031	*LBLC	21 13	Calculate U
032	RCL8	36 08	
033	1/X	52	
034	RCL6	36 06	
035	×	-35	
036	STO4	35 04	
037	RTN	24	
038	*LBLD	21 14	Add convective
039	1	01	factors
040	X⇄Y	-41	
041	*LBLE	21 15	
042	1	01	
043	STO6	35 06	
044	CLX	-51	
045	STO8	35 08	
046	R↓	-31	
047	GTOE	22 15	
048	*LBL2	21 02	
049	RTN	24	
050	*LBLE	21 15	
051	X⇄Y	-41	Add conductive
052	÷	-24	factors
053	*LBLD	21 14	
054	1/X	52	
055	ST+8	35-55 08	
056	GTO2	22 02	

STEP	KEY ENTRY	KEY CODE	COMMENTS
060			
070			
080			
090			
100			
110			

FLAGS	
0	
1	
2	
3	

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
				U		1 or π	Used	ΣR	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Steady State Conductive Heat Transfer, Heat Load and Logarithmic Mean Temperature Difference

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

Given any Three variables

$(Q, U, A \& \Delta t_m)$ OR $(Q, W, C_p \& \Delta t)$

The Program Computes the Fourth Variables:

$$Q = UA\Delta t_m, \quad U = \frac{Q}{A\Delta t_m}, \ldots \ldots \text{etc.}$$

$$Q = WCp\Delta t, \quad C_p = \frac{Q}{W\Delta t}, \ldots \ldots \text{etc}$$

Given Temperature Conditions

$(T_1, T_2, t_1 \& t_2)$, $(t_1 \& t_2)$ or $(T_1 \& T_2)$

The Program Computes:

$$\text{OR} \quad \Delta t_m = \frac{\Delta_2 - \Delta_1}{\ln(\Delta_2/\Delta_1)}$$

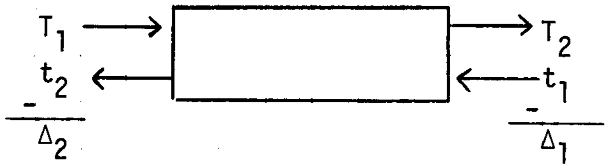
$$\Delta t = (t_2 - t_1), (T_2 - T_1).$$

To combine these three basic heat transfer equations will increase the flexibility and speed of heat transfer design.

Operating Limits and Warnings

Program Description II

Sketch(es)



Sample Problem(s) Determine U of an existing exchanger for the following data (Represented by the Above Sketch):

W = 247,000 lb per hr	Flow Rate
C_p = 0.585 Btu/(lb)(°F)	Heat Capacity of the Fluid
T_1 = 410°F	Hot Inlet Temperature
T_2 = 150°F	Hot Outlet Temperature
t_1 = 100°F	Cold Inlet Temperature
t_2 = 347.5°F	Cold Outlet Temperature
A = 9390 sq ft	Heat Transfer Area

Solution(s)

Q = 37,568,700 Btu/hr	Duty
Δt_m = 56°F	Mean Temperature Difference
U = 71.42 Btu/(hr)(°F)(sq ft)	Heat Transfer coefficient

Keystrokes:	Output:
247000[B] 0.585[C] 410[ENT↑] 150[−] [D] 0[A]	37568700(Q)
410[ENT↑] 347.5[ENT↑] 150[ENT↑] 100[E]	56.02 (Δt_m)
[D] 9390[C] 0[B]	71.42 (U)

Reference(s) McAdams, W.H., Heat Transmission, McGraw-Hill Book Co.

This program is a translation of the HP-65 Users' Library program #00648A submitted by Yu Tsung Pei.

User Instructions

Steady State Conductive Heat Transfer, Heat Load and Log Mean Temperature Difference

1 | Q | U or W | Δ or C_p | Δt_m or Δt | Δt_m or Δt | 2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load program				
2.	Compute Q				
	Input U Btu/(hr)(°F)(sw ft) or W lb/hr	U or W	B		U or W
	Input A sq ft or C_p Btu/(lb)(°F)	A or C_p	C		A or C_p
	Input Δt_m °F or Δt °F	Δt_m or Δt	D		Δt_m or Δt
2.	Compute U or W				
	Input Q Btu/hr	A	A		Q
	Input A sq ft or C_p Btu/(lb)(°F)	A or C_p	C		A or C_p
	Input Δt_m °F or Δt °F	ΔT_m or Δt	D		Δt_m or Δt
			0	B	U or W
2.	Compute A or C_p				
	Input Q Btu/hr	Q	A		Q
	Input U Btu/(hr)(°F)(sq ft) or W lb/hr	U or W	B		U or W
	Input Δt_m °F or Δt °F	Δt_m or Δt	D		Δt_m or Δt
			0	C	A or C_p
2.	Compute t_m or t				
	Input Q Btu/hr	Q	A		Q
	Input U Btu/(hr)(°F)(sq ft) or W lb/hr	U or W	B		U or W
	Input A sq ft or C_p Btu/(lb)(°F)	A or C_p	C		A or C_p
			0	D	Δt_m or Δt
3.	Compute Δt_m or Δt from T_1, T_2, t_1 & t_2.				
	T_1 T_2	T_1	↑		T_1
	t_2 t_1	t_2	↑		t_2
		T_2 or t_2	↑		T_2 or t_2
		t_1 or t_1	E		Δt_m or Δt

