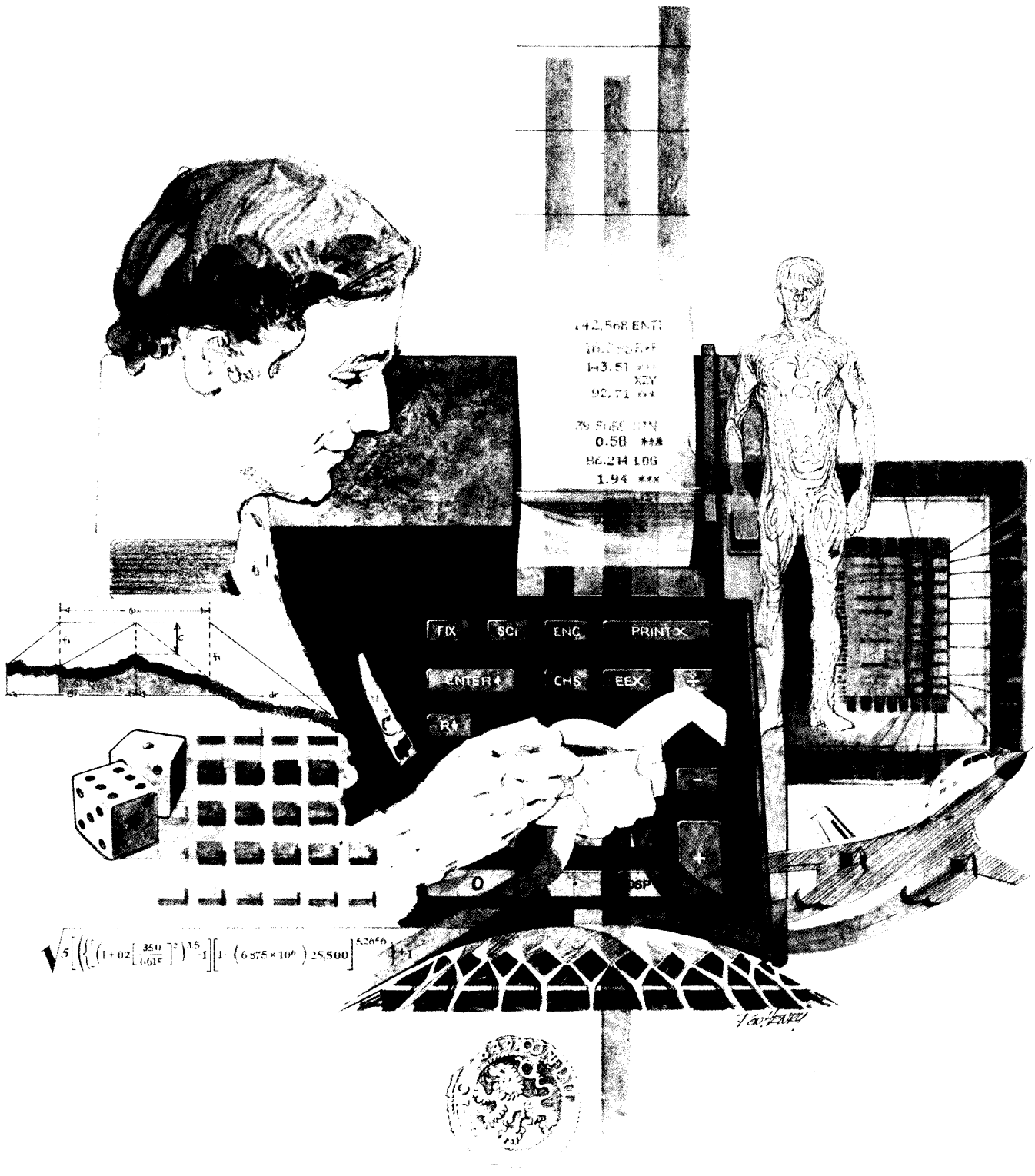


HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions
Physics



INTRODUCTION

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

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

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

A WORD ABOUT PROGRAM USAGE

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

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

The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.

