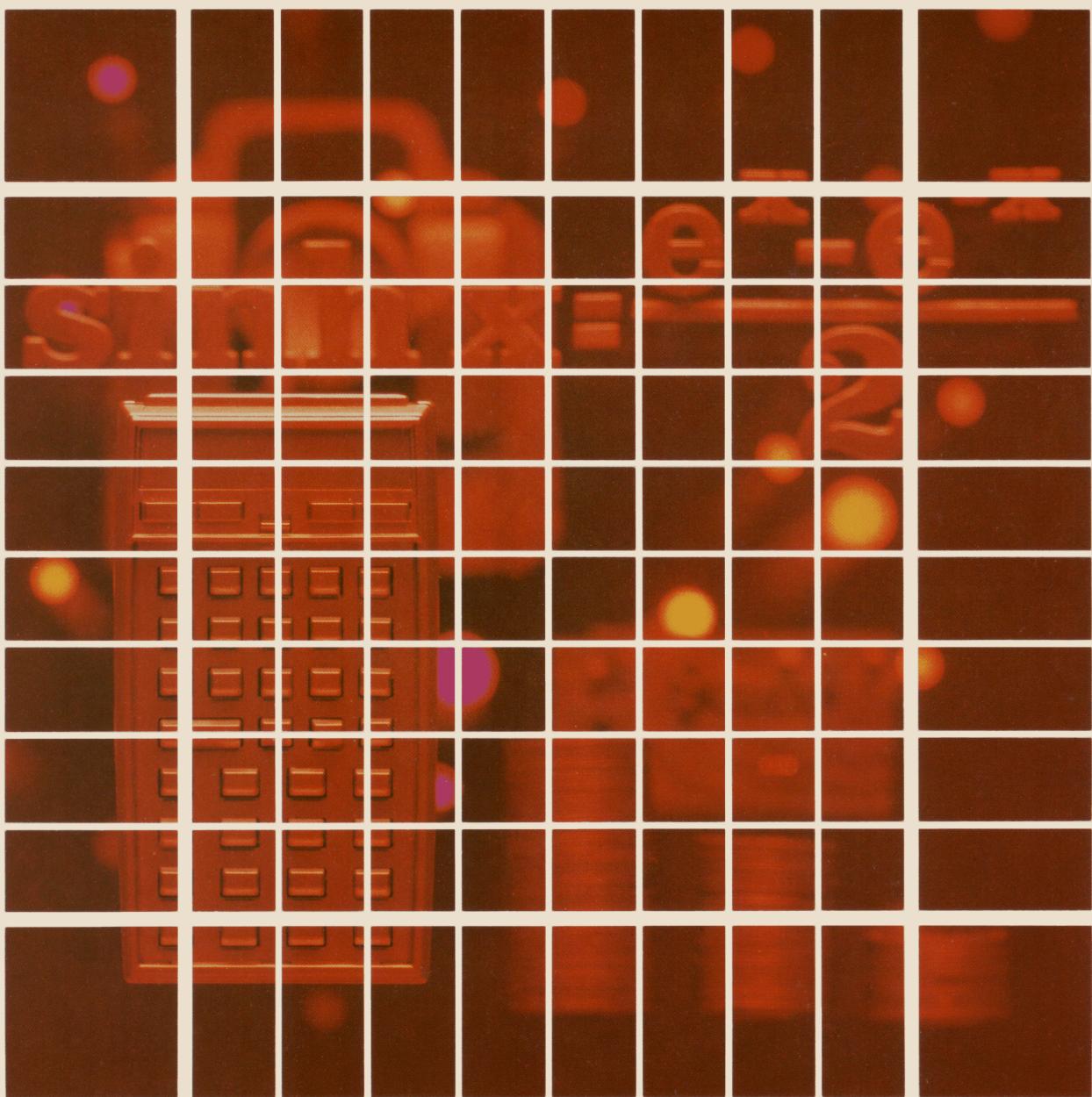


Includes barcode for easy software entry.

HEWLETT-PACKARD

HP-41

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Physics



NOTICE

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INTRODUCTION

This HP-41C Solutions book was written to help you get the most from your calculator. The programs were chosen to provide useful calculations for many of the common problems encountered.

They will provide you with immediate capabilities in your everyday calculations and you will find them useful as guides to programming techniques for writing your own customized software. The comments on each program listing describe the approach used to reach the solution and help you follow the programmer's logic as you become an expert on your HP calculator.

KEYING A PROGRAM INTO THE HP-41C

There are several things that you should keep in mind while you are keying in programs from the program listings provided in this book. The output from the HP 82143A printer provides a convenient way of listing and an easily understood method of keying in programs without showing every keystroke. This type of output is what appears in this handbook. Once you understand the procedure for keying programs from the printed listings, you will find this method simple and fast. Here is the procedure:

1. At the end of each program listing is a listing of status information required to properly execute that program. Included is the SIZE allocation required. Before you begin keying in the program, press **XEQ ALPHA SIZE ALPHA** and specify the allocation (three digits; e.g., 10 should be specified as 010).

Also included in the status information is the display format and status of flags important to the program. To ensure proper execution, check to see that the display status of the HP-41C is set as specified and check to see that all applicable flags are set or clear as specified.

2. Set the HP-41C to PRGM mode (press the **PRGM** key) and press **■ GTO □ □** to prepare the calculator for the new program.
3. Begin keying in the program. Following is a list of hints that will help you when you key in your programs from the program listings in this handbook.
 - a. When you see " (quote marks) around a character or group of characters in the program listing, those characters are ALPHA. To key them in, simply press **ALPHA**, key in the characters, then press **ALPHA** again. So "SAMPLE" would be keyed in as **ALPHA "SAMPLE" ALPHA**.
 - b. The diamond in front of each LBL instruction is only a visual aid to help you locate labels in the program listings. When you key in a program, ignore the diamond.
 - c. The printer indication of divide sign is /. When you see / in the program listing, press **+**.
 - d. The printer indication of the multiply sign is ×. When you see × in the program listing, press **×**.
 - e. The h character in the program listing is an indication of the **APPEND** function. When you see h, press **■ APPEND** in ALPHA mode (press **■** and the K key).
 - f. All operations requiring register addresses accept those addresses in these forms:
nn (a two-digit number)
IND nn (INDIRECT: **■**, followed by a two-digit number)
X, Y, Z, T, or L (a STACK address: **□** followed by X, Y, Z, T, or L)
IND X, Y, Z, T or L (INDIRECT stack: **■ □** followed by X, Y, Z, T, or L)

Indirect addresses are specified by pressing **■** and then the indirect address. Stack addresses are specified by pressing **□** followed by X, Y, Z, T, or L. Indirect stack addresses are specified by pressing **■ □** and X, Y, Z, T, or L.

Printer Listing

```
01 ♦LBL "SAM
PLE"
02 "THIS IS
A "
03 "H-SAMPLE
"
04 AVIEW
05 6
06 ENTER↑
07 -2
08 /
09 ABS
10 STO IND
L
11 "R3="
12 ARCL 03
13 AVIEW
14 RTN
```

Keystrokes

```
■ LBL ALPHA SAMPLE ALPHA
ALPHA THIS IS A ALPHA
ALPHA ■ APPEND SAMPLE
■ AVIEW ALPHA
6
ENTER↑
2 CHS
+
XEQ ALPHA ABS ALPHA
STO ■ □ L
ALPHA R3= ■ ARCL 03
■ AVIEW
ALPHA
■ RTN
```

Display

```
01 LBLT SAMPLE
02T THIS IS A
03T h SAMPLE
04 AVIEW
05 6
06 ENTER ↑
07 -2
08 /
09 ABS
10 STO IND L
11 R3=
12 ARCL 03
13 AVIEW
14 RTN
```

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	Calculates the wavelength of maximum emissive power for a given temperature, and calculates the emissive power.	
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	Computes temperature, Schwarzschild radius, and life- time of a black hole.	
3.	SPECIAL RELATIVITY CONVERSIONS.....	15
	Provides relativistic conversions between rest mass, velocity, energy, and momentum.	
*4.	THREE DIMENSIONAL SPECIAL RELATIVITY.....	23
	Computes intervals, dilation factors, and Lorentz trans- formations.	
5.	EINSTEIN'S TWIN PARADOX.....	32
	Calculates real and relative time based on the Lorentz transform.	
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	Computes the two unknown values based on any three known values of the following variables: distance, time, v-final, v-initial, and acceleration.	
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	Corrects for spillover between channels in a liquid scintillation spectrometer.	
*9.	SEMI-EMPIRICAL NUCLEAR MASS FORMULA.....	67
	Calculates approximate binding energies and mass.	
10.	CLEBSCH-GORDON COEFFICIENTS AND 3J SYMBOLS EVALUATION.	76
	Uses Racah formula to evaluate coupling of two states of angular momentum.	
11.	32-P REMAINING ON DAY OF YEAR.....	85
	Calculates DPM, CPM on any day given mCi on earlier date.	

* These programs require one additional memory module.

BLACK BODY THERMAL RADIATION

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.

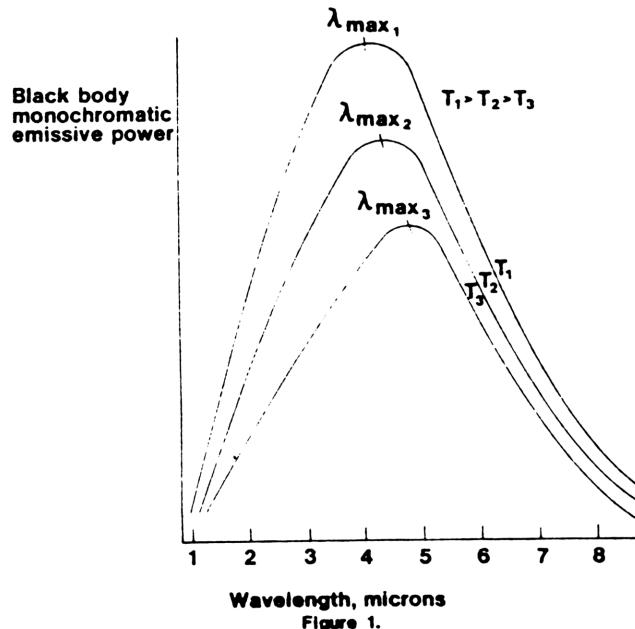


Figure 1.

Notes:

A half 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 ($E_b(0-\infty)$) increases. Also note that 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 particular wavelength, the emissive power from zero to a specified wavelength, and the emissive power between specified wavelengths.

Equations:

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

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

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

$$\begin{aligned} E_{b(0-\lambda)} &= \int_0^\lambda E_{b\lambda} d\lambda \\ &= 2\pi c_1 \sum_{k=1}^{\infty} -T/kc_2 e^{-\frac{k c_2}{\lambda T}} \left[\left(\frac{1}{\lambda}\right)^3 + \frac{3T}{\lambda^2 k c_2} \right. \\ &\quad \left. + \frac{6}{\lambda} \left(\frac{T}{k c_2}\right)^2 + 6 \left(\frac{T}{k c_2}\right)^3 \right] \end{aligned}$$

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

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-ft² or Watts/cm²;

$E_{b\lambda}$ is the emissive power at λ in Btu/hr-ft²-μm or Watts/cm²-μm;

$E_{b(0-\lambda)}$ is the emissive power for wavelengths less than λ in Btu/hr-ft² or Watts/cm²;

$E_{b(\lambda_1 - \lambda_2)}$ is the emissive power for wavelengths between λ_1 and λ_2 in Btu/hr-ft² or Watts/cm².

$$\begin{aligned} c_1 &= 1.8887982 \times 10^7 \text{ Btu-μm}^4/\text{hr-ft}^2 \\ &= 5.9544 \times 10^3 \text{ W-μm}^4/\text{cm}^2 \end{aligned}$$

$$c_2 = 2.58984 \times 10^4 \text{ μm-}^\circ\text{R} = 1.4388 \times 10^4 \text{ μm-K}$$

$$c_3 = 5.216 \times 10^3 \text{ μm-}^\circ\text{R} = 2.8978 \times 10^3 \text{ μm-K}$$

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

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

References: HP-67/97 Users' Library Program.

Example:

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 2400K?