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	0	00	Compute the Q
003	X⇄Y	-41	
004	X≠Y?	16-32	
005	GTO1	22 01	
006	RCL2	36 02	
007	RCL3	36 03	
008	RCL4	36 04	
009	×	-35	
010	×	-35	
011	STO1	35 01	
012	RTN	24	
013	*LBLB	21 12	Compute the U or W
014	0	00	
015	X⇄Y	-41	
016	X≠Y?	16-32	
017	GTO2	22 02	
018	RCL1	36 01	
019	RCL3	36 03	
020	RCL4	36 04	
021	×	-35	
022	÷	-24	
023	STO2	35 02	
024	RTN	24	
025	*LBLC	21 13	Compute the A or C
026	0	00	
027	X⇄Y	-41	
028	X≠Y?	16-32	
029	GTO3	22 03	
030	RCL1	36 01	
031	RCL2	36 02	
032	RCL4	36 04	
033	×	-35	
034	÷	-24	
035	STO3	35 03	
036	RTN	24	
037	*LBLD	21 14	
038	0	00	Compute Δt_m or Δt
039	X⇄Y	-41	
040	X≠Y?	16-32	
041	GTO4	22 04	
042	RCL1	36 01	
043	RCL2	36 02	
044	RCL3	36 03	
045	×	-35	
046	÷	-24	
047	STO4	35 04	
048	RTN	24	
049	*LBLE	21 15	
050	-	-45	Compute Δt_m or Δt
051	R↓	-31	from T_1,T_2,t_1 or t_2
052	X≠Y?	16-32	
053	GTO0	22 00	
054	R↑	16-31	
055	STO4	35 04	
056	RTN	24	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	*LBL0	21 00	
058	-	-45	
059	R↑	16-31	
060	X=Y?	16-33	$T_1-t_2 = \Delta_2$
061	R/S	51	
062	X≤Y?	16-35	$T_2-t_1 = \Delta_1$
063	X⇄Y	-41	
064	STO5	35 05	$\Delta_2 = \Delta_1 = \Delta t_m$
065	STO6	35 06	
066	R↓	-31	
067	ST-5	35-45 05	
068	ST÷6	35-24 06	
069	RCL5	36 05	
070	RCL6	36 06	
071	LN	32	
072	÷	-24	
073	STO4	35 04	
074	RTN	24	
075	*LBL1	21 01	
076	STO1	35 01	
077	R/S	51	
078	*LBL2	21 02	
079	STO2	35 02	
080	R/S	51	
081	*LBL3	21 03	
082	STO3	35 03	
083	R/S	51	
084	*LBL4	21 04	
085	STO4	35 04	
086	R/S	51	

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
	Q	U,W	A,C_p	Δt_m,Δt	Δ_1	Δ_2			

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Sun Altitude, Azimuth, Solar Pond Absorption

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

Given: Index of refraction of pond fluid; latitude; number of days after spring equinox, and number of hours before or after solar noon; the program computes: the sun's altitude h.

$$h = \sin^{-1}(\cos l \cos d \cos t + \sin l \sin d)$$

l - latitude in decimal degrees

d = sun's declination = 23.45 sin D

D = (no. of days after spring equinox)$(0.9856 \frac{\text{degrees}}{\text{day}})$

t = (no. of hours before or after solar noon);

the sun's azimuth A.

$$A = \cos^{-1}\left(\frac{\cos i \sin l - \sin d}{\cos l \sin i}\right)$$

i = 90 - h;

the fraction of solar radiation striking the pond surface which will penetrate the pond surface, E,

$$\text{Fraction } E = 2n(a^2 + b^2) \cos i \cos r$$

$$a = \frac{1}{\cos r + n\cos i} \quad \text{where } r - \sin^{-1}\left(\frac{\sin i}{n}\right)$$

$$b = \frac{1}{\cos i + n\cos r}$$

n = index of refraction of pond fluid

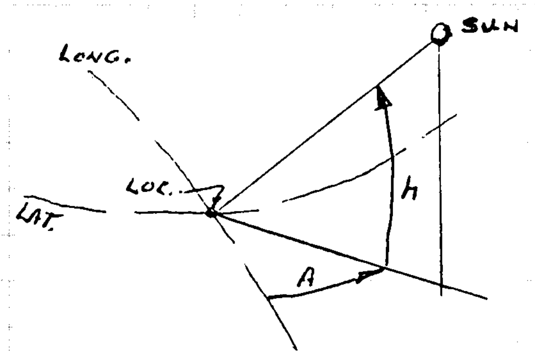
(refs: Smithsonian Physical Tables, 9th rev. Ed. & Weinberger, H., Solar energy, v8, n2,
1954 (p 729) 1964 (pp 45-56)

OPERATING LIMITS AND WARNINGS

Does not compute azimuth at latitude of 90 degrees.

Program Description II

Sketch(es)



Sample Problem(s)

Find the sun's altitude, azimuth, and the fraction of the sun's radiation which will penetrate the surface of a solar pond under the following circumstances:

Index of refraction of pond fluid n = 1.33

Latitude l = 46.00

Days after spring equinox = 68

Hours before solar noon = 4

Solution(s)

h = 35.99 degrees

A = 84.41 degrees

E = 0.96

Keystrokes:	Outputs:
23.45[STO][1] .9856[STO][2] 1.33[STO][3]	
46[A] 68[B] 4[C] ------------------------------------>	35.99
[R/S] -->	84.41
[R/S] -->	0.96

Reference(s)

Smithsonian Physical Tables, 9th rev. Ed., 1954, (p 729)

Weinberger, H., Solar Energy, vol 8, no. 2, 1964 (pp 45-56)

This program is a translation of the HP-65 Users' Library program #00683A submitted by Robert J. Zaworski.