REMEMBER! To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

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

TABLE OF CONTENTS

BLACK BODY THERMAL RADIATION	1
Calculates the wavelength of maximum emissive power for a given temperature.	
BLACK HOLE CHARACTERISTICS	9
Computes temperature, Schwarzschild radius, and lifetime of a black hole.	
SPECIAL RELATIVITY CONVERSIONS	13
Provides relativistic conversions between rest mass, velocity, energy, and momentum.	
THREE DIMENSIONAL SPECIAL RELATIVITY.	17
Computes intervals, dilation factors, and Lorentz transformations.	
EINSTEIN'S TWIN PARADOX	22
Calculate real and relative time and age differential based on the Lorentz transform.	
DELTA-V--ORBIT SIMULATOR	27
Computes orbit parameters from initial position and velocity data.	
EQUATIONS OF PARTICLE MOTION	32
Compute two unknown values based on the known values of the variables distance, time, V-final, V-initial, and acceleration.	
BALLISTICS TRAJECTORY COMPUTATIONS	37
Computes range, velocity, energy, time of flight, rise, and drop of a bullet.	
ISOTOPE OVERLAP CORRECTIONS	48
Corrects for spillover between channels in a liquid scintillation spectrometer.	
CRITICAL REACTOR CODE	52
Estimates the parameters of a reactor	
SEMI-EMPIRICAL NUCLEAR MASS FORMULA	59
Calculates approximate binding energies and mass excess for any nucleus.	
CLEBSCH-GORDON COEFFICIENTS AND $3J$ SYMBOLS EVALUATION	64
Uses Racah formula to evaluate coupling two states of angular momentum.	
32-P REMAINING ON MM,DDYYYY GIVEN MCI ON EARLIER MM,DDYYYY.	69
Given millicuries of 32-P on date 1, this program calculates the decays per minute and counts per minute on date 2 as well as the number of days between date 1 and date 2.	

Program Description I

1

Program Title Black Body Thermal Radiation

Contributor's Name Hewlett-Packard

Address 1000 N. E. Circle Blvd.

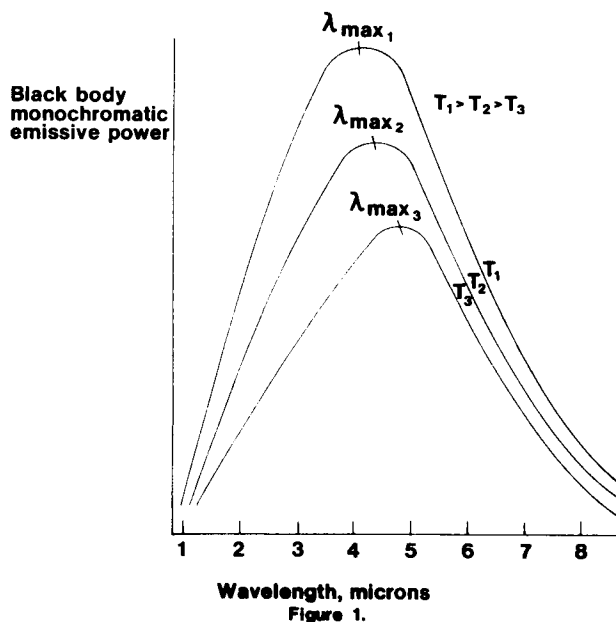
City Corvallis

State Oregon

Zip Code 97330

Program Description, Equations, Variables

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



(continued next page)

Operating Limits and Warnings

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

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

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

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 $\lambda_{\max}$ 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 .

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

$$= 5.9544 \times 10^3 \text{ W}\mu\text{m}^4/\text{cm}^2$$

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

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

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

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

Program Description II

Sketch(es)

Sample Problem(s) Example 1:

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

Keystrokes:

Outputs:

[f] [B]-----	→	$5.669 \times 10^{-12} \text{ W/cm}^2\text{-K}^4$
2400 [A] .4 [B] .7 [f] [E] [C] [÷] 100 [x]-----	→	2.641%
2500 [A] .7 [f] [E] [C] [÷] 100 [x]-----	→	3.337%

Example 2:

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

Keystrokes:

Outputs:

[f] [A]-----	→	$1.713 \times 10^{-9} \text{ Btu/hr-ft}^2\text{-}^\circ\text{R}^4$
Compute mean of visible range.		
.4 [+] .7 [+] 2 [÷]-----	→	$550.0 \times 10^{-3} \mu\text{m}$
Compute temperature of sun.		
[B]-----	→	$9.484 \times 10^3 \text{ }^\circ\text{R}$
(continued)		

Reference(s)

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

Compute percentage of power in visible range.