Keystrokes: (SIZE ≥ 009)

[USER]
[XEQ] [ALPHA] BB [ALPHA]
SI [R/S]
2400 [R/S]
.4 [R/S]
[F]
.7 [R/S]
[C]
[÷]
100 [x]

Display:

(set USER mode)
UNITS?
TEMP?
WAVELENGTH?
SOLVE
WV LNTH 2?
EbL-L=4.9679
EbTOT=188.094
0.0264
2.6412

User Instructions

Program Listings

01♦LBL "BB"		47 RCL 06	
02 CLRG	Initialize and prompt for units	48 /	Calculate T(λ_{max})
03 CF 22		49 "TEMP="	
04 "UNITS?"		50 ARCL X	
05 RDN		51 PROMPT	
06 PROMPT		52♦LBL C	
07 ROFF		53 RCL 05	Calculate E _b total
08 ASTO X		54 X↑2	
09 GTO IND		55 X↑2	
X		56 RCL 04	
10♦LBL "SI"		57 *	
11 5954.4	Store units	58 "EBTOT="	
12 STO 01		59 ARCL X	
13 14388		60 PROMPT	
14 STO 02		61♦LBL D	
15 2897.8		62 RCL 01	
16 STO 03		63 ENTER↑	Calculate E _{bλ}
17 5.6693 E		64 +	
-12		65 PI	
18 STO 04		66 *	
19 GTO 00		67 RCL 06	
20♦LBL "EN"		68 5	
21 18887982		69 Y↑X	
22 STO 01		70 /	
23 25998.4		71 RCL 02	
24 STO 02		72 RCL 06	
25 5216		73 /	
26 STO 03		74 RCL 05	
27 .171312		75 /	
E-08		76 E↑X	
28 STO 04		77 1	
29♦LBL 00	Input prompting	78 -	
30 "TEMP?"		79 /	
31 PROMPT		80 "EBL="	
32 STO 05		81 ARCL X	
33 "WAVELEN		82 PROMPT	
GTH?"		83♦LBL E	Calculate E _b (0- λ)
34 PROMPT		84 0	
35 STO 06		85 STO 08	
36 "SOLVE"		86 STO 07	
37 PROMPT		87♦LBL 01	
38♦LBL A		88 RDN	
39 RCL 03		89 CLX	
40 RCL 05		90 RCL 08	
41 /		91 RCL 02	
42 "WL MAX=		92 RCL 05	
"		93 /	
43 ARCL X		94 -	
44 PROMPT		95 STO 08	
45♦LBL B		96 3	
46 RCL 03		97 X<>Y	

Program Listings

98 /		149 "WV LNTH
99 RCL 06		150 PROMPT
100 X↑2		151 ENTER↑
101 /		152 ENTER↑
102 LASTX		153 SF 00
103 1/X		154 XEQ E
104 RCL 06		155 X<>Y
105 /		156 RCL 06
106 -		157 STO 00
107 6		158 RDN
108 RCL 06		159 STO 06
109 /		160 SF 00
110 RCL 08		161 XEQ E
111 X↑2		162 -
112 /		163 ABS
113 -		164 RCL 00
114 6		165 STO 06
115 RCL 08		166 RDN
116 X↑2		167 "EbL-L="
117 /		168 ARCL X
118 RCL 08		169 PROMPT
119 /		170 .END.
120 +		
121 RCL 08		
122 RCL 06		
123 /		
124 E↑X		
125 *		
126 RCL 08		
127 /		80
128 ST+ 07		
129 RCL 07		
130 /		
131 1 E-05		
132 X<=Y?		
133 GTO 01		
134 RDN		
135 CLX		
136 RCL 07		
137 ENTER↑		
138 +		90
139 PI		
140 *		
141 RCL 01		
142 *		
143 FS?C 00		
144 RTN		
145 "Eb0-L="		
146 ARCL X		
147 PROMPT	Calculate E _b (λ ₁ -λ ₂)	
148♦LBL F		00

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

7

BLACK BODY THERMAL RADIATION

PROGRAM REGISTERS NEEDED: 48

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PHYSICS

ROW 1 (1 - 4)



ROW 2 (4 - 10)



ROW 3 (10 - 13)



ROW 4 (13 - 17)



ROW 5 (17 - 20)



ROW 6 (20 - 23)



ROW 7 (23 - 27)



ROW 8 (27 - 30)



ROW 9 (30 - 33)



ROW 10 (33 - 36)



ROW 11 (36 - 42)



ROW 12 (42 - 49)



ROW 13 (49 - 57)



ROW 14 (58 - 62)



ROW 15 (63 - 75)



ROW 16 (76 - 83)



ROW 17 (83 - 95)



ROW 18 (96 - 108)



BLACK BODY THERMAL RADIATION

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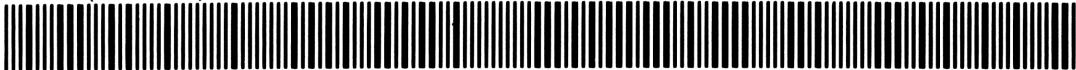
ROW 19 (109 - 121)



ROW 20 (122 - 131)



ROW 21 (131 - 141)



ROW 22 (142 - 146)



ROW 23 (147 - 149)



ROW 24 (149 - 158)



ROW 25 (159 - 167)



ROW 26 (167 - 170)



BLACK HOLE CHARACTERISTICS

This program computes the Schwarzschild radius, lifetime and temperature of a black hole.

A black hole of mass (M) in grams has a Schwarzschild radius (R_s) in centimeters of:

$$R_s = \frac{2GM}{c^2} = M \cdot 1.484986855 \times 10^{-28}$$

where G is the universal gravitational constant and c is the speed of light.

The lifetime of a black hole (t_L) in seconds is given by:

$$t_L = M \cdot (10^{-28})$$

The temperatures of a black hole (K) in degrees Kelvin is:

$$K = \frac{10^{26}}{M}$$

Notes:

M must be greater than zero.

Underflow occurs for R_s when $M < 6.734066343 \times 10^{-72}$

$$t_L \quad M < 2.154434653 \times 10^{-24}$$

Overflow occurs for K when $M < 1.000000001 \times 10^{-74}$

$$t_L \quad M > 2.154434650 \times 10^{33}$$

$$M \quad R_s > 1.484986854 \times 10^{72}$$

Example:

What is the temperature, Schwarzschild radius, and lifetime of a black hole with a mass of 1.99×10^{33} gm?

Keystrokes:

Display:

[USER]

(Set USER mode)

[XEQ] [ALPHA] SIZE [ALPHA] 004

ENTER KNOWN

[XEQ] [ALPHA] HOLE [ALPHA]

MASS=1.9900E33

1.99 [EEX] 33 [D]

TEMP=5.0251E-8

[B]

RAD=295,512.3832

[A]

LIFE=7.8806E71

[C]

User Instructions

Program Listings

<pre> 01♦LBL "HOL E" 02 CF 22 03 "ENTER K NOWN" 04 AVIEW 05 RTN 06♦LBL D 07 FS?C 22 08 GTO 00 09 RCL 03 10♦LBL 04 11 "MASS=" 12 ARCL X 13 AVIEW 14 RTN 15♦LBL 00 16 STO 03 17 GTO 04 18♦LBL A 19 FS?C 22 20 GTO 01 21 1.484986 22 RCL 03 23 * 24 STO 00 25♦LBL 05 26 "RAD=" 27 ARCL X 28 AVIEW 29 RTN 30♦LBL 01 31 STO 00 32 6.734066 33 * 34 STO 03 35 RCL 00 36 GTO 05 37♦LBL B 38 FS?C 22 39 GTO 02 40 1 E26 41 RCL 03 42 / 43 STO 01 44♦LBL 06 45 "TEMP=" 46 ARCL X 47 AVIEW </pre>	<p>Store and calculate mass</p> <p>Store and calculate radius</p> <p>Store and calculate temperature</p>	<pre> 48 RTN 49♦LBL 02 50 STO 01 51 1 E26 52 X<>Y 53 / 54 STO 03 55 RCL 01 56 GTO 06 57♦LBL C 58 FS?C 22 59 GTO 03 60 1 E-28 61 RCL 03 62 3 63 Y↑X 64 * 65 STO 02 66♦LBL 07 67 "LIFE=" 68 ARCL X 69 AVIEW 70 RTN 71♦LBL 03 72 STO 02 73 1 E28 74 * 75 3 76 1/X 77 Y↑X 78 STO 03 79 RCL 02 80 GTO 07 81 .END. </pre> <p>90</p> <p>00</p>	<p>Store and calculate Lifetime</p>
---	--	---	-------------------------------------

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

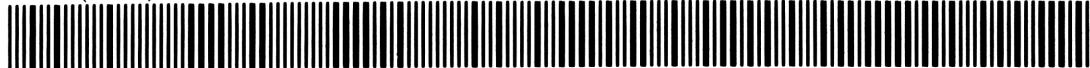
DATA REGISTERS				STATUS			
00	Radius	50		SIZE <u>004</u> TOT. REG. <u>29</u> USER MODE			
	Temperature			ENG <u> </u> FIX <u> </u> SCI <u> </u> ON X <u> </u> OFF <u> </u>			
	Lifetime			DEG <u> </u> RAD <u> </u> GRAD <u> </u>			
	Mass						
05		55		FLAGS			
				#	INIT S/C	SET INDICATES	CLEAR INDICATES
10		60					
15		65					
20		70					
25		75					
30		80					
35		85		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
		90					
40							
45		95					

BLACK HOLE CHARACTERISTICS

PROGRAM REGISTERS NEEDED: 26

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ROW 1 (1 - 3)



ROW 2 (3 - 6)



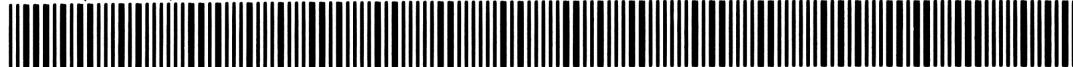
ROW 3 (7 - 12)



ROW 4 (12 - 20)



ROW 5 (21 - 21)



ROW 6 (21 - 28)



ROW 7 (29 - 32)



ROW 8 (32 - 39)



ROW 9 (39 - 45)



ROW 10 (45 - 52)



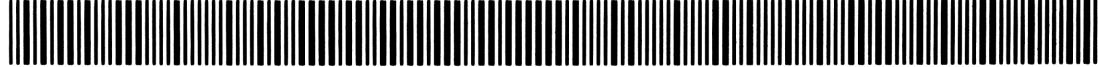
ROW 11 (53 - 60)



ROW 12 (60 - 67)



ROW 13 (67 - 74)



ROW 14 (75 - 81)



SPECIAL RELATIVITY CONVERSIONS

This program provides relativistic conversions between the following quantities: rest mass (m , in MeV); velocity (v , in units of $c=1$); energy (E , in MeV), and momentum (P). Given any two, it is possible to find the two unknowns by the following equations:

$$E = m / \text{SQRT}(1-v^2)$$

$$E = \text{SQRT } (P^2 + m^2)$$

$$E = P/v$$

Data may be entered in any order and recalled at any time. The program scans the registers and, after determining if there is enough data to solve for the unknown, selects the appropriate subset of equations.

Notes:

All data must be positive. Velocity must be less than 1. "DATA ERROR" message will be displayed if a real solution does not exist or the input data is outside these limits.

Examples:

- 1) Find the velocity and momentum of an electron (rest mass = .511 MeV) with a total energy of 1.0 MeV.

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 005

[XEQ] [ALPHA] SRC [ALPHA]

.511 [B]

1 [D]

[A]

[C]

Display:

ENTER KNOWNS

.5110

1.0000

V=0.8596

P=0.8596

- 2) At .9c, an electron has an energy of 1.1723 MeV. Find its rest mass and momentum.