User Instructions

Sun Altitude, Azimuth, Solar Pond Absorption

1 LAT DAYS HRS 2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter program				
2.	Introduce constants	23.45	STO	1	
		0.9856	STO	2	
		n	STO	3	
3.	Input latitude (0 to 90) in decimal degrees	latitude	A		l
4.	Input numberof days (0 to 365) after Spring Equinox	days	B		d
5.	Input number of hours (0 to 12) before or after solar noon, and compute altitude		C		h
6.	Compute azimuth		R/S		A
7.	Compute the fraction of solar rediation striking the pond surface which will penetrate the pond surface		R/S		E

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	COS	42	
003	STO4	35 04	cos l in 4
004	LSTX	16-63	
005	RTN	24	stops with latitude in x
006	*LBLB	21 12	
007	RCL2	36 02	
008	×	-35	
009	SIN	41	
010	RCL1	36 01	
011	×	-35	
012	STO5	35 05	d in 5
013	RTN	24	stops with decl.in x
014	*LBLC	21 13	
015	1	01	
016	5	05	
017	×	-35	
018	COS	42	
019	STO8	35 08	
020	RCL4	36 04	
021	×	-35	
022	RCL5	36 05	
023	COS	42	
024	×	-35	
025	RCL4	36 04	
026	GSBD	23 14	
027	RCL5	36 05	
028	SIN	41	
029	STO7	35 07	
030	×	-35	
031	+	-55	
032	STO6	35 06	
033	SIN⁻¹	16 41	
034	R/S	51	Stops with alt. in x
035	RCL6	36 06	
036	RCL4	36 04	
037	GSBD	23 14	
038	×	-35	
039	RCL7	36 07	
040	-	-45	
041	RCL4	36 04	
042	÷	-24	
043	RCL6	36 06	
044	GSBD	23 14	
045	÷	-24	
046	COS⁻¹	16 42	
047	R/S	51	Stops with azimuth in x
048	RCL6	36 06	
049	GSBD	23 14	
050	RCL3	36 03	
051	÷	-24	
052	SIN⁻¹	16 41	
053	COS	42	
054	STO7	35 07	cos r in 7
055	RCL6	36 06	
056	RCL3	36 03	
057	GSBE	23 15	
058	RCL6	36 06	
059	RCL7	36 07	
060	RCL3	36 03	
061	GSBE	23 15	
062	+	-55	
063	RCL3	36 03	
064	×	-35	
065	2	02	
066	×	-35	
067	RCL6	36 06	
068	×	-35	
069	RCL7	36 07	
070	×	-35	
071	RTN	24	
072	*LBLD	21 14	
073	COS⁻¹	16 42	
074	SIN	41	
075	RTN	24	
076	*LBLE	21 15	
077	×	-35	
078	+	-55	
079	ENT↑	-21	
080	×	-35	
081	1/X	52	
082	RTN	24	
083	R/S	51	

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
	23.45	0.9856 deg/day	n (index of refrac	cos l	d declination	cos i	sin d/cos r	cos t	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Total Daily Amount of Solar Radiation

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 9733

Program Description, Equations, Variables This program determines the total amount of solar radiation received by a horizonatal surface of unit area during one calendar day. The result is expressed as equivalent hours of direct sunshine if sun were stationary and directly overhead. Also computes length of daylight and accumulates total radiation in R7 for succesive calculations. Input variables are latitude, L, suns declineation (from nautical almanac) in decimal degrees.

Day Length = $24\ \theta/\pi$, θ expressed in radians

θ = Arc cos (-sin L Sin D/cos L cos D)

$$\text{Total Radiation} = 2\int_0^{\theta} \sin H\, d\theta$$

$$= (\sin L \sin D)\,\theta + \cos L \cos D \sin \theta$$

Operating Limits and Warnings

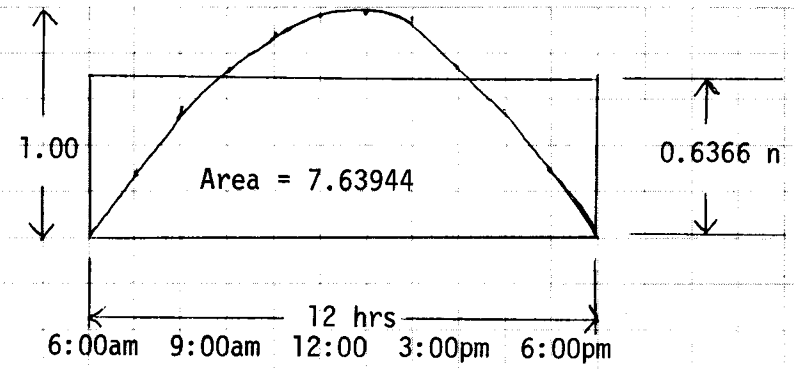
North latitudes and declinations are entered as positive values south as negative values.

The value 90-L+D must be greater than zero.

Equations assume surface level with horizon and ignores atmospheric refraction and assume cloudless sky.