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

Compute percentage of power under 0.4 microns.

[E] [C] [÷] 100 [x]-----→ **8.433%**

User Instructions

Black Body Thermal Radiation

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

[illegible]

97Program Listing I

7

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLc	21 16 11	Store English constants.	057	.	05	Convert to experimental σ .
002	1	01		058	.	-62	
003	8	08		059	6	06	
004	8	08		060	6	06	
005	8	08		061	9	09	
006	7	07		062	3	03	
007	9	09		063	EEX	-23	
008	8	08		064	CHS	-22	
009	2	02		065	1	01	
010	ST01	35 01		066	2	02	
011	2	02		067	ST04	35 04	
012	5	05		068	RTN	24	
013	8	08		069	*LBLc	21 16 13	
014	9	09		070	1	01	
015	8	08		071	.	-62	
016	.	-62		072	0	00	
017	4	04		073	1	01	
018	ST02	35 02	Store T and calculate $\lambda_{\max}$.	074	0	00	Store λ and calculate T for which λ would be $\lambda_{\max}$.
019	5	05		075	5	05	
020	2	02		076	STX4	35-35 04	
021	1	01		077	RCL4	36 04	
022	6	06		078	RTN	24	
023	ST03	35 03		079	*LBLA	21 11	
024	.	-62		080	ST05	35 05	
025	1	01		081	RCL3	36 03	
026	7	07		082	X $\div$ Y	-41	
027	1	01		083	$\div$	-24	
028	3	03		084	RTN	24	
029	1	01		085	*LBLB	21 12	
030	2	02		086	ST06	35 06	
031	EEX	-23		087	RCL3	36 03	
032	CHS	-22		088	X $\div$ Y	-41	
033	8	08	Store SI constants.	089	$\div$	-24	Calculate $E_{b(0-\infty)}$.
034	ST04	35 04		090	RTN	24	
035	RTN	24		091	*LBLC	21 13	
036	*LBLb	21 16 12		092	RCL5	36 05	
037	5	05		093	Y $\div$	53	
038	9	09		094	X $\div$	53	
039	5	05		095	RCL4	36 04	
040	4	04		096	X	-35	
041	.	-62		097	RTN	24	
042	4	04		098	*LBLD	21 14	
043	ST01	35 01		099	RCL1	36 01	
044	1	01		100	ENT1	-21	
045	4	04		101	+	-55	
046	3	03		102	Pi	16-24	
047	8	08		103	X	-35	
048	8	08		104	RCL6	36 06	
049	ST02	35 02		105	5	05	Calculate $E_{b\lambda}$.
050	2	02		106	Y $\times$	31	
051	8	08		107	$\div$	-24	
052	9	09		108	RCL2	36 02	
053	7	07		109	RCL6	36 06	
054	.	-62		110	$\div$	-24	
055	8	08		111	RCL5	36 05	
056	ST03	35 03		112	$\div$	-24	

REGISTERS

REGISTERS									
0	1	2	3	4	5	6	7	8	9
λ	c_1	c_2	c_3	σ	T	λ, λ'	sum	kc_2/T	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A		B		C		D		I	