Keystrokes:

[XEQ] [ALPHA] SRC [ALPHA]

.9 [A]

1.1723 [D]

[B]

[C]

Display:

ENTER KNOWNS

0.9000

1.1723

M=0.5110

P=1.0551

User Instructions

Program Listings

<pre> 01♦LBL "SRC" " 02 CLRG 03 SF 27 04 CF 22 05 CF 00 06 CF 01 07 CF 02 08 CF 03 09 CF 04 10 CF 05 11 CF 06 12 "ENTER K NOWNS" 13 PROMPT 14♦LBL A 15 1 16 XEQ 00 17 RCL 02 18 X=0? 19 GTO 01 20 RCL 03 21 X#0? 22 GTO 15 23 XEQ 06 24 ENTER↑ 25♦LBL 07 26 RDN 27 RCL 04 28 X<>Y 29 / 30 SF 00 31 GTO c 32♦LBL B 33 2 34 XEQ 00 35 X=0? 36 GTO 04 37 RCL 03 38 * 39 LASTX 40 X#0? 41 GTO 02 42 RCL 04 43 ENTER↑ 44 ENTER↑ 45 RCL 01 46 / 47♦LBL 02 48 ENTER↑ 49 RDN </pre>	<p>Initialize and prompt for knowns</p> <p>Storage and calculation of velocity</p> <p>Storage and calculation of rest mass</p>	<pre> 50 XEQ 03 51 RT↑ 52 * 53 SF 00 54 GTO c 55♦LBL 03 56 / 57 ASIN 58 COS 59 FS?C 05 60 GTO 10 61 RTN 62♦LBL D 63 3 64 XEQ 00 65 X=0? 66 GTO 06 67 RCL 02 68 X=0? 69 GTO 07 70 FC? 03 71 SF 05 72 SF 06 73♦LBL 08 74 X<>Y 75 ASIN 76 COS 77 / 78 FS?C 05 79 GTO 11 80 FS?C 06 81 GTO 12 82 RTN 83♦LBL C 84 4 85 XEQ 00 86 X=0? 87 GTO 09 88 RCL 02 89 X#0? 90 XEQ 08 91 RCL 03 92 X=0? 93 RDN 94 RCL 01 95 * 96 SF 00 97♦LBL c 98 X=0? 99 / 100 FC?C 00 </pre>	<p>SQRT $(1-y^2/x^2)$</p> <p>Storage and calculation of energy</p> <p>Storage and calculation of momentum</p> <p>Check for valid answer</p>
---	--	--	---

Program Listings

101 RTN		149 RCL 04	
102 FS?C 01	Select output routine	150 GTO d	
103 GTO 10		151+LBL 06	
104 FS?C 02		152 RCL 02	
105 GTO 11		153 XEQ c	
106 FS?C 03		154 RCL 04	
107 GTO 12		155 XEQ c	
108 FS?C 04		156 R-P	
109 GTO 13		157 RTN	
110+LBL 10	Velocity output	158+LBL 09	
111 CF 01		159 RCL 02	
112 "V="		160+LBL d	
113 ARCL X		161 XEQ c	
114 PROMPT		162 RCL 03	
115+LBL 11	Rest mass output	163 GTO 02	
116 CF 02		164+LBL 15	
117 "M="		165 SF 05	
118 ARCL X		166 GTO 03	
119 PROMPT		167 .END.	
120+LBL 12		70	
121 CF 03			
122 "E="			
123 ARCL X			
124 PROMPT			
125+LBL 13			
126 CF 04			
127 "P="	Momentum output		
128 ARCL X			
129 PROMPT			
130+LBL 00		80	
131 STO 00			
132 FS?C 22			
133 GTO b			
134 SF IND 0			
0			
135 RCL IND			
00			
136 X#0?			
137 STOP			
138 RCL 01			
139 RTN		90	
140+LBL b	Indirect storage routine		
141 RDN			
142 STO IND			
00			
143 STOP			
144+LBL 01			
145 RCL 03			
146 ENTER↑			
147 GTO 07			
148+LBL 04		00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS					
00	Indirect	50	SIZE 005 ENG _____ DEG _____	TOT. REG. 45	USER MODE ON ____ OFF ____			
	Velocity			FIX ____ SCI _____	ON ____ OFF ____			
	Rest Mass			RAD ____ GRAD _____				
	Total Energy							
	Momentum							
05		55	FLAGS					
#	INIT S/C	SET INDICATES		CLEAR INDICATES				
10	60							
15	65							
20	70							
25	75							
30	80							
35	85							
ASSIGNMENTS								
		FUNCTION		KEY	FUNCTION			
40	90							
45	95							

SPECIAL RELATIVITY CONVERSIONS

PROGRAM REGISTERS NEEDED: 41

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ROW 1 (1 - 5)



ROW 2 (5 - 11)



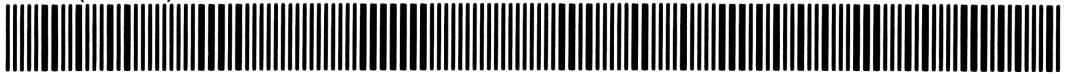
ROW 3 (12 - 12)



ROW 4 (13 - 21)



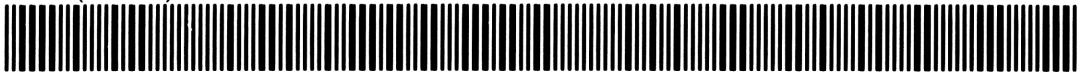
ROW 5 (22 - 30)



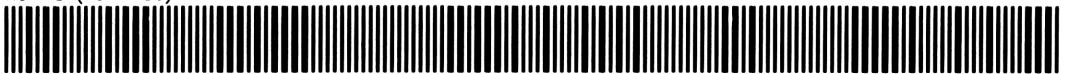
ROW 6 (30 - 36)



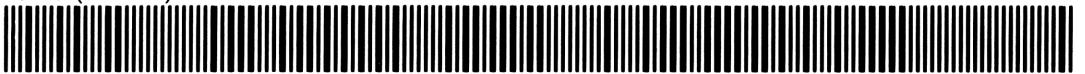
ROW 7 (37 - 48)



ROW 8 (49 - 56)



ROW 9 (57 - 64)



ROW 10 (65 - 72)



ROW 11 (73 - 81)



ROW 12 (82 - 90)



ROW 13 (90 - 99)



ROW 14 (100 - 106)



ROW 15 (107 - 113)



ROW 16 (113 - 121)



ROW 17 (121 - 127)



ROW 18 (128 - 135)



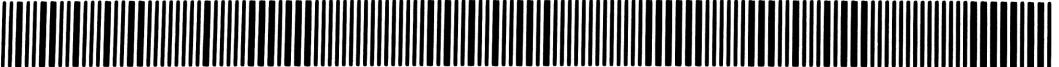
SPECIAL RELATIVITY CONVERSIONS

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 19 (135 - 145)



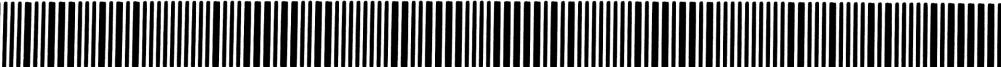
ROW 20 (146 - 153)



ROW 21 (154 - 161)



ROW 22 (162 - 167)



THREE DIMENSIONAL SPECIAL RELATIVITY

(requires one memory module)

Given an event as the components of a 4-vector $x'^\mu = (x', y', z', ct')$ in a frame of reference moving at a fraction of the speed of light $\beta = (\beta^x, \beta^y, \beta^z) = \bar{v}/c$, this program will calculate the speed, $|\beta|$, the time dilation factor, γ , the 4-vector of the event in the fixed frame, x^μ , and the invariant interval, $c\Delta\tau$.

Formulae:

$$\Delta \bar{x} = \Delta \bar{x}' + \bar{\beta}[(\gamma - 1) \frac{\bar{\beta} \cdot \bar{x}'}{\beta^2} + \gamma c \Delta t']$$

$$\Delta t = \gamma(t + \bar{\beta} \cdot \bar{x}/c^2)$$

$$\gamma = [1 - \beta^2]^{-\frac{1}{2}}$$

$$\beta = |\bar{\beta}| = [(\beta^x)^2 + (\beta^y)^2 + (\beta^z)^2]^{\frac{1}{2}}$$

$$|\Delta \bar{x}| = [\Delta x^2 + \Delta y^2 + \Delta z^2]^{\frac{1}{2}}$$

$$c^2 \Delta \tau^2 = c^2 \Delta t^2 - |\Delta \bar{x}|^2$$

Notes:

The coordinate frames are assumed to be synchronized so that the event $(0, 0, 0, 0)$ has the same coordinates in both frames.

For a spacelike interval, $c^2 \Delta \tau^2 < 0$, the calculator will display " $- |c\Delta\tau|$ "

Example:

An observer moving relative to earth with velocity $\vec{\beta} = (.4, .5, .6)$ measures the coordinates of an event as $x'^\mu = (1, 2, 3, 4)$.

- a) What are the coordinates of the event relative to the earth frame?
- b) What is the interval between the event and the origin $(0,0,0,0)$?

Keystrokes:

```
[XEQ] [ALPHA] SIZE [ALPHA] 016
[XEQ] [ALPHA] 3D [ALPHA]
3 [R/S]
.4 [R/S]
.5 [R/S]
.6 [R/S]
[R/S]
[R/S]
1 [R/S]
2 [R/S]
3 [R/S]
4 [R/S]
[R/S]
[R/S]
[R/S]
```

Display:

```
DIMENSIONS?
BX?
BY?
BZ?
SPEED=0.8775
D.F.=2.0851
X PRIME?
Y PRIME?
Z PRIME?
cT PRIME?
cT=15.0130
Z=10.7102
Y=8.4251
X=6.1401
cdT=1.4142
```

User Instructions

Program Listings

<pre> 01♦LBL "3D" 02 "DIMENSI ONS?" 03 PROMPT 04 XEQ E 05 CF 03 06 SF 02 07 FS? 00 08 CF 02 09 FS? 01 10 CF 02 11 FS? 01 12 SF 03 13 FS? 02 14 SF 03 15 "BX? " 16 FS? 02 17 PROMPT 18 "BY? " 19 FS? 03 20 PROMPT 21 "BZ? " 22 PROMPT 23 XEQ A 24 CLST 25 "X PRIME ? " 26 FS? 02 27 PROMPT 28 "Y PRIME ? " 29 FS? 03 30 PROMPT 31 "Z PRIME ? " 32 PROMPT 33 "cT PRIM E? " 34 PROMPT 35 XEQ B 36 XEQ e 37 RCL 13 38 X†2 39 / 40 RCL 14 41 1 42 - 43 * 44 RCL 14 45 RCL 07 46 * </pre>	<p>Input prompting for \bar{B}</p> <p>Input prompting for x^{μ}</p> <p>Calculate x^{μ}</p>	<pre> 47 + 48 STO 15 49 3 50 STO 00 51 STO 12 52♦LBL 00 53 RCL 00 54 STO 12 55 RCL 15 56 RCL IND 12 57 * 58 RCL 12 59 3 60 + 61 STO 12 62 CLX 63 RCL IND 12 64 + 65 5 66 ST+ 12 67 CLX 68 RDN 69 STO IND 12 70 5 71 ST- 12 72 2 73 FS? 00 74 ST- 00 75 .5 76 FS? 01 77 ST- 00 78 RCL 00 79 1 80 - 81 STO 00 82 X≠0? 83 GTO 00 84 RCL 07 85 XEQ e 86 + 87 RCL 14 88 * 89 STO 08 90 "cT=" 91 ARCL X 92 PROMPT 93 "Z=" 94 ARCL 11 </pre>	
---	---	---	--

Program Listings

<pre> 95 PROMPT 96 FS? 00 97 GTO D 98 "Y=" 99 ARCL 09 100 PROMPT 101 FS? 01 102 GTO D 103 "X=" 104 ARCL 10 105 PROMPT 106 GTO D 107+LBL A 108 STO 03 109 FS? 00 110 GTO 06 111 X<>Y 112 R-P 113 LASTX 114 STO 01 115 X<>Y 116 FS? 01 117 GTO 06 118 RT 119 STO 02 120 R-P 121+LBL 06 122 STO 13 123 ACOS 124 SIN 125 1/X 126 STO 14 127 RCL 13 128 "SPEED=" 129 ARCL X 130 PROMPT 131 "D.F.=" 132 ARCL Y 133 PROMPT 134 RTN 135+LBL B 136 STO 07 137 RDN 138 STO 06 139 RDN 140 STO 04 141 RDN 142 STO 05 143 RTN 144+LBL E 145 STO 12 </pre>	<p>Calculate $\bar{\beta}$ and γ.</p> <p>Store x^{μ}</p> <p>Set flags for \sim</p>	<pre> 146 GTO IND 147+LBL 01 148 CF 01 149 SF 00 150 RTN 151+LBL 02 152 CF 00 153 SF 01 154 RTN 155+LBL 03 156 CF 00 157 CF 01 158 RTN 159+LBL e 160 RCL 06 161 RCL 03 162 * 163 FS? 00 164 RTN 165 RCL 01 166 RCL 04 167 * 168 + 169 FS? 01 170 RTN 171 RCL 02 172 RCL 05 173 * 174 + 175 RTN 176+LBL D 177 RCL 06 178 FS?C 00 179 GTO 04 180 RCL 04 181 R-P 182 FS?C 01 183 GTO 04 184 RCL 05 185 R-P 186+LBL 04 187 X↑2 188 RCL 07 189 X↑2 190 - 191 CHS 192 CF 04 193 X<0? 194 SF 04 195 ABS </pre>	<p>correct no. of dimensions</p> <p>Calculate $\sum \beta_x^i$</p> <p>Compute $c\Delta\tau$</p>
---	---	--	---

Program Listings

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
#	NAME	INITIAL VALUE	SIZE		TOT. REG.	USER MODE
			REG	FORMAT	67	ON OFF
00	counter	50				X
	VEL y					
	VEL x					
	VEL z					
	y					
05	x	55				
	z					
	ct		00		n=1	
	T		01		n=2	
	Y'		02		n>2	
10	X'	60	03		n>1	
	Z'		04		used	
	indirect					
	β					
	Y					
15	used	65				
20		70				
25		75				
30		80				
35		85				
ASSIGNMENTS						
			FUNCTION	KEY	FUNCTION	KEY
40		90				
45		95				