Program Description II

Sketch(es)



Sample Problem(s)

(1) Equator, March 21 L = 0, D = 0

(2) North Pole, June 21, L = 90°, D = +23.45°

(3) Cupertino, CA 95014, September 15, 1974
L = 37.32°, Dec = +2.93°

Solution(s)

(1) DHY length = 12.00 hrs Total Rad = 7.6394 hrs
(2) " " = 24.00 " " " = 9.5508
(3) " " = 12 hrs, 17 min, 53 sec. Total Rad = 6.4439

Keystrokes:	Outputs:
(1) 0[E] 0[A] 0[B]	12.0000
[C]	7.6394
(2) 0[E] 90[A] 23.45[B]	24.0000
[C]	9.5508
(3) 0[E] 37.32[A] 2.93[B]	12.1753
[C]	6.4439

Reference(s)

(1) The Nautical Alamanac, U.S. Naval Observatory Purchase from Superintent of Documents, Washington D.C., 20402.
(2) American Practical Navigation, Bowditch U.S. Naval Oceanographic Office, pg 531, Also chapter XIV.
(3) Britannica Atlas

This program is a translation of the HP-65 Users' Library program 00996A submitted by Robert B. Egbert.

User Instructions

Total Daily Solar Rad

1 | LAT | DEC | $\int_0^\theta$ sin Hdθ | R-7 | 0 → R7 | 2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Read Card				
2.	0 → R7	0.00	F		0.00
3.	Input latitude °N +	LAT °N	A		LAT (+)
	or °S -	LAT °S	CHS	A	" (-)
4.	Input suns declination °N +	DEC °N	B		HOURS
	or °S -	DEC °S	CHS	B	DAYLIGHT
5.	Compute total rad = $2\int_0^\theta \sin H\, d\theta$		C		TOTAL RAD HRS
	To obtain total radiation for a number of days n (up to May of 365), repeat steps and 5.				
6.	Total radiation for N days		D		Σ^N TOT RAD

TABLE OF SUNS DECLINEATION (DECIMAL DEGREES)

DATE	DEC	DATE	DEC	DATE	DEC
Jan 1	-23.00	May 7	16.85	Sep 3	7.30
8	-22.38	14	18.67	10	4.88
15	-21.08	21	20.22	17	+2.20
22	-19.63	28	21.48	24	-0.50
29	-17.88	June4	22.45	Oct 1	-3.24
Feb 5	-15.87	11	23.10	8	-5.94
12	-13.63	18	23.42	15	-8.57
19	-11.22	25	23.40	22	-11.10
26	- 8.75	July2	23.05	29	-13.50
Mar 5	- 6.00	9	22.35	Nov 5	-15.72
12	- 3.27	16	21.35	12	-17.74
19	- 0.50	23	20.05	19	-19.50
26	+ 2.27	30	18.48	26	-20.97
Apr 5	5.00	Aug 6	16.66	Dec 3	-22.09
9	7.63	13	14.63	10	-22.93
16	10.17	20	12.40	17	-23.36
23	12.58	27	10.00	24	-23.42
30	14.82			31	-23.09

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	DSP4	-63 04	Enter latitude & store in R-1
003	STO1	35 01	
004	R/S	51	
005	*LBLB	21 12	
006	STO2	35 02	Enter sums declination and compute no. of hours of sunshine
007	DEG	16-21	
008	RCL1	36 01	
009	SIN	41	
010	RCL2	36 02	
011	SIN	41	
012	×	-35	
013	STO3	35 03	
014	RCL1	36 01	
015	COS	42	
016	RCL2	36 02	
017	COS	42	
018	×	-35	
019	STO4	35 04	
020	X≤Y?	16-35	This takes care of midnight sun
021	GTO1	22 01	
022	RCL3	36 03	
023	RCL4	36 04	
024	÷	-24	
025	CHS	-22	
026	COS⁻¹	16 42	
027	7	07	
028	.	-62	Converts degrees (θ) to length of day in hr, min,sec
029	5	05	
030	÷	-24	
031	STO5	35 05	
032	→HMS	16 35	
033	R/S	51	
034	*LBLC	21 13	
035	RCL5	36 05	θ is converted to radians to perform the integration & result is converted to hours
036	Pi	16-24	
037	×	-35	
038	2	02	
039	4	04	
040	÷	-24	
041	STO6	35 06	
042	RAD	16-22	
043	RCL3	36 03	
044	RCL6	36 06	
045	×	-35	
046	RCL4	36 04	
047	RCL6	36 06	
048	SIN	41	
049	×	-35	
050	+	-55	
051	2	02	
052	4	04	
053	×	-35	
054	Pi	16-24	
055	÷	-24	
056	ENT↑	-21	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	ENT↑	-21	
058	RCL7	36 07	
059	+	-55	
060	STO7	35 07	
061	R↓	-31	
062	R/S	51	Display sums accumulated in R-7
063	*LBLD	21 14	
064	RCL7	36 07	
065	R/S	51	
066	*LBLE	21 15	Stores zero in R-7 for new series of calculations
067	0	00	
068	STO7	35 07	
069	R/S	51	Limits of integration for midnight s or case
070	*LBL1	21 01	
071	2	02	
072	4	04	
073	STO5	35 05	
074	R/S	51	
080			
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
	LAT	DEC OF SUN	Sin Lx Sin D	cos Lx cos D	θ HOURS OF SUNSHINE	θ RADIANS	Z∫sin Hdθ		

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Temperature or Concentration Profile For A Semi-Infinite Solid

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

Many physical situations in heat and mass transfer may be solved within engineering tolerances by assuming an infinite geometry.

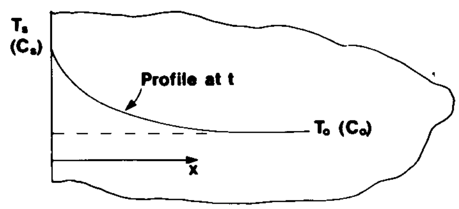


Figure 1.

