

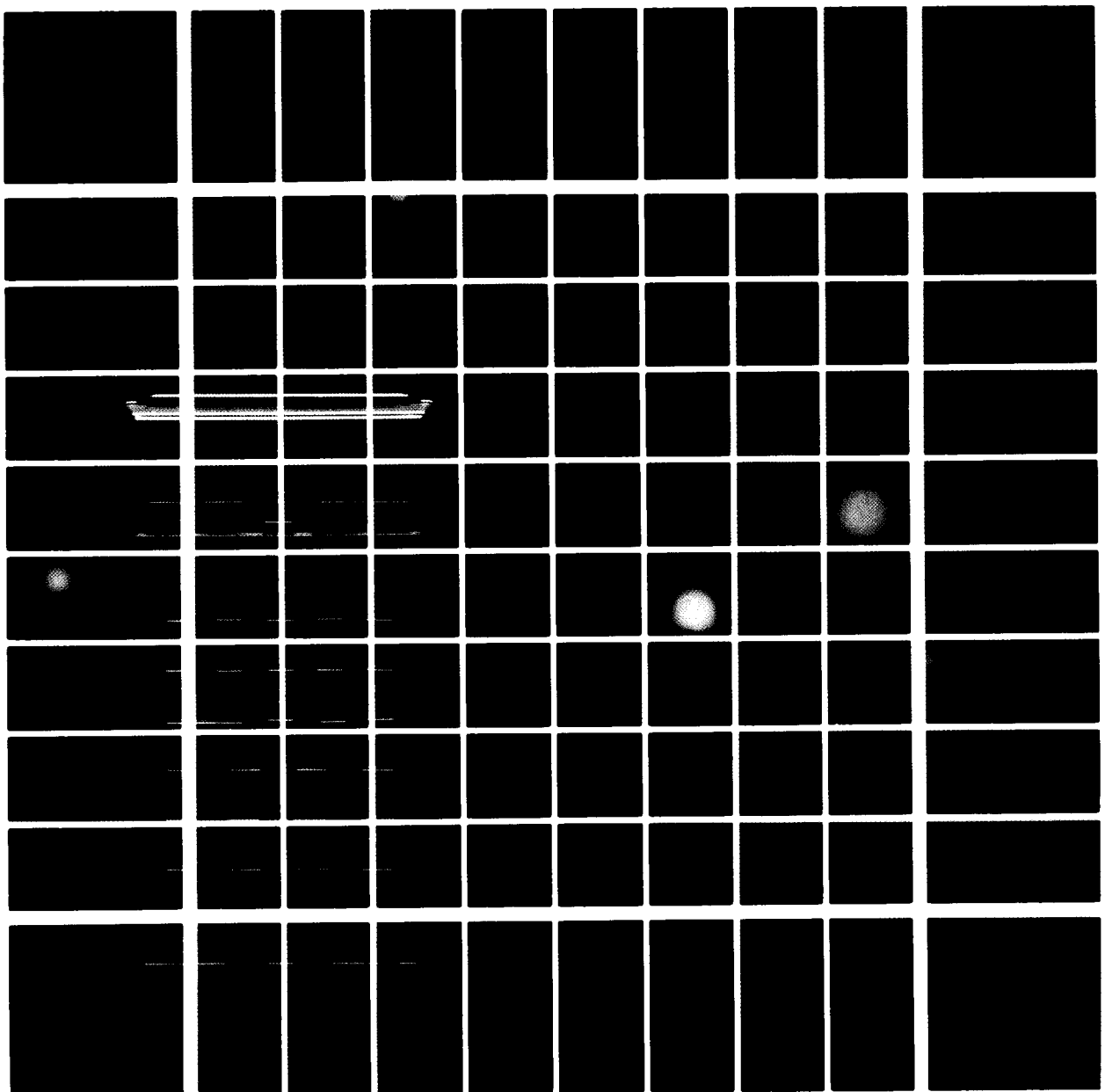
HEWLETT-PACKARD

HP-41

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Physics

Includes barcode for easy software entry.



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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 and 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 in 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 $\times$. When you see $\times$ in the program listing, press **×** .
 - e. The $\uparrow$ character in the program listing is an indication of the **APPEND** function. When you see $\uparrow$, 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 "↑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 ↑ SAMPLE
04 AVIEW
05 6
06 ENTER ↑
07 -2
08 /
09 ABS
10 STO IND L
11T R3=
12 ARCL 03
13 AVIEW
14 RTN

```

TABLE OF CONTENTS

1.	BLACK BODY THERMAL RADIATION.....	1
	Calculates the wavelength of maximum emissive power for a given temperature, and calculates the emissive power.	