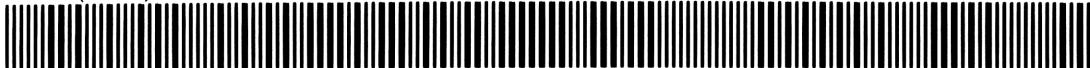
THREE DIMENSIONAL SPECIAL
RELATIVITY
PROGRAM REGISTERS NEEDED: 52

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PHYSICS

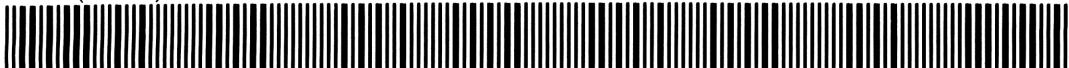
ROW 1 (1 - 2)



ROW 2 (2 - 6)



ROW 3 (7 - 13)



ROW 4 (13 - 18)



ROW 5 (18 - 24)



ROW 6 (25 - 28)



ROW 7 (28 - 31)



ROW 8 (31 - 33)



ROW 9 (33 - 37)



ROW 10 (38 - 50)



ROW 11 (51 - 62)



ROW 12 (63 - 71)



ROW 13 (72 - 79)



ROW 14 (80 - 89)



ROW 15 (90 - 95)



ROW 16 (96 - 101)



ROW 17 (102 - 107)



ROW 18 (107 - 116)



THREE DIMENSIONAL SPECIAL
RELATIVITY

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ROW 19 (117 - 128)



ROW 20 (128 - 131)



ROW 21 (131 - 140)



ROW 22 (141 - 149)



ROW 23 (150 - 158)



ROW 24 (159 - 169)



ROW 25 (169 - 179)



ROW 26 (179 - 189)



ROW 27 (190 - 199)



ROW 28 (199 - 203)



EINSTEINS TWIN PARADOX

The program is arranged to calculate subjective and real time differential between an observer on Earth and the pilot of a vehicle accelerating near the speed of light. Imagine the twins at age 21. One becomes an astronaut and volunteers for the first interstellar flight. He takes off and travels at a speed of 2.99×10^8 meters per second. The astronaut travels for what he measures to be a year, at which time he fires retro and navigational engines and turns around and heads toward Earth. The journey naturally takes another year. He is now 23 years old; but when he steps from the ship, his twin is over 48 years old!

Equation:

$$T_S = T_E \sqrt{1 - \frac{v^2}{c^2}}$$

where:

T_S =time passed on board ship

T_E =time passed on earth

v =ship velocity relative to earth

c =speed of light (2.9979×10^8 m/s)

Notes:

Be certain that the speed of the spacecraft is in meters per second.

Example:

If one twin travels for 10 years at 87% the speed of light, how much time will have passed for the twin left on earth?

Keystrokes:

```
[XEQ] [ALPHA] SIZE [ALPHA] 003  
[XEQ] [ALPHA] TWIN [ALPHA]  
2.9979 [EEX] 8 [ENTER↑]  
.87 [X] [A]  
10 [B]  
[C]
```

Display:

```
READY  
V=260,817,300.0  
TS=10.0000  
TE=20.2818
```

If the ship had only been going 1×10^4 m/s, how much time would have passed for the earth-bound twin?

```
[EEX] 4 [A]  
[C]
```

```
V=10,000.0000  
TE=10.0000
```

User Instructions

Program Listings

01♦LBL "TWI N"	Initialization	50 2.9979 E	
02 CF 22		51 /	
03 SF 27		52 X†2	
04 "READY"		53 -	
05 AVIEW		54 SQRT	
06 RTN		55 RTN	
07♦LBL A	Velocity	56 .END.	
08 FS?C 22			
09 GTO 00			
10 1		60	
11 RCL 01			
12 RCL 02			
13 /			
14 X†2			
15 -			
16 SQRT			
17 2.9979 E			
8			
18 *		70	
19♦LBL 00			
20 STO 00			
21 "Y="			
22 GTO 02	Ship time		
23♦LBL B			
24 FS?C 22			
25 GTO 00			
26 XEQ 01			
27 RCL 02			
28 *		80	
29♦LBL 00			
30 STO 01			
31 "TS="			
32 GTO 02			
33♦LBL C	Earth time		
34 FS?C 22			
35 GTO 00			
36 XEQ 01			
37 1/X			
38 RCL 01			
39 *		90	
40♦LBL 00			
41 STO 02			
42 "TE="			
43♦LBL 02	General output		
44 ARCL X			
45 AVIEW			
46 RTN			
47♦LBL 01	Lorentz trans-		
48 1	form	00	
49 RCL 00			

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
00	V	50	SIZE	003	TOT. REG.	18
	TS		ENG		SCI	
	TE		DEG		RAD	GRAD
05		55	FLAGS			
			#	INIT S/C	SET INDICATES	CLEAR INDICATES
10		60				
15		65				
20		70				
25		75				
30		80				
35		85				
40		90	ASSIGNMENTS			
			FUNCTION	KEY	FUNCTION	KEY
45		95				

EINSTEINS TWIN PARADOX

PROGRAM REGISTERS NEEDED: 16

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 4)



ROW 2 (4 - 9)



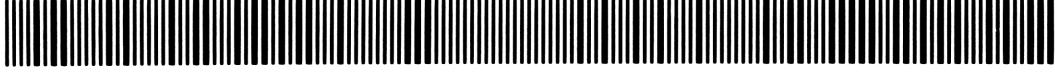
ROW 3 (10 - 17)



ROW 4 (17 - 24)



ROW 5 (24 - 31)



ROW 6 (31 - 37)



ROW 7 (38 - 46)



ROW 8 (47 - 52)



ROW 9 (53 - 56)



DELTA-V ORBIT SIMULATOR

(Requires One Memory Module)

This program calculates orbit parameters from initial position and velocity data both for elliptical and hyperbolic orbits in a plane. It is also possible to move the point of interest to anywhere along the orbit and then recalculate orbit parameters.

Equations Used:

$$E = \frac{1}{2} V_i^2 - \frac{Gm}{R_i}$$

$$\ell = VR \sin(\alpha_i - \theta_i)$$

$$\varepsilon = \sqrt{1 + \frac{2E\ell^2}{(Gm)^2}}$$

$$R_o = \frac{\ell^2}{Gm}$$

$$\theta' = \theta_i + \cos^{-1} \left(\frac{\frac{R_o}{R_i} - 1}{\varepsilon} \right)$$

$$R_{min} = \frac{R_o}{1 + \varepsilon}$$

$$a = \frac{R_o}{1 - \varepsilon^2}$$

$$b = a \sqrt{1 - \varepsilon^2}$$

$$T = 2\pi \sqrt{\frac{a^3}{Gm}}$$

$$S = \frac{R_{min}}{1 - \frac{1}{\varepsilon}}$$

$$\theta_a = \cos^{-1} \left(\frac{1}{\varepsilon} \right)$$

Given θ_{new} :

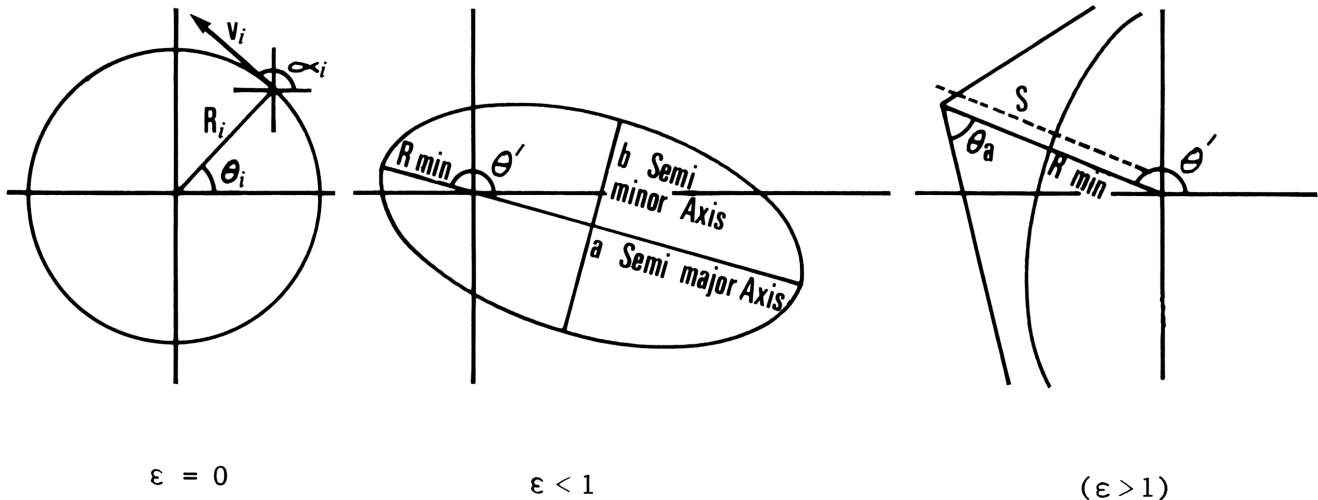
$$R_{new} = \frac{R_o}{1 + \varepsilon \cos(\theta_{new} - \theta')}$$

$$V_{new} = \sqrt{2 \left(E + \frac{Gm}{R_{new}} \right)}$$

$$\alpha_{new} = \theta_{new} + \sin^{-1} \left(\frac{\ell}{V_{new} R_{new}} \right)$$

For change in velocity:

$$\overline{V_{new}} = \overline{V_{old}} + \Delta \overline{V}$$



Where:

E = Energy

ℓ = Angular momentum

ϵ = Eccentricity

a = Semimajor axis

b = Semiminor axis

T = Period

S = Distance to asymptote vertex

θ_a = Angle between asymptotes and radius vector

α = Velocity angle

NOTE: This program becomes ill-conditioned and inaccurate near degenerate conics (circles, parabolas, and straight lines). Avoid all orbits where R_{min} is less than the radius of the attracting body (6.400×10^6 m for the Earth).

All inputs are in MKS units.

The value of an input may be maintained without being reentered by simply pressing [R/S] when prompted.

Example:

Execute a transfer from low earth orbit to high earth orbit.

$$R_{\text{init}} = 7.1 \times 10^6 \text{ m}, \theta_{\text{init}} = 0^\circ, V_{\text{init}} = 7.4 \times 10^3 \text{ m/s}, v_\Delta = 90^\circ$$

Keystrokes:

```
[XEQ] [ALPHA] SIZE [ALPHA] 011
[XEQ] [ALPHA] ORBIT [ALPHA]
5.979 [EEX] 24 [R/S]
7.1 [EEX] 6 [R/S]
0 [R/S]
7.4 [EEX] 3 [R/S]
90 [R/S]
90 [ENTER↑]
2300 [D]
[B]
[R/S]
359.9976 [ENTER↑]
180 [-] [C]
[R/S]
[R/S]
[R/S]
270.0009 [ENTER↑]
1450 [D]
[R/S]
[R/S]
[R/S]
[B]
[R/S]
[R/S]
[R/S]
[R/S]
[T=19.8193]
```

Display:

MASS ?
INIT. R ?
INIT. Δ ?
INIT. V ?
INIT. vΔ ?
R=7100000.00

R=7100000.000
E=0.6743
ΔP=359.9976
R=36501420.27
Δ=179.9976
V=1886.7759
vΔ=270.0009

R=36501420.27
Δ=179.9976
V=3336.7759
vΔ=270.0009
E=0.0186
ΔP=180.1643
RMIN=36501417.46
ELLIPSE
A=37192989.78
B=37186559.62
T=19.8193

User Instructions

SIZE: 011				
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Initialize.		[XEQ] ORBIT	MASS ?
3	Key in the mass of the attracting body.	M	[R/S]	INIT. R ?
4	Key in the initial distance from center of attracting body.	R _{init}	[R/S]	INIT. Δ ?
5	Key in the initial longitude.	θ _{init}	[R/S]	INIT. V ?
6	Key in the initial velocity.	v _{init}	[R/S]	INIT. vΔ ?
7	Key in the initial angle of velocity.	θ _{v init}	[R/S]	
8	Output current position.			R=
			[R/S]	Δ = (θ)
			[R/S]	V=
			[R/S]	vΔ = (α)
9	To output orbit geometry:		[B]	E=
				Δ P= (θ')
				RMIN=
a	If circular:			CIRCLE
				R=
				T= (hrs)
b	If elliptical:			ELLIPSE
				A=
				B=
				T= (hrs)
c	If parabolic:			PARABOLA
d	If hyperbolic:			HYPERBOLA
				S=
				Δ A= (θ _a)
10	To move to a new position in the old orbit,	θ _{new}	[C]	R=