In Figure 1 an infinitely thick wall initially at temperature T_0 or concentration C_0 is subject to a constant surface potential T_s or C_s. At a later time t, the internal profile will have been altered by the transport of heat or mass. This program computes values of temperature T or concentration C at time t for specified distances x from the outer surface.

Operating Limits and Warnings

This solution is exact for infinite configurations with constant cross sectional areas. However, finite geometries where the argument of the error function is greater than two will yield little or no error. This means transfer in finite bodies such as plates may be predicted until the effects of the step are felt on the far side. Also, geometries such as cylinders may be studied if the depth of penetration is small compared to the radius.

The routine used by this program will resolve error functions with arguments less than 4.5. For larger arguments, the value of the error function is set to 1.0.

Program Description I

Program Title Temperature or Concentration Profile For A Semi- Infinite Solid

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

Equations:

$$T = (T_0 - T_s)\,\mathrm{erf}\left(\frac{x}{2\sqrt{\frac{k}{\rho c_p}\,t}}\right) + T_s \quad *$$

where

k is thermal conductivity of the material;

ρ is the density of the material;

c_p is the specific heat of the material;

$k/\rho c_p$ is also known as the diffusivity of heat α.

Similarly, for mass transfer

$$C = (C_0 - C_s)\,\mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right) + C_s \quad *$$

where

D is the mass diffusivity.

*erf is the error function.

Operating Limits and Warnings

Program Description II

Sketch(es)

Example 1:

A large steel transmission shaft is case hardened by diffusion of carbon. The initial carbon concentration is 0.10% and the surface concentration is brought to 1.20% almost instantly. What is the carbon concentration at 1.0 mm (1×10^{-3} m) after 15 hours (54000 seconds), if the diffusivity of carbon in steel is taken to be 1.6×10^{-11} m^2/s?

Keystrokes	See Displayed
1.6 [EEX] [CHS] 11 [↑] 1 [↑] 1 [A] 1.2 [↑] .1 [B] 54000	
[C] [EEX] [CHS] 3 [D] ——→	0.59%

Example 2:

A furnace wall is at a constant 55°F. When the furnace is turned on the inside wall temperature is raised to 2000°F. How long will it take to raise the outside wall temperature 1°F?

k = 0.67 Btu/hr-ft-°F

Thickness = 1.5 feet

c = 0.2 Btu/lb °F

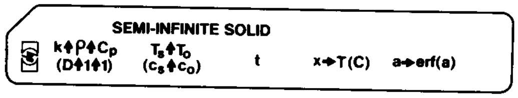
ρ = 150 lb/ft^3

Keystrokes **See Displayed**

An iterative solution is required since t is not a program output. Guess 5.0 hours for t.

Keystrokes	See Displayed
.67 [↑] 150 [↑] .2 [A] 2000 [↑] 55 [B] 5 [C] 1.5 [D] ——→	57.92°F
Guess 4.0	
Noting that x is stored in register 8.	
4.0 [C] [RCL] [8] [D] ——→	55.75°F
Guess 4.2	
4.2 [C] [RCL] [8] [D] ——→	56.04°F
Guess 4.18	
4.18 [C] [RCL] [8] [D] ——→	56.01°F
Noting that t is stored in register 7.	
[RCL] [7] [f] [→H.MS] ——→	≈4 hr. 10 min.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	To compute the error function			
	of an argument go to step 8.			
3	Input:			
	Conductivity	k	↑	k
	then density	ρ	↑	ρ
	then specific heat	c_p	A	α
	or heat (or mass) diffusivity	α (D)	↑	α (D)
	then 1.00	1	↑	1.00
	then 1.00	1	A	α (D)
4	Input:			
	Surface temperature (con-			
	centration)	T_s (C_s)	↑	T_s (C_s)
	then initial temperature			
	(concentration)	T_0 (C_0)	B	T_s (C_s)
5	Input time	t	C	t
6	Input distance from surface			
	and calculate temperature			
	or concentration	x	D	T (C)
7	For new case go to step 2, 3, or			
	4 and change inputs. For new			
	time go to step 5. For new x go			
	to step 6.			
8	Input argument and compute			
	error function	a	E	erf(a)

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	×	-35	
003	÷	-24	Store constants as α or D
004	STO6	35 06	
005	RTN	24	
006	*LBLB	21 12	
007	STO4	35 04	Store concentrations or temperatures
008	X⇄Y	-41	
009	STO5	35 05	
010	RTN	24	
011	*LBLC	21 13	
012	STO7	35 07	Store time
013	RTN	24	
014	*LBLD	21 14	
015	STO8	35 08	
016	2	02	
017	÷	-24	
018	RCL6	36 06	Calculate temp. or concentration given x
019	RCL7	36 07	
020	×	-35	
021	√X	54	
022	÷	-24	
023	GSBE	23 15	
024	RCL4	36 04	
025	RCL5	36 05	
026	-	-45	
027	×	-35	
028	RCL5	36 05	
029	+	-55	
030	RTN	24	
031	*LBLE	21 15	
032	STO1	35 01	
033	4	04	
034	.	-62	
035	5	05	
036	X≤Y?	16-35	
037	GTO0	22 00	
038	R↓	-31	
039	ENT↑	-21	
040	×	-35	
041	2	02	
042	×	-35	
043	STO2	35 02	
044	1	01	
045	STO3	35 03	
046	RCL1	36 01	
047	*LBL1	21 01	
048	RCL2	36 02	Evaluate the error function
049	RCL3	36 03	
050	2	02	
051	+	-55	
052	STO3	35 03	
053	÷	-24	
054	RCL1	36 01	
055	×	-35	
056	STO1	35 01	
057	+	-55	
058	X≠Y?	16-32	
059	GTO1	22 01	
060	2	02	
061	×	-35	
062	Pi	16-24	
063	√X	54	
064	÷	-24	
065	RCL2	36 02	
066	2	02	
067	÷	-24	
068	e^x	33	
069	÷	-24	
070	RTN	24	
071	*LBL0	21 00	
072	1	01	
073	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
	Part. Sum	$2a^2$	$2n + 1$	$T_0(C_0)$	$T_s(C_s)$	α	t	x	Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Transient Temperature Distribution In A Semi-Infinite Solid With Convection Boundary Condition