2.	BLACK HOLE CHARACTERISTICS.....	8
	Computes temperature, Schwarzschild radius, and life-time of a black hole.	
3.	SPECIAL RELATIVITY CONVERSIONS.....	12
	Provides relativistic conversions between rest mass, velocity, energy, and momentum.	
*4.	THREE DIMENSIONAL SPECIAL RELATIVITY.....	18
	Computes intervals, dilation factors, and Lorentz transformations.	
5.	EINSTEIN'S TWIN PARADOX.....	25
	Calculates real and relative time based on the Lorentz transform.	
*6.	DELTA-V-ORBIT SIMULATOR.....	30
	Computes orbit parameters from initial position and velocity data.	
7.	EQUATIONS OF MOTION.....	39
	Computes the two unknown values based on any three known values of the following variables: distance, time, v-final, v-initial, and acceleration.	
8.	ISOTOPE OVERLAP CORRECTIONS.....	46
	Corrects for spillover between channels in a liquid scintillation spectrometer.	
*9.	SEMI-EMPIRICAL NUCLEAR MASS FORMULA.....	52
	Calculates approximate binding energies and mass.	
10.	CLEBSCH-GORDON COEFFICIENTS AND 3J SYMBOLS EVALUATION.	59
	Uses Racah formula to evaluate coupling of two states of angular momentum.	
11.	32-P REMAINING ON DAY OF YEAR.....	66
	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.

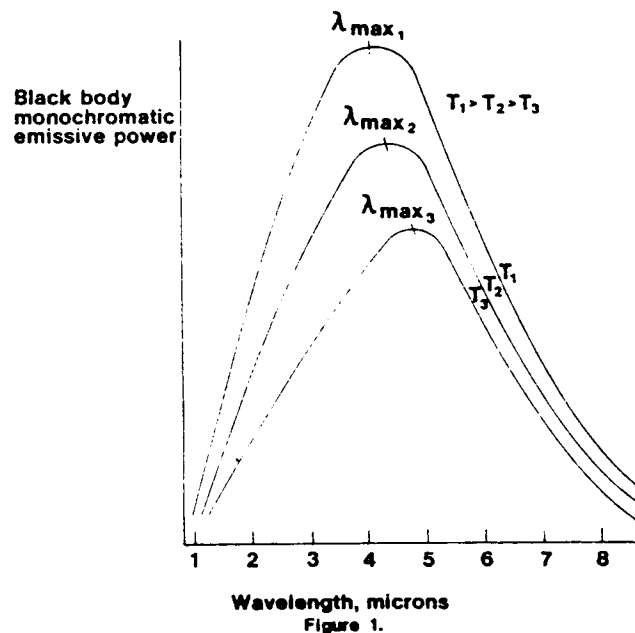


Figure 1.

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 (total emissive power $E_b(0-\infty)$) 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:

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

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

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

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

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

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

where:

$\lambda_{\max}$ is the wavelength of maximum emissivity in microns;

T is the absolute temperature in $^{\circ}\text{R}$ 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 $\text{Btu/hr-ft}^2\text{-}\mu\text{m}$ or $\text{Watts/cm}^2\text{-}\mu\text{m}$;

$E_{b(0-\lambda)}$ 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 .

$$c_1 = 1.8887982 \times 10^7 \text{ Btu-}\mu\text{m}^4/\text{hr-ft}^2 \\ = 5.9544 \times 10^3 \text{ W}\mu\text{m}^4/\text{cm}^2$$

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

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

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

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

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 $\geq$ 009)

Display:

[USER]

(set USER mode)

[XEQ] [ALPHA] BB [ALPHA]

UNITS?

SI [R/S]

TEMP?

2400 [R/S]

WAVELENGTH?

.4 [R/S]

SOLVE

[F]

WV LNTH 2?