User Instructions

SIZE: 011

Program Listings

<pre> 01♦LBL "ORB IT" 02 SF 21 03 SF 27 04♦LBL A 05 CF 22 06 "MASS ?" 07 PROMPT 08 6.6732 E -11 09 * 10 FS?C 22 11 STO 04 12 "INIT. " 13 ASTO 05 14 "HR ?" 15 PROMPT 16 FS?C 22 17 STO 00 18 CLA 19 ARCL 05 20 "F4 ?" 21 PROMPT 22 FS?C 22 23 STO 01 24 CLA 25 ARCL 05 26 "FV ?" 27 PROMPT 28 FS?C 22 29 STO 02 30 CLA 31 ARCL 05 32 "FVA ?" 33 PROMPT 34 FS?C 22 35 STO 03 36 XEQ 51 37 GTO 09 38♦LBL B 39 "E=" 40 ARCL 08 41 AVIEW 42 "ΔP=" 43 ARCL 10 44 RCL 10 45 AVIEW 46 RCL 08 47 1 48 + 49 1/X </pre>	<pre> Initialize ----- Input </pre>	<pre> 50 RCL 09 51 * 52 STO 05 53 "RMIN=" 54 ARCL 05 55 AVIEW 56 RCL 08 57 ENTER↑ 58 FRC 59 X=Y? 60 GTO 01 61 RCL 09 62 1 63 RCL 08 64 X=0? 65 GTO 03 66 "ELLIPSE" "AVIEW 67 X↑2 68 - 69 / 70 / 71 ENTER↑ 72 "A=" 73 ARCL X 74 AVIEW 75 LASTX 76 SQRT 77 * 78 "B=" 79 ARCL X 80 AVIEW 81 RDN 82 GTO 00 83♦LBL 03 84 "CIRCLE" 85 AVIEW 86 "R=" 87 ARCL 05 88 RCL 05 89 AVIEW 90♦LBL 00 91 3 92 Y↑X 93 RCL 04 94 / 95 SQRT 96 2 97 * 98 PI 99 * </pre>	<p>R_{min}</p> <p>$e \geq 1$</p> <p>$e=0$</p> <p>Ellipse</p> <p>Circle</p> <p>Period calculation</p>
---	-------------------------------------	--	---

Program Listings

100 3600		149 X<>Y	
101 /		150 /	
102 "T="		151 RCL 06	
103 ARCL X		152 +	
104 AVIEW		153 2	
105 STOP		154 *	
106 GTO B	-----	155 SQRT	
107♦LBL 01	Hyperbola or	156 STO 02	
108 RCL 05	parabola	157 RCL 07	v _{new}
109 1		158 RCL 00	
110 RCL 08		159 RCL 02	
111 1/X		160 *	
112 -		161 /	
113 X#0?		162 INT	
114 GTO 00		163 X=0?	
115 "PARABOL		164 LASTX	
A"		165 ASIN	
116 AVIEW		166 RCL 07	
117 STOP		167 RCL 01	
118 GTO B		168 RCL 10	
119♦LBL 00		169 -	
120 "HYPERBO		170 SIN	
LA"		171 *	
121 AVIEW		172 X>0?	
122 /		173 GTO 00	
123 "S="		174 CLX	
124 ARCL X		175 180	
125 AVIEW		176 -	
126 RCL 08		177 CHS	
127 1/X		178 RT	
128 ACOS		179♦LBL 00	
129 "ΔR="		180 RDN	
130 ARCL X		181 RCL 01	
131 AVIEW		182 +	
132 STOP		183 XEQ 50	
133 GTO B		184 STO 03	
134♦LBL C	Move to new θ	185 GTO 09	α _{new}
135 XEQ 50		186♦LBL D	-----
136 STO 01		187 P-R	Change velocity
137 RCL 10		188 RCL 03	
138 -		189 RCL 02	
139 COS		190 P-R	
140 RCL 08		191 ST+ Z	
141 *		192 RDN	
142 1		193 ST+ Z	
143 +		194 RDN	
144 RCL 09		195 R-P	
145 /		196 STO 02	
146 1/X		197 RDN	
147 STO 00	R _{new}	198 XEQ 50	
148 RCL 04		199 STO 03	

Program Listings

200 XEQ 51	-----	251 RCL 04	
201♦LBL 09	Output position	252 X↑2	
202 "R="	and velocity	253 /	
203 ARCL 00		254 1	
204 AVIEW		255 +	
205 "Δ="		256 SQRT	
206 ARCL 01		257 STO 08	Eccentricity
207 AVIEW		258 RCL 01	
208 "V="		259 RCL 07	
209 ARCL 02		260 X↑2	
210 AVIEW		261 RCL 04	
211 "VΔ="		262 /	
212 ARCL 03		263 STO 09	
213 AVIEW		264 RCL 00	R_o
214 STOP		265 /	
215 GTO 09	-----	266 1	
216♦LBL 50	Scale an angle	267 -	
217 1		268 RCL 08	
218 P-R		269 /	
219 R-P		270 INT	
220 RDN		271 X≠0?	
221 X≠0?		272 GTO 00	
222 X>0?		273 CLX	
223 RTH		274 LASTX	
224 360		275♦LBL 00	
225 +		276 ACOS	
226 RTH	-----	277 RCL 03	
227♦LBL 51	Calculate new	278 RCL 01	
228 RCL 02	orbit geometry	279 -	
229 X↑2		280 COS	
230 2		281 LASTX	
231 /		282 SIN	
232 RCL 04		283 *	
233 RCL 00		284 X<0?	
234 /		285 GTO 00	
235 -		286 RDN	
236 STO 06	Energy	287 CHS	
237 RCL 03		288 R↑	
238 RCL 01		289♦LBL 00	
239 -		290 RDN	
240 SIN		291 +	
241 RCL 00		292 XEQ 50	
242 *		293 STO 10	
243 RCL 02		294 .END.	$\theta'(\Delta P)$
244 *			
245 STO 07	Angular momentum		
246 X↑2			
247 2			
248 *			
249 RCL 06			
250 *		00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
00	Dist (R)	50		SIZE ENG DEG	011	TOT. REG. 77	USER MODE
	Bearing (Δ)				FIX	SCI	ON X OFF
	Speed (V)				RAD	GRAD	
	Speed bearing (V Δ)						
G*M				FLAGS			
05	Temp	55		#	INIT S/C	SET INDICATES	CLEAR INDICATES
	Energy			21		Printer Enabled	Printer Disabled
	Ang. mom.			22		Numeric Input	
	e			27		USER On	USER Off
10	R_o						
	θ' (ΔP)	60					
15		65					
20		70					
25		75					
30		80					
35		85					
ASSIGNMENTS							
40		90		FUNCTION	KEY	FUNCTION	KEY
45		95					

DELTA-V ORBIT SIMULATOR

PROGRAM REGISTERS NEEDED: 67

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SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 3)



ROW 2 (4 - 8)



ROW 3 (8 - 11)



ROW 4 (12 - 14)



ROW 5 (14 - 20)



ROW 6 (21 - 27)



ROW 7 (28 - 33)



ROW 8 (34 - 39)



ROW 9 (40 - 47)



ROW 10 (48 - 54)



ROW 11 (55 - 65)



ROW 12 (66 - 71)



ROW 13 (72 - 79)



ROW 14 (79 - 84)



ROW 15 (85 - 94)



ROW 16 (95 - 102)



ROW 17 (103 - 112)



ROW 18 (113 - 116)



DELTA-V ORBIT SIMULATOR

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 19 (117 - 120)



ROW 20 (120 - 128)



ROW 21 (129 - 134)



ROW 22 (135 - 147)



ROW 23 (148 - 160)



ROW 24 (161 - 172)



ROW 25 (173 - 182)



ROW 26 (182 - 191)



ROW 27 (192 - 199)



ROW 28 (200 - 206)



ROW 29 (207 - 212)



ROW 30 (213 - 223)



ROW 31 (223 - 233)



ROW 32 (234 - 246)



ROW 33 (247 - 259)



ROW 34 (260 - 271)



ROW 35 (272 - 284)



ROW 36 (284 - 293)



DELTA-V ORBIT SIMULATOR

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PHYSICS

ROW 37 (293 - 293)



EQUATIONS OF MOTION

This program provides an interchangeable solution between time, displacement, final velocity, initial velocity, and acceleration. Given any three knowns, the two unknowns will be calculated. The motion must be linear and have constant acceleration.

Equations:

$$x = \frac{t(VF+VI)}{2}$$

$$x = VF(t) - \frac{1}{2} a t^2$$

$$x = \frac{VF^2 - VI^2}{2a}$$

$$x = VI(t) + \frac{1}{2} a t^2$$

$$VF = VI + a t$$

where:

t = time

x = displacement

VF = final velocity

VI = initial velocity

a = acceleration

Notes:

Any consistent set of units may be used.

Displacement, acceleration, and velocity should be considered as signed quantities. For example: if VI and a are in opposite directions, one should be input as negative.

All equations assume initial displacement, X_0 , equals zero.

Example:

If a rock is dropped off a 50 foot cliff, how long does it take to drop, and how fast is it going when it hits bottom? ($a=32.16 \text{ ft/s}^2$)

Keystrokes:	Display
[XEQ] [ALPHA] SIZE [ALPHA] 005	
[XEQ] [ALPHA] MOTION [ALPHA]	T?
[R/S]	X?
50 [R/S]	VF?
[R/S]	VI?
0 [R/S]	A?
32.16 [R/S]	T=1.7634
[R/S]	X=50.0000
[R/S]	VF=56.7098
[R/S]	VI=0.0000
[R/S]	a=32.1600

(time = 1.7634 seconds and final velocity = 56.7098 feet/second)

User Instructions

Program Listings

01♦LBL "MOT ION"	Initialize	51 FS? 03 52 GTO 00 53 RCL 04 54 RCL 02 55 + 56 2 57 / 58 RCL 00 59 *	t, VF and VI known
02 CF 00 03 CF 01 04 CF 02 05 CF 03 06 CF 04 07 CF 22 08 "T?" 09 PROMPT	Input	60 STO 01 61 SF 01 62 GTO 09 63♦LBL 00 64 FS? 00 65 GTO 00 66 RCL 02 67 X↑2 68 RCL 04 69 X↑2 70 - 71 RCL 03 72 2 73 * 74 /	x
10 FS?C 22 11 SF 00 12 STO 00 13 "X?" 14 PROMPT 15 FS?C 22 16 SF 01 17 STO 01 18 "VF?" 19 PROMPT 20 FS?C 22 21 SF 02 22 STO 02 23 "VI?" 24 PROMPT 25 FS?C 22 26 SF 04 27 STO 04 28 "A?" 29 PROMPT 30 FS?C 22 31 SF 03 32 STO 03 33 FS? 01	x known?	75 STO 01 76 SF 01 77 GTO 05 78♦LBL 00 79 RCL 02 80 RCL 00 81 * 82 RCL 03 83 RCL 00 84 X↑2 85 * 86 2 87 / 88 -	x
34 GTO 01 35 FS? 02 36 GTO 00 37 RCL 04 38 RCL 00 39 *	VF known?	89 STO 01 90 SF 01 91 GTO 08 92♦LBL 01 93 FS? 02 94 GTO 03 95 FS? 03 96 GTO 00 97 RCL 01 98 RCL 00 99 /	VF known?
40 RCL 03 41 RCL 00 42 X↑2 43 * 44 2 45 / 46 + 47 STO 01 48 SF 01 49 GTO 02 50♦LBL 00	x a known?	100 2 101 *	a known? t, x and VI known

Program Listings

102 RCL 04		153 *	
103 -		154 RCL 02	
104 STO 02	VF	155 +	
105 SF 02		156 RCL 03	
106 GTO 07		157 /	
107♦LBL 00		158 STO 00	t
108 FS? 00	t known	159 SF 00	
109 GTO 02		160 GTO 08	
110 RCL 01		161♦LBL 00	
111 RCL 03	x, a and VI known	162 FS? 00	t known?
112 *		163 GTO 07	
113 2		164♦LBL 09	
114 *		165 RCL 02	VF, x and VI known
115 RCL 04		166 X↑2	
116 X↑2		167 RCL 04	
117 +		168 X↑2	
118 SQRT		169 -	
119 RCL 01		170 RCL 01	
120 SIGN		171 /	
121 *		172 2	
122 STO 02	VF	173 /	
123 SF 02		174 STO 03	a
124 GTO 05		175 SF 03	
125♦LBL 02	x, a and t known	176♦LBL 05	
126 RCL 01		177 RCL 01	VF, x and VI known
127 RCL 00		178 RCL 02	
128 /		179 RCL 04	
129 RCL 03		180 +	
130 RCL 00		181 /	
131 *		182 2	
132 2		183 *	
133 /		184 STO 00	t
134 +		185 SF 00	
135 STO 02	VF	186 GTO 10	
136 SF 02		187♦LBL 07	
137 GTO 08		188 RCL 02	
138♦LBL 03	a unknown?	189 RCL 01	
139 FC? 03		190 RCL 00	
140 GTO 00		191 /	
141 RCL 02		192 -	
142 X↑2	VF, a and x known	193 RCL 00	
143 RCL 01		194 /	
144 RCL 03		195 2	
145 *		196 *	
146 2		197 STO 03	a
147 *		198 SF 03	
148 -		199♦LBL 08	
149 SQRT		200 RCL 02	VF, a and t known
150 RCL 01		201 RCL 03	
151 SIGN		202 RCL 00	
152 CHS		203 *	