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	e ^x	33		169	X ² Y?	16-35	
114	1	01		170	GT01	22 01	
115	-	-45		171	R↓	-31	
116	÷	-24		172	CLX	-51	
117	RTN	24		173	RCL7	36 07	
118	*LBL E	21 15	Calculate E _{b(0-λ)} .	174	ENT↑	-21	
119	0	00		175	+	-55	
120	ST08	35 08		176	Pi	16-24	
121	ST07	35 07		177	x	-35	
122	*LBL1	21 01		178	RCL1	36 01	
123	R↓	-31		179	x	-35	
124	CLX	-51		180	RTN	24	
125	RCL8	36 08		181	*LBL e	21 16 15	Calculate E _{b(λ-λ')} .
126	RCL2	36 02		182	ENT↑	-21	
127	RCL5	36 05		183	ENT↑	-21	
128	÷	-24		184	GSBE	23 15	
129	-	-45		185	X ² Y	-41	
130	ST08	35 08		186	RCL6	36 06	
131	3	03		187	ST00	35 00	
132	X ² Y	-41		188	R↓	-31	
133	÷	-24		189	ST06	35 06	
134	RCL6	36 06		190	GSBE	23 15	
135	X ²	53		191	-	-45	
136	÷	-24		192	ABS	16 31	
137	LSTX	16-63		193	RCL0	36 00	
138	1/X	52		194	ST06	35 06	
139	RCL6	36 06		195	R↓	-31	
140	÷	-24		196	RTN	24	
141	-	-45					
142	6	06					
143	RCL6	36 06					
144	÷	-24		200			
145	RCL8	36 08					
146	X ²	53					
147	÷	-24					
148	-	-45					
149	6	06					
150	RCL9	36 08					
151	X ²	53					
152	÷	-24					
153	RCL8	36 08					
154	÷	-24		210			
155	+	-55					
156	RCL8	36 08					
157	RCL6	36 06					
158	÷	-24					
159	e ^x	33					
160	x	-35					
161	RCL8	36 08					
162	÷	-24					
163	ST+7	35-55 07					
164	RCL7	36 07		220			
165	÷	-24					
166	EEY	-23					
167	CHS	-22					
168	5	05					

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS	TRIG	DISP
T→λ _{max}	λ→T(λ _{max})	E→E _{b(0-λ)}	D→E _{b-λ}	E→E _{b(0-λ)}	1	ON OFF		
a Eng	b SI	c Exp σ	d	e λ'→E _{b(λ-λ')}	2	0 ☐ ☒	DEG ☒	FIX ☐
0	1 E _{b(0-λ)}	2	3	4	3	1 ☐ ☒	GRAD ☐	SCI ☐
5	6	7	8	9		2 ☐ ☒	RAD ☐	ENG ☒
						3 ☐ ☒		n <u>3</u>

Program Description I

Program Title *Black Hole Characteristics*

Contributor's Name *Geoff Kidd*

Address *1514 Oxford St #301*

City *Berkeley*

State *CA*

Zip Code *94709*

Program Description, Equations, Variables

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:

$$t_L = M^3 \cdot (10^{-28}).$$

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

$$K = 10^{26}/M$$

Operating Limits and Warnings

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

This program has been verified only with respect to the numerical example given in Program Description II. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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Program Description II

Sketch(es)

Sample Problem(s)

- 1.) The sun has a mass 1.99×10^{33} gm. What would be the temperature, Schwarzschild radius, and lifetime of a black hole of that mass?
- 2.) Given a Schwarzschild radius of 6.96×10^{10} cm, what is the mass of the black hole? What is the temperature?

Solution(s) 1.) 1.99 **EEX** 33 **D** $\rightarrow 1.9900 \times 10^{33}$
A $\rightarrow 2.9551 \times 10^5$ R_s
B $\rightarrow 5.0251 \times 10^{-8}$ K
C $\rightarrow 7.8806 \times 10^{71}$ t_L

2.) 6.96 **EEX** 10 **A** $\rightarrow 6.9600 \times 10^{10}$
D $\rightarrow 4.6869 \times 10^{38}$ M
B $\rightarrow 2.1336 \times 10^{-13}$ K

Reference(s) Harwit, Martin Astrophysical Concepts Wiley, New York

11

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter program				
2.	Enter mass	M			m
	or Schwarzschild radius	R_s			R_s
	or temperature	K			K
	or lifetime	t_L			t_L
3.	Compute mass				m
	or Schwarzschild radius				R_s
	or temperature				K
	or lifetime				t_L
	For a different variable, go to 3				
	For a new case, go to 2				
	Before any computations, at				
	least one of the four variables				
	must have been entered or				
	results will be unpredictable				
	Note: a new value <u>entered</u>				
	for R_s , t_L or K causes the				
	mass stored in memory to be				
	recalculated.				