.7 [R/S]

EbL-L=4.9679

[C]

EbTOT=188.094

[÷]

0.0264

100 [x]

2.6412

DISPLAY

[illegible]

Program Listings

01*LBL "BB"	Initialize and prompt for units	47 RCL 06	Calculate $T(\lambda_{\max})$
02 CLRG		48 /	
03 CF 22		49 "TEMP="	
04 "UNITS?"		50 ARCL X	
05 AON		51 PROMPT	
06 PROMPT		52*LBL C	Calculate E_b total
07 AOFF		53 RCL 05	
08 ASTO X		54 X↑2	
09 GTO IND		55 X↑2	
X		56 RCL 04	
10*LBL "SI"	Store units	57 *	
11 5954.4		58 "EbTOT="	
12 STO 01		59 ARCL X	
13 14388		60 PROMPT	
14 STO 02		61*LBL D	Calculate $E_{b\lambda}$
15 2897.8		62 RCL 01	
16 STO 03		63 ENTER↑	
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 $E_b(0-\lambda)$
34 PROMPT		84 0	
35 STO 06		85 STO 08	
36 "SOLVE"		86 STO 07	
37 PROMPT		87*LBL 01	
38*LBL A	Calculate $\lambda_{\max}$	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		2?"	
100 X↑2		150 PROMPT	
101 /		151 ENTER↑	
102 LASTX		152 ENTER↑	
103 1/X		153 SF 00	
104 RCL 06		154 XEQ E	
105 /		155 X<>Y	
106 -		156 RCL 06	
107 6		157 STO 00	
108 RCL 06		158 RDN	
109 /		159 STO 06	
110 RCL 08		160 SF 00	
111 X↑2		161 XEQ E	
112 /		162 -	
113 -		163 ABS	
114 6		164 RCL 00	
115 RCL 08		165 STO 06	
116 X↑2		166 RDN	
117 /		167 "EbL-L="	
118 RCL 08		168 ARCL X	
119 /		169 PROMPT	
120 +		170 .END.	
121 RCL 08			
122 RCL 06			
123 /			
124 E↑X			
125 *			
126 RCL 08			
127 /			
128 ST+ 07	80		
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			
148 LBL F	Calculate		
	$E_b(\lambda_1 - \lambda_2)$	00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS⁷

DATA REGISTERS				STATUS			
00	λ	50		SIZE 009	TOT. REG. 57	USER MODE	
	C_1			ENG	FIX 4	SCI	ON X OFF
	C_2			DEG	RAD	GRAD	
	C_3			FLAGS			
	σ						
05	T	55		#	INIT S/C	SET INDICATES	CLEAR INDICATES
	λ, λ'			00		Used	
	sum			22		Used	
	kc_2/T						
10		60					
15		65					
20		70					
25		75					
30		80					
35		85					
				ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
40		90					
45		95					

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

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

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

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

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

[XEQ] [ALPHA] HOLE [ALPHA]

ENTER KNOWN

1.99 [EEX] 33 [D]

MASS=1.9900E33

[B]

TEMP=5.0251E-8

[A]

RAD=295,512.3832

[C]

LIFE=7.8806E71

9

SIZE: 004

[illegible]

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 GTD 00 09 RCL 03 10♦LBL 04 11 "MASS=" 12 ARCL X 13 AVIEW 14 RTN 15♦LBL 00 16 STO 03 17 GTD 04 18♦LBL A 19 FS?C 22 20 GTD 01 21 1.484986 85 E-28 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 34 E27 33 * 34 STO 03 35 RCL 00 36 GTD 05 37♦LBL B 38 FS?C 22 39 GTD 02 40 1 E26 41 RCL 03 42 / 43 STO 01 44♦LBL 06 45 "TEMP=" 46 ARCL X 47 AVIEW </pre>	Store and calculate mass	<pre> 48 RTN 49♦LBL 02 50 STO 01 51 1 E26 52 X<>Y 53 / 54 STO 03 55 RCL 01 56 GTD 06 57♦LBL C 58 FS?C 22 59 GTD 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 GTD 07 81 .END. </pre>	Store and calculate Lifetime
	Store and calculate radius		
	Store and calculate temperature	90	
		00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS¹¹

[illegible]

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 KNOWN

.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 KNOWN

0.9000

1.1723

M=0.5110

P=1.0551

Program Listings

15

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

Program Listings