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

Given the data set:

x = Depth from surface

α = Thermal diffusivity

k = Thermal conductivity

h = Heat transfer coefficient

θ = Time

The program computes the following factor $\bar{x}$

$$\bar{x} = \text{ERF} \frac{x}{2\sqrt{\alpha\theta}} + \left[\text{EXP}\left(\frac{hx}{k} + \frac{h^2\alpha\theta}{k^2}\right)\right]\left[1 - \text{ERF}\left(\frac{x}{2\sqrt{\alpha\theta}} + \frac{h\sqrt{\alpha\theta}}{k}\right)\right]$$

where ERF = Error function

EXP = Exponential

The user must then manually compute the desired temperature $T(x,\theta)$, according to:

$$T(x,\theta) = T_\infty + (T_i - T_\infty)\,\bar{x}$$

where T_∞ = Sink temperature

T_i = Initial solid temperature

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

For the data set:

$x = 10^{-2}$ cm.
$\theta = 10^{-1}$ cm.
$\alpha = 7.141 \times 10^{-3}\ cm^2\ sec^{-1}$
$k = 6.322 \times 10^{-3}$ cal $cm^{-1}\ sec^{-1}\ {}^{0}C^{-1}$
$h = 6.0 \times 10^{-1}$ cal $cm^{-2}\ sec^{-1}\ {}^{0}C^{-1}$

Solution(s) The program computes the value:

$\underline{x} = 0.3973$

for T_i = 1050°C and T_∞ = 450°C

$T(x,\theta) = T_\infty + (T_i - T_\infty)\ \underline{x} = 688.40°C$

Keystrokes: Outputs:

1[EEX][CHS] 2[STO][4] 1[EEX][CHS] 1[STO][5] 7.141[EEX][CHS] 3[STO][6]
6[EEX][CHS] 1[STO] [7] 6.322[EEX][CHS] 3[STO][8]
[A][B][C][D] ---> 0.3973
1050[ENT↑] 450[-][x] 450[+] --------------------------->688.40

Reference(s)

Hockman, J.P. Heat Transfer Third Edition pgs. 91-96 McGraw Hill, 1972

This program is a translation of the HP-65 Users' Library program #01472A submitted by John S. Wasylyr.

User Instructions

$T(x,\theta)$

A B C D

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load program				
2.	Enter data	x	STO	4	
3.	Enter data	θ	STO	5	
4.	Enter data	α	STO	6	
5.	Enter data	h	STO	7	
6.	Enter data	k	STO	8	
7.	Press		A		See 1 below
8.			B		" 2 "
9.			C		" 3 "
10.			D		$\bar{x}$
11.	Enter $(T_i - T_\infty)$	$(T_i - T_\infty)$			
12.	Press		x		
13.	Enter T_∞	T_∞			
14.	Press		+		$T(x,\theta)$
	For new case, go to step 2				
	1. Calculates $\frac{x}{2\sqrt{\alpha\theta}} + \frac{h\sqrt{\alpha\theta}}{k}$				
	2. Calculates $ERF(\frac{x}{2\sqrt{\alpha\theta}} + \frac{h\sqrt{\alpha\theta}}{k})$				
	3. Calculates & Stores: $R8 = ERFC\left(\frac{x}{2\sqrt{\alpha\theta}} + \frac{h\sqrt{\alpha\theta}}{k}\right) EXP\left(\frac{hx}{k} + \frac{h^2\alpha\theta}{k^2}\right)$				
	$ERF\left(\frac{x}{2\sqrt{\alpha\theta}}\right)$ in stack				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	RCL8	36 08	
003	ST÷7	35-24 07	Calc (h/k) Sto R-7
004	RCL6	36 06	
005	ST×5	35-35 05	Calc ($\alpha\theta$) Sto R-5
006	RCL4	36 04	
007	RCL7	36 07	
008	×	-35	
009	STO6	35 06	Calc (hx/k) Sto R-6
010	RCL4	36 04	
011	2	02	
012	÷	-24	
013	RCL5	36 05	
014	√X	54	
015	÷	-24	
016	STO4	35 04	Calc ($4/2\sqrt{\alpha\theta}$) Sto R-4
017	RCL7	36 07	
018	RCL5	36 05	
019	√X	54	
020	×	-35	
021	+	-55	Calc ($x/2\sqrt{\alpha\theta} + h\sqrt{\alpha\theta}/k$)
022	RTN	24	
023	*LBLB	21 12	
024	STO1	35 01	
025	ENT↑	-21	Calc
026	×	-35	ERF($x/2\sqrt{\alpha\theta} + h\sqrt{\alpha\theta}/k$)
027	2	02	
028	×	-35	
029	STO2	35 02	
030	1	01	
031	STO3	35 03	
032	RCL1	36 01	
033	*LBL1	21 01	
034	RCL2	36 02	
035	RCL3	36 03	
036	2	02	
037	+	-55	
038	STO3	35 03	
039	÷	-24	
040	RCL1	36 01	
041	×	-35	
042	STO1	35 01	
043	+	-55	
044	X≠Y?	16-32	
045	GTO1	22 01	
046	2	02	
047	×	-35	
048	Pi	16-24	
049	√X	54	
050	RCL2	36 02	
051	2	02	
052	÷	-24	
053	eˣ	33	
054	×	-35	
055	÷	-24	
056	RTN	24	
057	*LBLC	21 13	Calc
058	1	01	ERFC($\frac{x}{2\sqrt{\alpha\theta}} + \frac{h\sqrt{\alpha\theta}}{k}$)
059	X⇄Y	-41	
060	-	-45	
061	STO8	35 08	Store R-8
062	RCL7	36 07	
063	RCL5	36 05	
064	√X	54	
065	×	-35	
066	X²	53	Calc
067	RCL6	36 06	EXP($\frac{hx}{k} + \frac{h^2 x\theta}{k^2}$)
068	+	-55	
069	eˣ	33	
070	RCL8	36 08	Calc (EXP)(ERFC)
071	×	-35	Sto R-8
072	STO8	35 08	Calc. ERF ($\frac{x}{2\sqrt{\alpha\theta}}$)
073	RCL4	36 04	
074	GTOB	22 12	
075	RTN	24	
076	*LBLD	21 14	Calc
077	RCL8	36 08	ERF + (EXP)(ERFC)
078	+	-55	
079	RTN	24	