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS												
001	/LBL A	31 25 11	Schwarzschild		6	06													
	R F? 3	35 71 03	Radius		R X2y	35 52	$M = \frac{10^{26}}{R}$												
	GTO 0	22 00			÷	81													
	1	01		060	STO 3	33 03													
	.	83			RCL 1	34 01													
	4	04	$R_s =$		R RTN	35 22													
	8	08	$M =$		/LBL C	31 25 13	Lifetime												
	4	04	$1.484986855 \times 10^{-28}$		R F? 3	35 71 03													
010	8	08			GTO 0	22 00													
	6	06			EEX	43	$t_L = M^3 \cdot 10^{-28}$												
	8	08			CHS	42													
	5	05			2	02													
	5	05			8	08													
	EEX	43		070	RCL 3	34 03													
	2	02			ENT	41													
	8	08			3	03													
	CHS	42			R yx	35 63													
	RCL 3	34 03			Xy	71													
020	X	71			STO 2	33 02													
	STO 0	33 00			R RTN	35 22													
	R RTN	35 22			/LBL 0	31 25 00	Entered value												
	/LBL 0	31 25 00	Entered value of		STO 2	33 02	t_L , compute												
	STO 0	33 00	R_s , compute		EEX	43	new mass												
	6	06	new mass	080	2	02													
	.	83			8	08													
	7	07			X	71													
	3	03	$M =$		3	03	$M = \sqrt[3]{t_L \cdot 10^{28}}$												
	4	04	$R_s = 6.734066344$		R 1/x	35 62													
030	0	00	$\times 10^{27}$		R yx	35 63													
	6	06			STO 3	33 03													
	6	06			RCL 2	34 02													
	3	03			R RTN	35 22													
	4	04		090	/LBL D	31 25 14	Mass												
	4	04			R F? 3	35 71 03													
	EEX	43			GTO 0	22 00	If new value not												
	2	02			RCL 3	34 03	entered, display												
	7	07			R RTN	35 22	old. Else store												
	X	71			/LBL 0	31 25 00	value entered.												
040	STO 3	33 03			STO 3	33 03													
	RCL 0	34 00			R RTN	35 22													
	R RTN	35 22			R/S	84													
	/LBL B	31 25 12	Temperature				Flag 0-4 off												
	R F? 3	35 71 03	$K = 10^{26}/M$	100			deg mode												
	GTO 0	22 00					SCL												
	EEX	43					DSP 4												
	2	02					are initial values												
	6	06					Labels used:												
	RCL 3	34 03					A, B, C, D, O												
050	÷	81																	
	STO 1	33 01																	
	R RTN	35 22																	
	/LBL 0	31 25 00	Entered value of	110															
	STO 1	33 01	K , compute																
	EEX	43	new mass																
	2	02																	
REGISTERS																			
0	R_s	1	K	2	t_L	3	M	4		5		6		7		8		9	
S0		S1		S2		S3		S4		S5		S6		S7		S8		S9	
A		B		C		D		E		F		G		H		I		J	

Program Description I

Program Title SPECIAL RELATIVITY CONVERSIONS

Contributor's Name Ctein

Address 298 Vista Grande

City Daly City

State

Ca

Zip Code 94014

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

$$(I)-- E = m / \text{SQRT}(1-v^2) \quad // \quad (II)-- E = \text{SQRT}(P^2 + m^2) \quad // \quad (III)-- E = P/v$$

$$(IV)-- P = vE \quad // \quad (V)-- P = \text{SQRT}(E^2 - m^2) \quad // \quad (VI)-- v = P/E \quad // \quad (VII) m = \text{SQRT}(E^2 - P^2)$$

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. If insufficient data, then the program displays Error. The following selection patterns are used:

TO FIND:	v	m	E	P
GIVEN:	m, E	v, E	v, m	v, E
	use V, VI	use IV, VII	use I	use IV
	m, P	v, P	v, P	v, m
	use II, VI	use III, VII	use III	use I, IV
	E, P	E, P	m, P	m, E
	use VI	use VII	use II	use V

Because of the complexity of this program, a chart is provided on the next page which diagrams the access patterns used by each labeled subsection. Boxes are used to represent direct jumps, and circles represent subroutine calls. The user is advised to review this carefully before modifying this program.