101 RTN	Select output routine	149 RCL 04	
102 FS?C 01		150 GTO d	
103 GTO 10		151*LBL 06	
104 FS?C 02		152 RCL 02	
105 GTO 11	Velocity output	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	Rest mass output	157 RTN	
110*LBL 10		158*LBL 09	
111 CF 01		159 RCL 02	
112 "V="		160*LBL d	
113 ARCL X	Energy output	161 XEQ c	
114 PROMPT		162 RCL 03	
115*LBL 11		163 GTO 02	
116 CF 02		164*LBL 15	
117 "M="	Momentum output	165 SF 05	
118 ARCL X		166 GTO 03	
119 PROMPT		167 .END.	
120*LBL 12			
121 CF 03	Indirect storage routine	70	
122 "E="			
123 ARCL X			
124 PROMPT			
125*LBL 13			
126 CF 04			
127 "P="			
128 ARCL X			
129 PROMPT			
130*LBL 00			
131 STO 00		80	
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			
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, ASSIGNMENTS¹⁷

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

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:

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

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

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

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

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

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

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]

[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

Program Listings

21

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

Program Listings

95 PROMPT 96 FS? 00 97 GTO D 98 "Y="		146 GTO IND 12 147♦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	correct no. of dimensions
100 PROMPT 101 FS? 01 102 GTO D 103 "X="	Calculate $ \beta $ and γ	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	Calculate $\sum \beta^i x^i$
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 R↑ 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.="	Store x^u		Compute $c\Delta\tau$
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	Set flags for		

Program Listings

23

196	SQRT	51	
197	FS?C 04		
198	CHS		
199	"cdT="		
200	ARCL X		
201	AVIEW		
202	RTN		
203	.END.		
10		60	
20		70	
30		80	
40		90	
50		00	

²⁴REGISTERS, STATUS, FLAGS, ASSIGNMENTS

[illegible]

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

[illegible]

Program Listings

01♦LBL "TWI N"	Initialization	50 2.9979 E 8	60
02 CF 22	Velocity	51 /	
03 SF 27		52 X↑2	
04 "READY"		53 -	
05 AVIEW		54 SQR T	
06 RTN		55 RTN	
07♦LBL A		56 .END.	
08 FS?C 22			
09 GTO 00			
10 1			
11 RCL 01			
12 RCL 02			
13 /			
14 X↑2			
15 -			
16 SQR T			
17 2.9979 E			
8			
18 *			
19♦LBL 00			70
20 STO 00			
21 "V="			
22 GTO 02			
23♦LBL B			
24 FS?C 22	Ship time		
25 GTO 00			
26 XEQ 01			
27 RCL 02			
28 *			
29♦LBL 00			80
30 STO 01			
31 "TS="			
32 GTO 02			
33♦LBL C			
34 FS?C 22	Earth time		
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			
48 1	Lorentz trans- form		
49 RCL 00			00

29

DATA REGISTERS				STATUS			
00	V	50		SIZE	003	TOT. REG. 18	USER MODE
	TS			ENG		FIX 4	SCI ON OFF
	TE			DEG		RAD	GRAD
				FLAGS			
05		55		#	INIT S/C	SET INDICATES	CLEAR INDICATES
10		60					
15		65					
20		70					
25		75					
30		80					
35		85					
				ASSIGNMENTS			
40		90		FUNCTION	KEY	FUNCTION	KEY
45		95					

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:

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

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

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

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

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

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

Given θ_{new} :

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

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

For change in velocity:

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

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

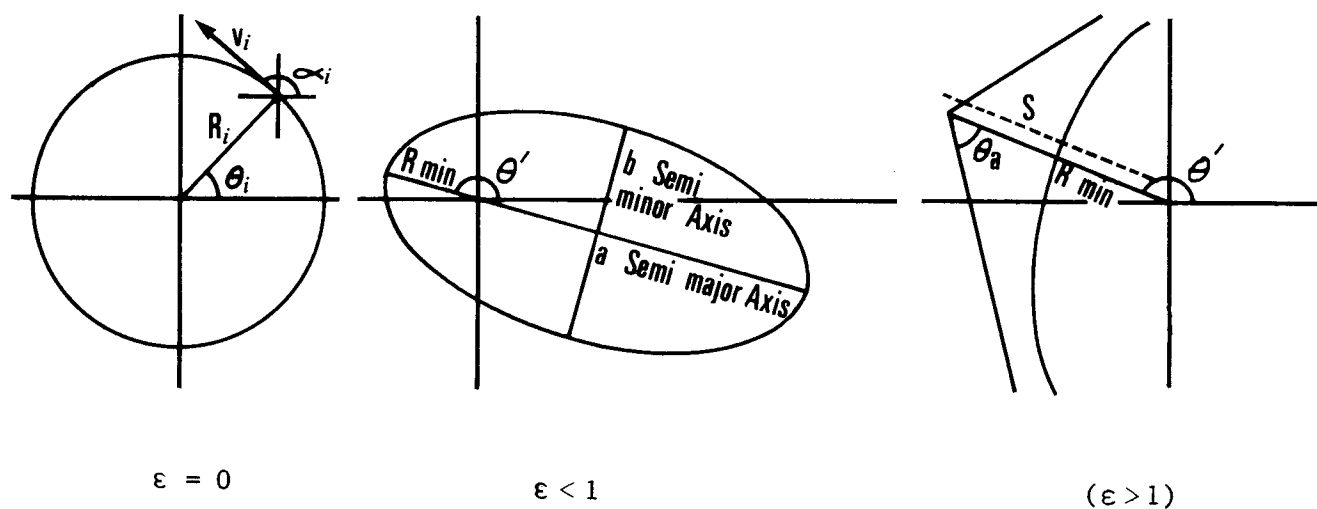
$$R_o = \frac{\ell^2}{Gm}$$

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

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

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

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



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 ($6.400 \times 10^6 \text{m}$ 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.