Program Listings

204 -		51	
205 STO 04	VI		
206 SF 04			
207♦LBL 10	-----		
208 "T="	Output		
209 ARCL 00			
210 AVIEW			
211 STOP			
212 "X="			
213 ARCL 01		60	
214 AVIEW			
215 STOP			
216 "VF="			
217 ARCL 02			
218 AVIEW			
219 STOP			
220 "VI="			
221 ARCL 04			
222 AVIEW			
223 STOP		70	
224 "A="			
225 ARCL 03			
226 AVIEW			
227 RTN			
228 .END.			
30		80	
40		90	
50		00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
00	r	50	SIZE 005 TOT. REG. 51			USER MODE
	x		ENG FIX 4 SCI			ON OFF
	VF		DEG RAD GRAD			
	a					
	VI					
05		55	FLAGS			
			#	INIT S/C	SET INDICATES	CLEAR INDICATES
			00		t known	
			01		x known	
			02		VF known	
10		60	03		a known	
			04		VI known	
15		65				
20		70				
25		75				
30		80				
35		85				
ASSIGNMENTS						
40		90	FUNCTION	KEY	FUNCTION	KEY
45		95				

EQUATIONS OF MOTION

PROGRAM REGISTERS NEEDED: 47

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SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 3)



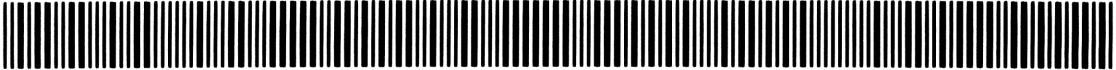
ROW 2 (3 - 9)



ROW 3 (10 - 16)



ROW 4 (17 - 23)



ROW 5 (23 - 30)



ROW 6 (30 - 37)



ROW 7 (38 - 49)



ROW 8 (49 - 59)



ROW 9 (60 - 68)



ROW 10 (69 - 79)



ROW 11 (80 - 91)



ROW 12 (91 - 99)



ROW 13 (100 - 109)



ROW 14 (109 - 121)



ROW 15 (122 - 132)



ROW 16 (133 - 141)



ROW 17 (142 - 154)



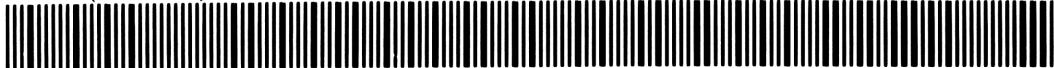
ROW 18 (155 - 163)



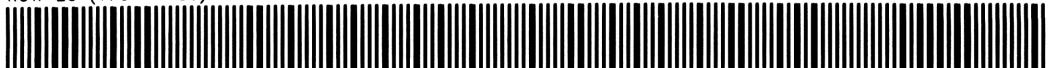
EQUATIONS OF MOTION

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PHYSICS

ROW 19 (164 - 175)



ROW 20 (176 - 186)



ROW 21 (187 - 198)



ROW 22 (199 - 208)



ROW 23 (209 - 216)



ROW 24 (216 - 222)



ROW 25 (223 - 228)



ISOTOPE OVERLAP CORRECTIONS

This program corrects for spillover between channels when two radioactive isotopes are being counted in a liquid scintillation spectrometer. Background subtraction for each isotope is also provided. The program may be used with single isotope.

Isotopes x and y are counted in machine channels A and B, respectively.

Let a = fractioned spillover of isotope y from channel B to A.
 b = fractioned spillover of isotope x from channel A to B.

$$C_x = \text{corrected counts/min isotope } x \text{ in channel A} = \frac{C_A - a C_B}{1-ab},$$

where C_A and C_B are the observed counts/min in each channel.

$$C_y = \frac{C_B - b C_A}{1-ab}$$

Outputs

Total counts/min isotope x = $C_x (1+b) = T_x$

Total counts/min isotope y = $C_y (1+a) = T_y$

Example:

2 isotopes, Spillover A → B = 10%, Spillover B → A = 20%, BKA = 10 CPM, BKB = 50 CPM.

For the following values of CPM A and CPM B, calculate the corrected values and totals.

<u>Sample#</u>	<u>A</u>	<u>B</u>
1	1,000	500
2	2,000	1,000
3	1,400	2,200

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 011	
[XEQ] [ALPHA] IOC [ALPHA]	ISOTOPES?
2 [R/S]	SPILOVER B-A?
.2 [R/S]	BKA?
10 [R/S]	SPILOVER A-B?
.1 [R/S]	BKB?
50 [R/S]	CPM A?
1,000 [R/S]	CPM B?
500 [R/S]	TX=1,010.
[R/S]	TY=430.
[R/S]	NEXT=2
[R/S]	CPM A?
2,000 [R/S]	CPM B?
1,000 [R/S]	TX=2,020
[R/S]	TY=920
[R/S]	NEXT=3
[R/S]	CPM A?
1,400 [R/S]	CPM B?
2,200 [R/S]	TX=1,078
[R/S]	TY=2,462
[R/S]	NEXT=4
[R/S]	CPM A?
[R/S]	TOT. TX=4,108 (Pressing [R/S] with no input displays totals and resets for new case)
[R/S]	TOT. TY=3,812

User Instructions

Program Listings

01♦LBL "IOC"	Initialize and prompt for data input	47 -	from CPMB and and store
"		48 STO 05	
02 CF 00		49 RTN	
03 CLRG		50♦LBL C	Calculate TX
04 2		51 RCL 04	and TY
05 "ISOTOPE		52 RCL 01	
S?"		53 RCL 05	
06 PROMPT		54 *	
07 X=Y?		55 -	
08 SF 00		56 1	
09 2		57 RCL 01	
10 STO 10		58 RCL 03	
11 "SPLOVER		59 *	
B-A?"		60 -	
12 PROMPT		61 /	
13 ENTER↑		62 1	
14 "BKA?"		63 RCL 03	
15 PROMPT		64 +	
16 XEQ D		65 *	
17 FC? 00		66 ST+ 06	
18 GTO 00		67 STO 07	
19 "SPLOVER		68 FIX 0	
A-B?"		69 RCL 05	
20 PROMPT		70 RCL 03	
21 ENTER↑		71 RCL 04	
22 "BKB?"		72 *	
23 PROMPT		73 -	
24 XEQ E		74 1	
25♦LBL 00		75 RCL 01	
26 CF 22		76 RCL 03	
27 "CPM A?"		77 *	
28 CLX		78 -	
29 PROMPT		79 /	
30 FC?C 22		80 1	
31 GTO "TOT		81 RCL 01	
"		82 +	
32 XEQ A		83 *	
33 FC? 00		84 ST+ 08	
34 GTO 01		85 STO 09	
35 "CPM B?"		86 RCL 07	
36 PROMPT		87 "TX= "	Display TX
37 XEQ B		88 ARCL X	
38♦LBL 01		89 AVIEW	
39 GTO C		90 STOP	
40♦LBL A		91 RCL 09	
41 RCL 00		92 FC? 00	
42 -		93 GTO 00	
43 STO 04		94 "TY= "	Display TY
44 RTN		95 ARCL X	
45♦LBL B		96 AVIEW	
46 RCL 02		97 STOP	

(cont'd.)

Program Listings

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
REG#	NAME	DEC#	SIZE		TOT. REG.	USER MODE
			011	011	50	ON OFF X
00	BKA	50				
	a					
	BKB					
	b					
	CA					
05	CB	55				
	ΣCX					
	CX			#	INIT S/C	FLAGS
	ΣCY				SET INDICATES	CLEAR INDICATES
	CY			00	2 isotopes	
10	sample number	60				
15		65				
20		70				
25		75				
30		80				
35		85				
ASSIGNMENTS						
			FUNCTION	KEY	FUNCTION	KEY
40		90				
45		95				

ISOTOPE OVERLAP CORRECTIONS

PROGRAM REGISTERS NEEDED: 40

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SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 5)



ROW 2 (5 - 9)



ROW 3 (10 - 11)



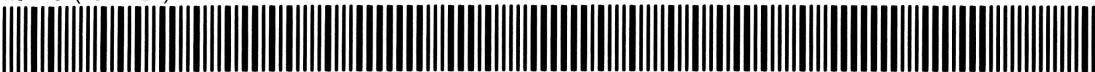
ROW 4 (11 - 17)



ROW 5 (17 - 19)



ROW 6 (19 - 24)



ROW 7 (24 - 29)



ROW 8 (30 - 34)



ROW 9 (34 - 38)



ROW 10 (39 - 47)



ROW 11 (48 - 59)



ROW 12 (60 - 70)



ROW 13 (71 - 83)



ROW 14 (84 - 90)



ROW 15 (91 - 96)



ROW 16 (97 - 102)



ROW 17 (103 - 107)



ROW 18 (108 - 111)



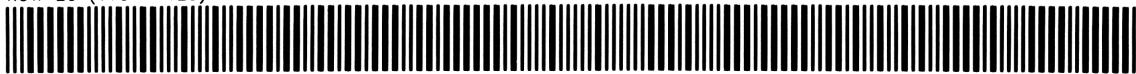
ISOTOPE OVERLAP CORRECTIONS

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 19 (112 - 116)



ROW 20 (116 - 123)



ROW 21 (123 - 133)



ROW 22 (133 - 133)



SEMI-EMPIRICAL NUCLEAR MASS FORMULA

(requires one memory module)

A Semi-Empirical formula is used to calculate approximate binding energies and mass excess for any nucleus with a given nuclear charge, Z, and number of neutrons, N.

Definition: Binding energy (B.E.) = $Z * M_p + N * M_n - M(Z,N)$

M_p = proton mass (energy) in MeV, M_n = neutron mass in MeV

$M(Z,N)$ = mass of nucleus having Z protons and N neutrons.

Mass Excess = $M(Z,N) - A * (\text{amu})$

$A = Z + N$, 1 (amu) = $M(6,6)/12$ --- 1/12 mass of ^{12}C

Weizsacker's Semi-Empirical mass formula contains seven terms

$$M(Z,N) = Z * M_p + N * M_n + E_v + E_s + E_c + E_{\text{sym}} + E_{\text{pair}}$$

$$E_v = -a_1 * A$$

$E_{\text{pair}} = \pm 34/A^{3/4}$ depending on whether Z and N are both odd or both even.

$$E_s = a_2 * A^{2/3}$$

$$E_{\text{pair}} = 0 \text{ for odd } A \text{ nuclei}$$

$$E_c = a_3 * Z^2 / A^{1/3}$$

$$E_{\text{sym}} = a_4 * (Z-N)^2 / A$$

Notes:

The semiempirical formula has been derived from measured masses and binding energies and is expected to work for nuclei reasonably close to the valley of stability. Usually $N \geq Z$ especially for heavier nuclei.

Example:

What is the binding energy, the mass, mass excess, volume energy, surface energy, coulomb energy, symmetry energy, and pairing energy of the element titanium (Z = 22, N = 26)?