Operating Limits and Warnings

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

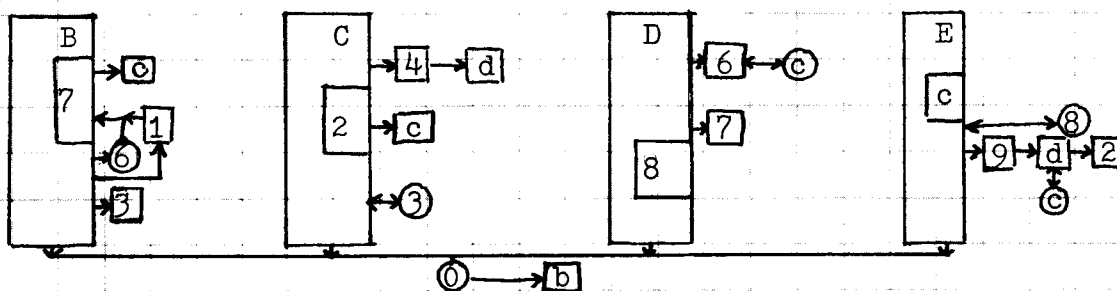
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Program Description II

Special Relativity

Sketch(es)



Sample Problem(s)

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

2) Given an E of 500 MeV and a P of 498 MeV/c, what is the particle's mass and velocity.

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

4) An electron is traveling at $.3c$. Find its momentum and energy.

Solution(s)

1) $\underline{A}$, $.511$, $\underline{C}$, 1 , $\underline{D}$, $\underline{B}$, $v = .8596c$; $\underline{E}$, $P = .8596 \text{ MeV}/c$.

2) $\underline{A}$, 500 , $\underline{D}$, 498 , $\underline{E}$, $\underline{B}$, $v = .996c$; $\underline{C}$, $m = 44.6766 \text{ MeV}$

3) $\underline{A}$, $.9$, $\underline{B}$, 1.1723 , $\underline{D}$, $\underline{C}$, $m = .511 \text{ MeV}$; $\underline{E}$, $P = 1.0551 \text{ MeV}/c$

4) $\underline{A}$, $.3$, $\underline{B}$, $.511$, $\underline{C}$, $\underline{D}$, $E = .5357 \text{ MeV}$; $\underline{E}$, $P = .1607 \text{ MeV}/c$

Reference(s) — HP-65 library program #308 by this author.

15

[illegible]