$$R_{init} = 7.1E6m, \theta_{init} = 0^\circ, V_{init} = 7.4E3 \text{ m/s}, V_{\Delta} = 90^\circ$$

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 011	
[XEQ] [ALPHA] ORBIT [ALPHA]	MASS ?
5.979 [EEX] 24 [R/S]	INIT. R ?
7.1 [EEX] 6 [R/S]	INIT. Δ ?
0 [R/S]	INIT. V ?
7.4 [EEX] 3 [R/S]	INIT. V_{Δ} ?
90 [R/S]	R=7100000.00
90 [ENTER↑]	
2300 [D]	R=7100000.000
[B]	E=0.6743
[R/S]	ΔP =359.9976
359.9976 [ENTER↑]	
180 [+] [C]	R=36501420.27
[R/S]	Δ =179.9976
[R/S]	V=1886.7759
[R/S]	V_{Δ} =270.0009
270.0009 [ENTER↑]	
1450 [D]	R=36501420.27
[R/S]	Δ =179.9976
[R/S]	V=3336.7759
[R/S]	V_{Δ} =270.0009
[B]	E=0.0186
[R/S]	ΔP =180.1643
[R/S]	RMIN=36501417.46
[R/S]	ELLIPSE
[R/S]	A=37192989.78
[R/S]	B=37186559.62
[R/S]	T=19.8193

User Instructions

33

				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. V Δ ?
7	Key in the initial angle of velocity.	$\theta_{V_{init}}$	[R/S]	
8	Output current position.			R=
			[R/S]	$\Delta = (\theta)$
			[R/S]	V=
			[R/S]	V $\Delta = (\alpha)$
9	To output orbit geometry:		[B]	E=
				$\Delta_P = (\theta')$
				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=
				$\Delta_A = (\theta_a)$
10	To move to a new position in the old orbit,	θ_{new}	[C]	R=

Program Listings

35

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

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	v_{new}
108 RCL 05	parabola	157 RCL 07	
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 R↑	
128 ACOS		179♦LBL 00	
129 "∠A="		180 RDN	
130 ARCL X		181 RCL 01	
131 AVIEW		182 +	
132 STOP		183 XEQ 50	
133 GTO B	-----	184 STO 03	α_{new}
134♦LBL C	Move to new θ	185 GTO 09	
135 XEQ 50		186♦LBL D	Change velocity
136 STO 01		187 P-R	
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

37

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

[illegible]

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)

41

DISPLAY

[illegible]

Program Listings

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

Program Listings

43

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

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

REGISTERS, STATUS, FLAGS, ASSIGNMENTS⁴⁵

DATA REGISTERS				STATUS			
00	t	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			
				FUNCTION	KEY	FUNCTION	KEY
40		90					
45		95					

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.

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

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.

Sample#	A	B
1	1,000	500
2	2,000	1,000
3	1,400	2,200

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 011
 [XEQ] [ALPHA] IOC [ALPHA]
 2 [R/S]
 .2 [R/S]
 10 [R/S]
 .1 [R/S]
 50 [R/S]
 1,000 [R/S]
 500 [R/S]
 [R/S]
 [R/S]
 [R/S]
 2,000 [R/S]
 1,000 [R/S]
 [R/S]
 [R/S]
 [R/S]
 1,400 [R/S]
 2,200 [R/S]
 [R/S]
 [R/S]
 [R/S]
 [R/S]
 [R/S]

Display:

ISOTOPES?
 SPLOVER B-A?
 BKA?
 SPLOVER A-B?
 BKB?
 CPM A?
 CPM B?
 TX=1,010.
 TY=430.
 NEXT=2
 CPM A?