SET STATUS

FLAGS (ON / OFF): 0 OFF ☒; 1 OFF ☒; 2 OFF ☒; 3 OFF ☒

TRIG: DEG ☒ GRAD ☐ RAD ☐

DISP: FIX ☒ SCI ☐ ENG ☐ n 4

REGISTERS

0	1	2	3	4	5	6	7	8	9
	Used	Used	Used	x	α	θ	h	k	Used

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Conservation of Energy

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

These cards convert kinetic energy, potential energy and pressure-volume work to energy. Card 1 is for English untis while Card 2 is for SI or metric units. Energy is stored as a running total. When a zero is displayed, pressing the B, C, D or E keys will cause the running total to be converted to an equivalent velocity, height, pressure or energy per unit mass. The cards may be used in a large number of fluid flow problems, where velocity, elevation and pressure change along the path of flow.

Operating Limits and Warnings

Downstream values should be input as negatives. However, when an output is called for, the calculator displays the relative value with no regard to upstream or downstream location.

Flashing zeros will result when the total energy sum stored in register 8 is negative and an attempt is made to calculate velocity.

Program Description I

Program Title **CONSERVATION OF ENERGY**

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

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

Program Description, Equations, Variables

$$\frac{v_1{}^2}{2} + gz_1 + \frac{P_1}{\rho} + \frac{E_1}{\dot{m}} = \frac{v_2{}^2}{2} + gz_2 + \frac{P_2}{\rho} + \frac{E_2}{\dot{m}}$$

where

v is the fluid velocity;

z is the height above a reference datum;

P is the pressure;

E is an energy term which could represent inputs of work or friction loses (negative value);

g is the acceleration of gravity;

ρ is the fluid density;

$\dot{m}$ is the mass flow rate (assumed to be unity);

subscripts 1 and 2 refer to upstream and downstream values respectively.

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example 1:

A water tower is 100 feet high. What is the zero flow rate pressure at the base? The density of water is 62.4 lb/ft^3.

Keystrokes — **See Displayed**

Using card 1

62.4 [A] 100 [C] [D] ——→ 43.33 psig

If water is flowing out of the tower at a velocity of 10 ft/sec, what is the static pressure?

10 [CHS] [B] [D] ——→ 42.66 psig

What is the maximum frictionless flow velocity which could be achieved with the 100 foot tower?

62.4 [A] 100 [C] [B] ——→ 80.21 ft/sec

If 10000 pounds of water are pumped to the top of the tower every hour, at a velocity of 20 ft/sec, with a frictional pressure drop of 2 psi, how much power is needed at the pump?

62.4 [A] 20 [B] 2 [D] 100 [C] [E] ——→ 0.14 Btu/lb

10000 [×] ——→ 1424.29 (Btu/hr)

Solution(s)

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

Example 2:

An incompressible fluid ($\rho = 735\ kg/m^3$) flows through the converging passage of Figure 1. At point 1 the velocity is 3 m/s and at point 2 the velocity is 15 m/s. The elevation difference between points 1 and 2 is 3.7 meters. Assuming frictionless flow, what is the static pressure difference between points 1 and 2?

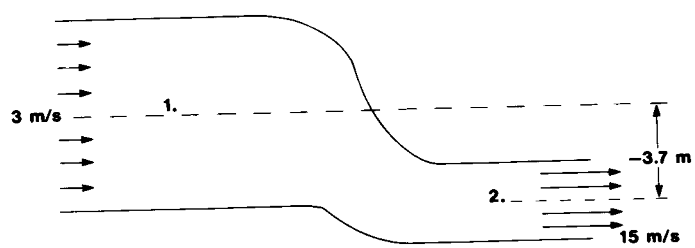


Figure 1.