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL A	31 25 11	RESET		*LBL 8	31 25 08	v in X
	CL REG	31 43			x←y	35 52	
	CF 3	35 61 03			asin	32 62	SQRT(1-v ²)
	R/S	84		060	cos	31 63	
	*LBL B	31 25 12	FIND/STORE v		/	81	eq.I gives E
	1	01			RTN	35 22	
	GSB 0	31 22 00	store new v		*LBL E	31 25 15	FIND/STORE P
	RCL 2	34 02	m		4	04	
	x=0?	31 51	if m is unknown		GSB 0	31 22 00	store new P
010	GTO 1	22 01	then go to 1		x=0?	31 51	if v is unknown
	RCL 3	34 03	E		GTO 9	22 09	then go to 9.
	x≠0?	31 61	if E,m are known		RCL 2	34 02	if m,v known,
	GTO 3	22 03	then go to 3		x≠0?	31 61	then eq.I gives
	GSB 6	31 22 06	eq.II gives E	070	GSB 8	31 22 08	E.
	ENTER	41			RCL 3	34 03	If R ₂ contains
	*LBL 7	31 25 07			x=0?	31 51	E(i.e.≠0), then
	R ↓	35 53			R ↓	35 53	this takes prior-
	RCL 4	34 04	P		RCL 1	34 01	ity.
	x←y	35 52	E		x	71	eq.IV gives P
020	/	81	eq. VI gives v		*LBL c	32 25 13	if variable or
	GTO c	22 31 13	check out P		x=0?	31 51	result is not
	*LBL C	31 25 13	FIND/STORE m		/	81	legitimate,end.
	2	02		080	RTN	35 22	check/store 'x'
	GSB 0	31 22 00	store new m		*LBL 0	31 25 00	store (i)
	x=0?	31 51	if v is unknown		ST I	35 33	if data has been
	GTO 4	22 04	then go to 4		F? 3	35 71 03	entered,go to b
	RCL 3	34 03	E		GTO b	22 31 12	check contents
	x	71	eq.IV gives P		RCL(i)	34 24	of register 'x'
	LST x	35 82	E		x≠0?	31 61	and display if
030	x≠0?	31 61	if E is known,		R/S	84	good. Otherwise
	GTO 2	22 02	go to 2		RCL 1	34 01	RCL v and return
	RCL 4	34 04	P		RTN	35 22	STORE NEW "x"
	ENTER	41		090	*LBL b	32 25 12	in register defi-
	ENTER	41			R ↓	35 53	ned by (i)
	RCL 1	34 01	v		STO(i)	33 24	
	/	81	eq.III gives E		R/S	84	
	*LBL 2	31 25 02	eq. V or VII		*LBL 1	31 25 01	FIND v;m UNKNOWN
	ENTER	41			RCL 3	34 03	E
	R ↓	35 53			ENTER	41	eq.VI gives v
040	GSB 3	31 22 03	SQRT(x ² -y ²)		GTO 7	22 07	FIND m;v UNKNOWN
	R ↑	35 54			*LBL 4	31 25 04	P
	x	71	eq.VII gives m		RCL 4	34 04	go to d
	GTO c	22 31 13	check for valid		GTO d	22 31 14	EQ. II
	*LBL 3	31 25 03	results	100	*LBL 6	31 25 06	m
	/	81	find		RCL 2	34 02	check validity
	asin	32 62	SQRT(1-y ² /x ²)		GSB c	32 22 13	P
	cos	31 63			RCL 4	34 04	check validity
	RTN	35 22			GSB c	32 22 13	E=SQRT(m ² +p ²)
	*LBL D	31 25 14	FIND/STORE E		R→P	32 72	
050	3	03			RTN	35 22	FIND P:v UNKNOWN
	GSB 0	31 22 00	store new E		*LBL 9	31 25 09	m
	x=0?	31 51	if v is unknown		RCL 2	34 02	check validity
	GTO 6	22 06	then go to 6.	110	*LBL d	32 25 14	E
	RCL 2	34 02	if m is unknown		GSB c	32 22 13	eq.V or VII
	x=0?	31 51	then go to 7.		RCL 3	34 03	
	GTO 7	22 07			GTO 2	22 02	

REGISTERS

0	velocity ²	mass	energy	momentum	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I	used			

Program Description I

Program Title Three Dimensional Special Relativity

Contributor's Name William C. Wickes

Address Princeton University, Department of Physics

City Princeton

State N.J.

Zip Code 08540

Program Description, Equations, Variables

- Given the components of any 4-vector, in particular $x'^{\mu} = (x', y', z', ct')$ or $p'^{\mu} = (p'^x, p'^y, p'^z, E')$, calculate the components x^{μ} or p^{μ} in a frame in which the original frame^C is moving with velocity $\vec{\beta} = (\beta^x, \beta^y, \beta^z)$.
 $\vec{p}$ = momentum
 E = total energy
 $\vec{\beta} = \vec{v}/c$ $\vec{v}$ = velocity
- For any $\vec{\beta}$, calculate the time-dilation/length contraction factor γ .
- For a 4-vector Δx^{μ} connecting any two space-time events, calculate the invariant interval $c\Delta\tau$.

Formulae:

$$\begin{aligned}\Delta\vec{x} &= \Delta\vec{x}' + \vec{\beta}[(\gamma-1)\frac{\vec{\beta}\cdot\vec{x}'}{\beta^2} + \gamma c\Delta t'] \\ \Delta t &= \gamma(t + \vec{\beta}\cdot\vec{x}/c^2) \\ \gamma &= [1-\beta^2]^{-1/2}\end{aligned}$$

$$\begin{aligned}\beta &= |\vec{\beta}| = [\beta^x^2 + \beta^y^2 + \beta^z^2]^{1/2} \\ |\Delta\vec{x}| &= [\Delta x^2 + \Delta y^2 + \Delta z^2]^{1/2} \\ c^2\Delta\tau^2 &= c^2\Delta t^2 - |\Delta\vec{x}|^2\end{aligned}$$

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

Operating Limits and Warnings
display " - |c\Delta\tau|"