Keystrokes:

```
[XEQ] [ALPHA] SIZE [ALPHA] 025
[XEQ] [ALPHA] NM [ALPHA]
22 [R/S]
26 [R/S]
```

Display:

```
NUM PROT?
NUM NEUT?
B.E.=-404.5143
B.E./A=-8.4274
M=44,677.9077
M/A=930.7897
M.E.=0.0000
M.E./A=0.0000
EV=-752.6400
EV/A=-15.6800
ES=245.1351
ES/A=5.1070
Ec=95.4884
Ec/A=1.9893
ESYM=9.3667
ESYM/A=0.1951
EP=-1.8644
EP/A=-0.0388
```

User Instructions

Program Listings

01♦LBL "NM"	Initialize and store constants	50 RCL 00
02 CF 01		51 /
03 CF 00		52 "B.E./A="
04 CLRG		"
05 -931.504		53 ARCL X
06 STO 08		54 PROMPT
07 938.793		55 RTN
08 STO 09		56♦LBL D
09 939.576		57 17.024
10 STO 10		58 STO 03
11 -15.68		59 XEQ 04
12 STO 11		60 "M="
13 18.56		61 ARCL X
14 STO 12		62 PROMPT
15 .717		63 RCL 00
16 STO 13		64 /
17 28.1		65 "M/A="
18 STO 14		66 ARCL X
19 -17		67 PROMPT
20 STO 15		68 RTN
21 "NUM PRO	Prompt for inputs	69♦LBL E
T?"		70 XEQ 01
22 PROMPT		71 16.024
23 FS?C 22		72 XEQ 04
24 STO 01		73 "M.E.="
25 "NUM NEU		74 ARCL X
T?"		75 PROMPT
26 PROMPT		76 RCL 00
27 FS?C 22		77 /
28 STO 02		78 "M.E./A="
29 RCL 02		"
30 RCL 01		79 ARCL X
31 +		80 PROMPT
32 STO 00		81 RTN
33 XEQ C		82♦LBL a
34 XEQ D		83 RCL 20
35 XEQ E		84 "EV="
36 XEQ a		85 ARCL X
37 XEQ b		86 PROMPT
38 XEQ c		87 RCL 00
39 XEQ d		88 /
40 XEQ e		89 "EV/A="
41 GTO "NM"		90 ARCL X
42♦LBL C	Calculate Binding Energy	91 PROMPT
43 XEQ 01		92 RTN
44 19.024		93♦LBL b
45 STO 03		94 RCL 21
46 XEQ 04		95 "ES="
47 "B.E.="		96 ARCL X
48 ARCL X		97 PROMPT
49 PROMPT		98 RCL 00

Program Listings

99 /		150 1/X	
100 "ES/A="		151 Y↑X	
101 ARCL X		152 X↑2	
102 PROMPT		153 XEQ 02	
103 RTN		154 RCL 01	
104♦LBL c	Display Coulomb	155 X↑2	
105 RCL 22	Energy	156 RCL 00	
106 "Ec="		157 3	
107 ARCL X		158 1/X	
108 PROMPT		159 Y↑X	
109 RCL 00		160 /	
110 /		161 XEQ 02	
111 "Ec/A="		162 RCL 01	
112 ARCL X		163 RCL 02	
113 PROMPT		164 -	
114 RTN		165 X↑2	
115♦LBL d	Display Symmetry	166 RCL 00	
116 RCL 23	Energy	167 /	
117 "ESYM="		168 XEQ 02	
118 ARCL X		169 -1	
119 PROMPT		170 RCL 01	
120 RCL 00		171 Y↑X	
121 /		172 -1	
122 "ESYM/A="		173 RCL 02	
"		174 Y↑X	
123 ARCL X		175 +	
124 PROMPT		176 RCL 00	
125 RTN		177 .75	
126♦LBL e	Display Pairing	178 Y↑X	
127 RCL 24	Energy	179 /	
128 "EP="		180 XEQ 02	
129 ARCL X		181 SF 01	
130 PROMPT		182 RTN	
131 RCL 00		183♦LBL 02	
132 /		184 RCL IND	
133 "EP/A="		03	
134 ARCL X		185 *	
135 PROMPT		186 RCL 03	
136 RTN		187 9	
137♦LBL 01	Calculation of	188 +	
138 8	all terms	189 STO 03	
139 STO 03		190 X<>Y	
140 RCL 00		191 STO IND	
141 XEQ 02		03	
142 RCL 01		192 8	
143 XEQ 02		193 ST- 03	
144 RCL 02		194 RTN	
145 XEQ 02		195♦LBL 04	
146 RCL 00		196 0	
147 XEQ 02		197 STO 06	
148 RCL 00		198♦LBL 05	
149 3		199 ISG 03	

Program Listings

200 GTO 10		51	
201 GTO 06			
202♦LBL 10			
203 RCL IND			
03			
204 ST+ 06			
205 GTO 05			
206♦LBL 06			
207 RCL 06			
208 RTN		60	
209 .END.			
20		70	
30		80	
40		90	
50		00	

SEMI-EMPIRICAL NUCLEAR MASS
FORMULA
PROGRAM REGISTERS NEEDED: 65

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 5)



ROW 2 (5 - 7)



ROW 3 (7 - 11)



ROW 4 (11 - 15)



ROW 5 (15 - 21)



ROW 6 (21 - 25)



ROW 7 (25 - 28)



ROW 8 (29 - 35)



ROW 9 (36 - 40)



ROW 10 (40 - 44)



ROW 11 (44 - 47)



ROW 12 (47 - 52)



ROW 13 (52 - 57)



ROW 14 (58 - 65)



ROW 15 (65 - 70)



ROW 16 (71 - 73)



ROW 17 (73 - 78)



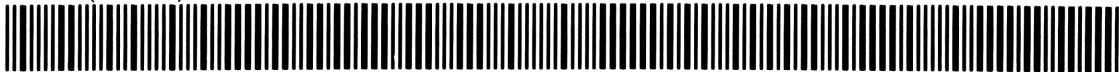
ROW 18 (78 - 84)



SEMI-EMPIRICAL NUCLEAR MASS
FORMULA

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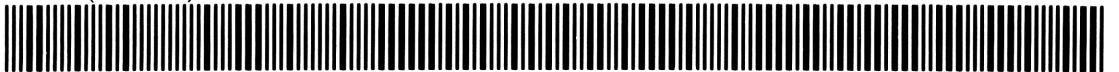
ROW 19 (84 - 90)



ROW 20 (90 - 96)



ROW 21 (97 - 103)



ROW 22 (104 - 110)



ROW 23 (111 - 116)



ROW 24 (116 - 122)



ROW 25 (122 - 126)



ROW 26 (127 - 133)



ROW 27 (133 - 141)



ROW 28 (141 - 147)



ROW 29 (147 - 157)



ROW 30 (158 - 168)



ROW 31 (168 - 177)



ROW 32 (177 - 184)



ROW 33 (185 - 195)



ROW 34 (196 - 204)



ROW 35 (204 - 209)



CLEBSCH-GORDON COEFFICIENTS AND 3J SYMBOLS EVALUATION

This program will evaluate all valid Clebsch-Gordon Coefficients and/or "3j" symbols coupling two states of angular momentum which are small enough so that the capacity of the calculator's factorial function is not exceeded. The fundamental formula used by the program is the Racah Formula:

$$\underbrace{\begin{pmatrix} j_1 & j_2 & J \\ m_1 & m_2 & -M \end{pmatrix}}_{3j \text{ Symbol}} =$$

$$(-1)^{j_1 - j_2 + M} \sqrt{\Delta(j_1 j_2 J)} \quad \sqrt{(j_1 + m_1)! (j_1 - m_1)! (j_2 + m_2)! (j_2 - m_2)! (J + M)! (J - M)!}$$

$$\cdot \sum_t (-1)^t \left[t! (J - j_2 + t + m_1)! (J - j_1 + t - m_2)! (j_1 + j_2 - J - t)! \right. \\ \left. \cdot (j_1 - t - m_1)! (j_2 - t + m_2)! \right]^{-1}$$

$$\text{with } \Delta(j_1 j_2 J) = \left[(j_1 + j_2 - J)! (j_2 + J - j_1)! (J + j_1 - j_2)! \right] \div (j_1 + j_2 + J + 1)!$$

$$\text{subject to the restraints } 1) \quad |j_1 - j_2| \leq J \leq |j_1 + j_2|$$

$$2) \quad m_1 + m_2 = M$$

$$\text{The Clebsch-Gordon Coefficient, } \langle j_1 j_2 m_1 m_2 | JM \rangle = \frac{\sqrt{2J + 1}}{(-1)^{j_1 - j_2 + m}} \begin{pmatrix} j_1 & j_2 & J \\ m_1 & m_2 & -M \end{pmatrix}$$

If any one term in the Racah formula is greater than 69, an out of range message will result. If illegitimate values are entered for j_1 , j_2 , and J or m_1 , m_2 , and M spurious results (i.e., non-zero) may be obtained or the calculator may get caught in a "loop" which will not terminate until the "t" value in the Racah formula exceeds 69.

Example:

Suppose the C.G. coefficient $\langle j_1 j_2 m_1 m_2 | JM \rangle$ is needed with $j_1 = 3/2$, $j_2 = 2$, $J = 5/2$, $M_1 = 1/2$, $M_2 = 0$, $M = 1/2$

Keystrokes:

[XEQ] ALPHA] SIZE [ALPHA] 018

[XEQ] [ALPHA] CGC [ALPHA]

1.5 [R/S]

2 [R/S]

2.5 [R/S]

.5 [R/S]

0 [R/S]

.5 [R/S]

[R/S]

Display:

J1=?

J2=?

J=?

M1=?

M2=?

M=?

C.G.=2.9277 E-1

3J=1.1952 E-1

User Instructions

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1.	Load the program.			
2.	Initialize.		[XEQ] CGC	J1=?
3.	Key in J1 value.	J1	[R/S]	J2=?
4.	Key in J2 value.	J2	[R/S]	J=?
5.	Key in J value.	J	[R/S]	M1=?
6.	Key in M1 value.	M1	[R/S]	M2=?
7.	Key in M2 value.	M2	[R/S]	M=?
8.	Key in M.	M	[R/S]	C.G.=
			[R/S]	3J=

SIZE: 018

Program Listings

<pre> 01♦LBL "CGC " 02 SCI 4 03 CLRG 04 "J1=?"" 05 PROMPT 06 STO 01 07 "J2=?"" 08 PROMPT 09 STO 02 10 "J=?" 11 PROMPT 12 STO 03 13 "M1=?"" 14 PROMPT 15 STO 11 16 "M2=?"" 17 PROMPT 18 STO 12 19 "M=?" 20 PROMPT 21 CHS 22 STO 10 23 RCL 01 24 RCL 02 25 RCL 03 26 - 27 + 28 FACT 29 STO 04 30 RCL 02 31 RCL 03 32 RCL 01 33 - 34 + 35 FACT 36 ST* 04 37 RCL 03 38 RCL 01 39 RCL 02 40 - 41 + 42 FACT 43 ST* 04 44 1 45 RCL 01 46 RCL 02 47 RCL 03 48 + 49 + 50 + </pre>	<p>Clears Registers and stores variables</p> <p>Begins computation</p>	<pre> 51 FACT 52 RCL 04 53 X<>Y 54 / 55 SQRT 56 STO 04 57 RCL 01 58 RCL 11 59 + 60 FACT 61 RCL 01 62 RCL 11 63 - 64 FACT 65 * 66 STO 05 67 RCL 02 68 RCL 12 69 + 70 FACT 71 RCL 02 72 RCL 12 73 - 74 FACT 75 * 76 ST* 05 77 RCL 03 78 RCL 10 79 + 80 FACT 81 RCL 03 82 RCL 10 83 - 84 FACT 85 * 86 ST* 05 87 RCL 05 88 SQRT 89 STO 05 90 RCL 01 91 RCL 02 92 RCL 10 93 + 94 - 95 -1 96 X<>Y 97 Y↑X 98 STO 06 99 RCL 04 100 RCL 05 101 RCL 06 </pre>	<p>STORES</p> <p>$\sqrt{\Delta(J_1 J_2 J)}$</p>
--	--	---	--

Program Listings

102 *		153 -	
103 *		154 X<0?	
104 STO 13	Computes summation in Racah Formula	155 GTO 03	
105 CLX		156 FACT	
106 SF 00		157 STO 07	
107 RCL 11		158 RCL 02	
108 STO 15		159 RCL 16	
109 RCL 12		160 +	
110 STO 16		161 RCL 14	
111 RCL 10		162 -	
112 STO 17		163 X<0?	
113 0		164 GTO 03	
114 STO 14		165 FACT	
115♦LBL 02		166 STO 08	
116 RCL 03		167 CF 00	
117 RCL 14		168 RCL 04	
118 RCL 15		169 RCL 05	
119 +		170 RCL 06	
120 +		171 *	
121 RCL 02		172 *	
122 -		173 RCL 07	
123 X<0?		174 RCL 08	
124 GTO 03		175 *	
125 FACT		176 *	
126 STO 04		177 RCL 14	
127 RCL 03		178 FACT	
128 RCL 14		179 *	
129 +		180 1/X	
130 RCL 01		181 -1	
131 RCL 16		182 RCL 14	
132 +		183 Y↑X	
133 -		184 *	
134 X<0?		185 ST+ 09	
135 GTO 03		186 1	
136 FACT		187 ST+ 14	
137 STO 05		188 GTO 02	
138 RCL 01		189♦LBL 03	
139 RCL 02		190 1	Checks to see if Σ finished
140 +		191 ST+ 14	t
141 RCL 03		192 FS? 00	
142 RCL 14		193 GTO 02	
143 +		194 RCL 09	
144 -		195 RCL 13	
145 X<0?		196 *	
146 GTO 03		197 STO 00	Computes Clebsch-
147 FACT		198 -1	Gordon Coeffi-
148 STO 06		199 RCL 01	cient
149 RCL 01		200 RCL 17	
150 RCL 14		201 -	
151 RCL 15		202 RCL 02	
152 +		203 -	