Solution(s)

Keystrokes	**See Displayed**
Using card 2	
735 [A] 3 [B] 3.7 [C] 15 [CHS] [B] [D] ⟶	–52710.82 (Nt/m²)

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

Example 3:

A reservoir's level is 25 meters above the discharge pond. Assuming 85% power generation efficiency, how much power can be generated with a flow rate of 20 m^3/s?

$$\rho = 1000 \text{ kg/m}^3$$

Keystrokes	**See Displayed**
Using card 2	
1000 [A] 25 [C] [E] ⟶	245.17 (joule/kg)
.85 [×] ⟶	208.39 (joule/kg)
20 [↑] 1000 [×] ⟶	20000 (kg/s)
[×] ⟶	4167826.25 (watts)

Solution(s)

Reference(s)

User Instructions

CONSERVATION OF ENERGY-ENGLISH
ρ(START) (lb/ft3) | v (ft/sec) | z (ft) | P (psi) | E (Btu)

CONSERVATION OF ENERGY-SI
ρ(START) (kg/m3) | v (m/s) | z (m) | P (N/m2) | E (J/kg)

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	For English units (pounds, feet,			
	seconds, Btus), enter			
	Card 1. for SI units			
	(kilograms, meters, seconds,			
	watts), enter Card 2			
2	Input fluid density	ρ	A	g
3	Input the following (negative			
	values are downstream values):			
	Fluid velocity	v	B	0.00
	Height from reference datum	z	C	0.00
	Pressure	P	D	0.00
	Energy input	E	E	0.00
4	Repeat step 3 for all input			
	values			
5	Calculate the unknown:			
	Fluid velocity	0.00	B	v
	Height from reference datum	0.00	C	z
	Pressure	0.00	D	P
	Energy	0.00	E	E
6	For new case go to step 2, or			
	store 0.00 in register 8 and go			
	to step 3.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO4	35 04	
003	CLX	-51	
004	STO8	35 08	
005	7	07	
006	7	07	
007	8	08	Store ρ and constants
008	.	-62	
009	1	01	
010	6	06	
011	STO5	35 05	
012	3	03	
013	2	02	
014	.	-62	
015	1	01	
016	7	07	
017	STO6	35 06	
018	RTN	24	
019	*LBLB	21 12	
020	ENT↑	-21	
021	ABS	16 31	Velocity
022	×	-35	
023	2	02	
024	÷	-24	
025	0	00	
026	X≠Y?	16-32	
027	GTO1	22 01	
028	RCL8	36 08	
029	2	02	
030	×	-35	
031	√X	54	
032	RTN	24	
033	*LBLC	21 13	
034	ENT↑	-21	
035	RCL6	36 06	
036	×	-35	
037	0	00	Height
038	X≠Y?	16-32	
039	GTO1	22 01	
040	RCL8	36 08	
041	RCL6	36 06	
042	÷	-24	
043	RTN	24	
044	*LBLD	21 14	
045	ENT↑	-21	
046	1	01	
047	4	04	
048	4	04	
049	STO7	35 07	
050	×	-35	
051	RCL4	36 04	
052	÷	-24	Pressure
053	RCL6	36 06	
054	×	-35	
055	0	00	
056	X≠Y?	16-32	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	GTO1	22 01	
058	RCL8	36 08	
059	RCL7	36 07	
060	÷	-24	
061	RCL4	36 04	
062	×	-35	
063	RCL6	36 06	
064	÷	-24	
065	RTN	24	
066	*LBLE	21 15	
067	ENT↑	-21	
068	RCL5	36 05	
069	×	-35	
070	RCL6	36 06	
071	×	-35	
072	0	00	Energy
073	X≠Y?	16-32	
074	GTO1	22 01	
075	RCL8	36 08	
076	RCL5	36 05	
077	÷	-24	
078	RCL6	36 06	
079	÷	-24	
080	RTN	24	
081	*LBL1	21 01	
082	R↓	-31	
083	ST+8	35-55 08	Summation
084	0	00	
085	RTN	24	
090			
100			
110			

REGISTERS

0	1	2	3	4	5	6	7	8	9
				ρ	778.16	g	144	ΣE	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
001	*LBLA	21 11	
002	STO4	35 04	Store and gravity
003	CLX	-51	constant
004	STO8	35 08	
005	9	09	
006	.	-62	
007	8	08	
008	0	00	
009	6	06	
010	6	06	
011	5	05	
012	STO6	35 06	
013	RTN	24	
014	*LBLB	21 12	
015	ENT↑	-21	
016	ABS	16 31	
017	×	-35	
018	2	02	
019	÷	-24	Velocity
020	0	00	
021	X≠Y?	16-32	
022	GTO1	22 01	
023	RCL8	36 08	
024	2	02	
025	×	-35	
026	√X	54	
027	RTN	24	
028	*LBLC	21 13	
029	ENT↑	-21	
030	RCL6	36 06	
031	×	-35	Height
032	0	00	
033	X≠Y?	16-32	
034	GTO1	22 01	
035	RCL8	36 08	
036	RCL6	36 06	
037	÷	-24	
038	RTN	24	
039	*LBLD	21 14	
040	ENT↑	-21	
041	RCL4	36 04	
042	÷	-24	
043	0	00	
044	X≠Y?	16-32	Pressure
045	GTO1	22 01	
046	RCL8	36 08	
047	RCL4	36 04	
048	×	-35	
049	RTN	24	
050	*LBLE	21 15	
051	ENT↑	-21	
052	0	00	Energy
053	X=Y?	16-33	
054	RCL8	36 08	
055	RTN	24	
056	*LBL1	21 01	
057	R↓	-31	Summation
058	ST+8	35-55 08	
059	0	00	
060	RTN	24	

LABELS

A ρ	B v	C z	D P	E E
a	b	c	d	e
0	1 Σ	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	2

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