 CPM B?
 TX=2,020
 TY=920
 NEXT=3
 CPM A?
 CPM B?
 TX=1,078
 TY=2,462
 NEXT=4
 CPM A?
 TOT. TX=4,108
 TOT. TY=3,812

(Pressing [R/S]
 with no input
 displays totals
 and resets for
 new case)

(cont'd.)

Program Listings

98 RCL 10		51	
99 "NEXT= "			
100 ARCL X			
101 AVIEW			
102 STOP			
103 ADV			
104 ISG 10			
105 RCL 10			
106 GTO 00			
107♦LBL "TOT			
"	Display totals	60	
108 RCL 06	and return to		
109 "TOT. TX	Label IOC		
=			
110 ARCL X			
111 AVIEW			
112 STOP			
113 FC? 00			
114 RTN			
115 RCL 08			
116 "TOT. TY		70	
=			
117 ARCL X			
118 AVIEW			
119 STOP			
120 0			
121 STO 10			
122 GTO "IOC			
"			
123♦LBL D	Store BKA		
124 STO 00		80	
125 RDN			
126 STO 01			
127 RTN			
128♦LBL E	Store BKB		
129 STO 02			
130 RDN			
131 STO 03			
132 RTN			
133 .END.			
		90	
50		00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS⁵

DATA REGISTERS				STATUS			
00	BA	50		SIZE 011	TOT. REG. 50	USER MODE	
	a			ENG	FIX 4	SCI	ON OFF X
	BKB			DEG	RAD	GRAD	
	b						
	CA						
05	CB	55					
	ΣCX						
	CX						
	ΣCY						
	CY						
10	sample number	60					
15		65					
20		70					
25		75					
30		80					
35		85					
40		90					
45		95					

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

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

Weizsacker's Semi-Empirical mass formula contains seven terms

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

$$E_v = -a_1 * A$$

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

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

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

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

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

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]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[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

Program Listings

55

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

Program Listings

57

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	



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:

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

$$\begin{aligned} (-1)^{j_1 - j_2 + M} & \sqrt{\Delta(j_1 j_2 J)} \sqrt{(j_1 + m_1)! (j_1 - m_1)! (j_2 + m_2)! (j_2 - m_2)! (J + M)! (J - M)!} \\ & \cdot \sum_t (-1)^t \left[t! (J - j_2 + t + m_1)! (J - j_1 + t - m_2)! (j_1 + j_2 - J - t)! \right. \\ & \left. \cdot (j_1 - t - m_1)! (j_2 - t + m_2)! \right]^{-1} \end{aligned}$$

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

subject to the restraints 1) $|j_1 - j_2| \leq J \leq |j_1 + j_2|$

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

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

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:

Display:

[XEQ] ALPHA] SIZE [ALPHA] 018

[XEQ] [ALPHA] CGC [ALPHA]

J1=?

1.5 [R/S]

J2=?

2 [R/S]

J=?

2.5 [R/S]

M1=?

.5 [R/S]

M2=?

0 [R/S]

M=?

.5 [R/S]

C.G.=2.9277 E-1

[R/S]

3J=1.1952 E-1

User Instructions

61

[illegible]

Program Listings

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

Program Listings

63

102 *	Computes summation in Racah Formula	153 -	Checks to see if Σ finished t
103 *		154 X<0?	
104 STO 13		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	Computes Clebsch-Gordon Coefficient	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	
140 +		191 ST+ 14	
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	
147 FACT		198 -1	
148 STO 06		199 RCL 01	
149 RCL 01		200 RCL 17	
150 RCL 14		201 -	
151 RCL 15		202 RCL 02	
152 +		203 -	

Program Listings

204	Y↑X		51	
205	RCL 03			
206	2			
207	*			
208	1			
209	+			
210	SQRT			
211	*			
212	RCL 00			
213	*			
214	"C.G.="		60	
215	ARCL X			
216	AVIEW			
217	STOP			
218	"3J="			
219	ARCL 00			
220	AVIEW			
221	RTN			
222	.END.			
20			70	
30			80	
40			90	
50			00	

65

•

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

69

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

REGISTERS, STATUS, FLAGS, ASSIGNMENTS⁷¹

[illegible]

Hewlett-Packard Software

In terms of power and flexibility, the problem-solving potential of the HP-41C 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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Calendars
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* Some books require additional memory modules to accomodate all programs.

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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



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