Program Listings

204	Y ₁ X
205	RCL 03
206	2
207	*
208	1
209	+
210	SQRT
211	*
212	RCL 00
213	*
214	"C.G. ="
215	ARCL X
216	AVIEW
217	STOP
218	"3J ="
219	ARCL 00
220	AVIEW
221	RTN
222	.END.
20	
30	
40	
50	

51	
60	
70	
80	
90	
00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
#	Value		SIZE		TOT. REG.	USER MODE
			018		59	ON OFF X
00	J1		ENG		FIX 4	SCI
	J2		DEG		RAD	GRAD
	J					
	Used					
05	Used	55				
	Used					
	Used					
	Used					
	Used					
10	-M	60				
	M1					
	M2					
	Used					
	Used					
15	Used	65				
	Used					
	Used					
20		70				
25		75				
30		80				
35		85				
ASSIGNMENTS						
40	90		FUNCTION	KEY	FUNCTION	KEY
45		95				

CLEBSCH-GORDON COEFFICIENTS
AND 3j SYMBOLS EVALUATION
PROGRAM REGISTERS NEEDED: 42

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 4)



ROW 2 (4 - 10)



ROW 3 (10 - 16)



ROW 4 (16 - 23)



ROW 5 (24 - 36)



ROW 6 (36 - 47)



ROW 7 (48 - 60)



ROW 8 (61 - 73)



ROW 9 (74 - 85)



ROW 10 (86 - 96)



ROW 11 (97 - 108)



ROW 12 (109 - 119)



ROW 13 (120 - 131)



ROW 14 (131 - 142)



ROW 15 (143 - 154)



ROW 16 (155 - 164)



ROW 17 (165 - 176)



ROW 18 (177 - 187)



CLEBSCH-GORDON COEFFICIENTS
AND 3j SYMBOLS EVALUATION

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 19 (187 - 195)



ROW 20 (196 - 206)



ROW 21 (207 - 214)



ROW 22 (215 - 222)



ROW 23 (222 - 222)



32-P REMAINING ON DAY OF YEAR

This program calculates decays per minute (DPM) and counts per minute (CPM) remaining on any day given millicuries (mCi) on an earlier day. This program also calculates CPM and mCi remaining of 32-P sample on a day given CPM on an earlier date.

$$\text{mCi on date 2} = (\text{initial mCi}) (0.5)^n$$

where $n = 14.3/\Delta\text{days}$ = the number of half lives of 32P which have occurred.

$$\text{DPM on date 2} = (\text{mCi on date 2}) (2.2 \times 10^9 \text{ DPM})$$

$$\text{CPM on date 2} = 0.3 \text{ DPM}$$

(assumes 30% counting efficiency and no quenching)

Note:

Program fails if Date 1 = Date 2 or if Date 1 is more recent than Date 2.

Reference:

HP-67/HP-97 USERS LIBRARY Physics Solutions Book.

Example:

- 1) How many DPM and CPM remain of a 0.130 mCi 32P sample given: date of specific radioactivity rating as Feb. 1, 1979, and present date Aug. 4, 1979.
- 2) How many CPM and mCi remain on Aug. 4, 1979, of a 4.2×10^6 CPM sample of 32P as measured on Aug. 11, 1978?

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 013
[XEQ] [ALPHA] 32P [ALPHA]
2.011979 [R/S]
8.041979 [R/S]
0.130 [R/S]
[R/S]
[R/S]
8.111978 [R/S]
8.041979 [R/S]
[R/S]
4.2 [EEX]6 [R/S]
[R/S]

Display:

DATE1?
DATE2?
MCI ON 1?
DPM=3.8280E4
CPM=1.148E4
DATE 1?
DATE 2?
MCI ON 1?
CPM ON 1?
CPM=1.E-1
MCI=1.85E-10

User Instructions

Program Listings

<pre> 01+LBL "32P " 02 CLRG 03 CF 22 04 "DATE1?" 05 PROMPT 06 XEQ A 07 "DATE2?" 08 PROMPT 09 XEQ B 10 XEQ C 11 CF 22 12 "MCI ON 1?"" 13 PROMPT 14 FC?C 22 15 GTO 05 16 XEQ D 17 XEQ E 18 GTO "32P " 19+LBL 05 20 "CPM ON 1?"" 21 PROMPT 22 XEQ D 23 XEQ C 24 GTO "32P " 25+LBL A 26 FIX 2 27 RCL 04 28 RCL 02 29 - 30 3 31 GTO 00 32+LBL B 33 RCL 03 34 RCL 02 35 + 36 4 37+LBL 00 38 STO 00 39 RDN 40 365.25 41 STO 05 42 30.6001 43 STO 06 44 RDN 45 RDN 46 FS?C 22 </pre>	<p>Initialize and input prompts</p> <p>Calculation of Δ Days and storage of constants</p>	<pre> 47 GTO 01 48 STO IND 00 49 122.1 50 - 51 RCL 05 52 / 53 INT 54 STO 09 55 RCL 05 56 * 57 INT 58 RCL IND 00 59 - 60 CHS 61 STO 01 62 RCL 06 63 / 64 INT 65 STO 07 66 RCL 01 67 X<>Y 68 RCL 06 69 * 70 INT 71 - 72 STO 06 73 RCL 07 74 1 75 RCL 08 76 % 77 - 78 - 79 RCL 07 80 14 81 / 82 XEQ 02 83 RCL 09 84 1 E6 85 * 86 + 87 FIX 6 88 RTN 89+LBL 01 90 RDN 91 ENTER↑ 92 INT 93 STO 07 94 - 95 1 E2 </pre>	<p>Break date into months, days, and years</p>
--	---	---	--

Program Listings

96 *		146 STO 10	
97 ENTER↑		147 14.3	
98 INT		148 STO 11	
99 STO 08		149 2.2 E9	
100 -		150 STO 12	
101 1 E4		151 RTN	
102 *		152♦LBL E	Compute DPM and CPM
103 STO 09	Compute Julian day number	153 2	
104 RCL 07		154 RCL 02	
105 1		155 RCL 11	
106 +		156 /	
107 ENTER↑		157 Y↑X	
108 1/X		158 1/X	
109 .7		159 RCL 10	
110 +		160 RCL 12	
111 CHS		161 *	
112 XEQ 02		162 *	
113 RCL 06		163 SCI 4	
114 *		164 "DPM="	
115 INT		165 ARCL X	
116 RCL 09		166 PROMPT	
117 RCL 05		167 ENTER↑	
118 *		168 .3	
119 INT		169 *	
120 +		170 "CPM="	
121 RCL 08		171 ARCL X	
122 +		172 PROMPT	
123 STO IND		173 RTN	
00		174♦LBL C	Compute CPM and mCi
124 1720982		175 RCL 02	
125 +		176 RCL 11	
126 FIX 0		177 /	
127 RTN		178 .5	
128♦LBL 02		179 X<>Y	
129 INT		180 Y↑X	
130 ST+ 09		181 RCL 10	
131 12		182 *	
132 *		183 "CPM="	
133 -		184 ARCL X	
134 RTN		185 PROMPT	
135♦LBL C	Store Δ Days	186 .3	
136 FIX 0		187 /	
137 STO 02		188 RCL 12	
138 FS?C 22		189 /	
139 RTN		190 SCI 2	
140 RCL 04		191 "MCI="	
141 RCL 03		192 ARCL X	
142 -		193 PROMPT	
143 STO 02		194 RTN	
144 RTN		195 .END.	
145♦LBL D	Store Constants		

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
#	INIT S/C	SET INDICATES		CLEAR INDICATES		FLAGS	
		013	61	ON	OFF		
00	indirect address	50					
	used						
	Δ days						
	Day 1						
	Day 2						
05	365.25	55					
	30.6001						
	MM						
	DD						
	YYYY						
10	used	60					
	used						
	used						
15		65					
20		70					
25		75					
30		80					
35		85					
ASSIGNMENTS							
		FUNCTION	KEY	FUNCTION	KEY		
40	90						
45	95						

32-P REMAINING ON DAY OF YEAR

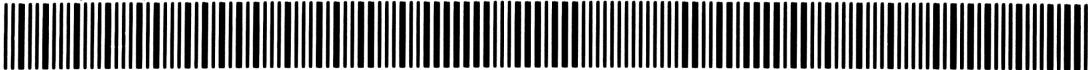
PROGRAM REGISTERS NEEDED: 49

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 1 (1 - 4)



ROW 2 (4 - 7)



ROW 3 (7 - 12)



ROW 4 (12 - 15)



ROW 5 (16 - 20)



ROW 6 (20 - 22)



ROW 7 (23 - 27)



ROW 8 (28 - 38)



ROW 9 (39 - 42)



ROW 10 (42 - 49)



ROW 11 (49 - 58)



ROW 12 (59 - 71)



ROW 13 (72 - 82)



ROW 14 (82 - 91)



ROW 15 (92 - 101)



ROW 16 (101 - 112)



ROW 17 (112 - 123)



ROW 18 (123 - 128)



32-P REMAINING ON DAY OF YEAR

HEWLETT PACKARD
SOLUTION BOOK:
PHYSICS

ROW 19 (129 - 137)



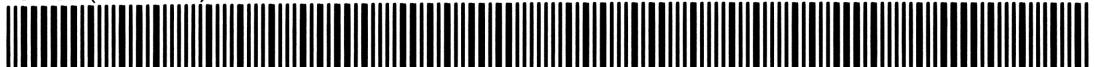
ROW 20 (138 - 147)



ROW 21 (147 - 153)



ROW 22 (154 - 164)



ROW 23 (164 - 170)



ROW 24 (170 - 178)



ROW 25 (179 - 186)



ROW 26 (186 - 192)



ROW 27 (193 - 195)



NOTES

NOTES

Hewlett-Packard Software

In terms of power and flexibility, the problem-solving potential of the HP-41 programmable calculator is nearly limitless. And in order to see the practical side of this potential, HP has different types of software to help save you time and programming effort. Every one of our software solutions has been carefully selected to effectively increase your problem-solving potential. Chances are, we already have the solutions you're looking for.

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To increase the versatility of your HP-41, HP has an extensive library of "Application Pacs". These programs transform your HP-41 into a specialized calculator in seconds. Included in these pacs are detailed manuals with examples, miniature plug-in Application Modules, and keyboard overlays. Every Application Pac has been designed to extend the capabilities of the HP-41.

You can choose from:

Aviation (Pre-Flight Only) 00041-15018	Statistics 00041-15002
Clinical Lab 00041-15024	Stress Analysis 00041-15027
Circuit Analysis 00041-15024	Games 00041-15022
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Mathematics 00041-15003	Machine Design 00041-15020
Structural Analysis 00041-15021	Navigation 00041-15017
Surveying 00041-15005	Real Estate 00041-15016
Securities 00041-15026	Thermal and Transport Science 00041-15019
	Petroleum Fluids 00041-15039

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The Users' Library provides the best programs from contributors and makes them available to you. By subscribing to the HP-41 Users' Library you'll have at your fingertips literally hundreds of different programs from many different application areas.

*Users' Library Solutions Books

Hewlett-Packard offers a wide selection of Solutions Books complete with user instructions, examples, and listings. These solution books will complement our other software offerings and provide you with a valuable tool for program solutions.

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Home Construction Estimating 00041-90096	Heating, Ventilating & Air Conditioning 00041-90140
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Real Estate 00041-90136	Solar Engineering 00041-90138
Small Business 00041-90137	Calendars 00041-90145
Geometry 00041-90084	Cardiac/Pulmonary 00041-90097
High-Level Math 00041-90083	Chemistry 00041-90102
Test Statistics 00041-90082	Games 00041-90099
Antennas 00041-90093	Optometry I (General) 00041-90143
Chemical Engineering 00041-90100	Optometry II (Contact Lens) 00041-90144
Control Systems 00041-90092	Physics 00041-90142
Electrical Engineering 00041-90088	Surveying 00041-90141
Fluid Dynamics and Hydraulics 00041-90139	Time Module Solutions 00041-90395
Games II 00041-90443	

*Some books require additional memory modules to accomodate all programs.

PHYSICS

BLACK BODY THERMAL RADIATION
BLACK HOLE CHARACTERISTICS
SPECIAL RELATIVITY CONVERSIONS
THREE DIMENSIONAL SPECIAL RELATIVITY
EINSTEIN'S TWIN PARADOX
DELTA-V-ORBIT SIMULATOR
EQUATIONS OF MOTION
ISOTOPE OVERLAP CORRECTIONS
SEMI-EMPIRICAL NUCLEAR MASS FORMULA
CLEBSCH-GORDON COEFFICIENTS AND 3J SYMBOLS EVALUATION
32-P REMAINING ON DAY OF YEAR