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

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19

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Set number space dimensions N (default is N=3)	1,2,or 3		E	N
2.	Enter $\vec{\beta}$ (if N=3) (if N>1)	β^x β^y β^z			
3.	Enter x^μ (if N=3) (if N>1)	x y z ct			β^{***} γ
4.	Compute x^μ		C		x^{***} (if N=3) y^{***} (if N>1) z^{***} ct
5.	Compute $c\Delta\tau$ Result is positive if $c\Delta\tau$ negative if $c\Delta\tau$		D		$\pm c\Delta\tau $
6.	To calculate the speed β corresponding to a dilation factor γ	γ	f	A	β

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBL D	31 25 14			LST X	35 82	
	RCL 6	34 06			STO 1	33 01	
	F? 0	35 71 00			X $\div$ Y	35 52	
	GTO 4	22 04		060	F? 1	35 71 01	
	RCL 4	34 04			GTO 6	22 06	
	R $\rightarrow$ P	32 72			R $\uparrow$	35 54	
	F? 1	35 71 01	Compute $\sum x_i^2$		STO 2	33 02	
	GTO 4	22 04			R $\rightarrow$ P	32 72	$1/\beta$
	RCL 5	34 05			LBL 6	31 25 06	
010	R $\rightarrow$ P	32 72			STO A	33 11	
	LBL 4	31 25 04			COS $^{-1}$	32 63	$\sqrt{1-\beta^2}$
	X 2	32 54			SIN	31 62	
	RCL 7	34 07			1/X	35 62	
	X 2	32 54		070	STO B	33 12	γ
	-	51	$c^2 - x^2$		RCL A	34 11	
	CHS	42			-X-	31 84	DISPLAY β
	X < 0	31 71			X $\div$ Y	35 52	
	SFO	35 51 02	SPACE LIKE?		RTN	35 22	
	ABS	35 64	SFO		LBL B	31 25 12	
020	$\sqrt{x}$	31 54			STO 7	33 07	
	F? 2	35 71 02			R $\downarrow$	35 53	
	CHS	42	- for SPACE LIKE		STO 6	33 06	
	RTN	35 22			R $\downarrow$	35 53	STO β
	LBL Q	32 25 11	Calculate β	080	STO 4	33 04	
	STO B	33 12	from γ		R $\downarrow$	35 53	
	X 2	32 54			STO 5	33 05	
	1/X	35 62			RTN	35 22	
	1	01			LBL C	31 25 13	$x' \rightarrow x''$
	-	51			GSB E	32 22 15	$\beta \cdot x'$
030	CHS	42			RCL A	34 11	
	$\sqrt{x}$	31 54			X 2	32 54	
	STO A	33 11			$\div$	81	
	RTN	35 22			RCL B	34 12	
	LBL E	32 25 15		090	1	01	
	RCL 6	34 06	Compute $\beta \cdot x'$		-	51	
	RCL 3	34 03			X	71	
	X	71	$= \sum \beta^i x_i^i$		RCL B	34 12	
	F? 3	35 71 00			RCL 7	34 07	
	RTN	35 22			X	71	
040	RCL 1	34 01			$\div$	61	
	RCL 4	34 04			STO C	33 13	
	X	71			3	03	
	$\div$	61			STO 0	33 00	USE R0 AS COUNTER
	F? 1	35 71 01		100	ST I	35 33	
	RTN	35 22			LBL 0	31 25 00	compute one
	RCL 2	34 02			RCL 0	34 00	component each
	RCL 5	34 05			ST I	35 33	cycle
	X	71			RCL C	34 13	
	$\div$	61			RCL (1)	34 24	
050	RTN	35 22			X	71	
	LBL A	31 25 11	Compute γ		RCL I	35 34	
	STO 3	33 03			3	03	
	F? 0	35 71 00			$\div$	61	
	GTO 6	22 06		110	ST I	35 33	
	X $\div$ Y	35 52			CLX	44	
	R $\rightarrow$ P	32 72			RCL (1)	34 24	

REGISTERS

0 Counter	1 β^2	2 β^2	3 β^2	4 γ	5 X	6 β	7 CT	8	9
S0	S1	S2	S3	S4 γ'	S5 X'	S6 β'	S7 CT'	S8	S9
A β	B γ	C	D	E	I USED				

67 Program Listing II

21

[illegible]

Program Description I

Program Title Einsteins Twin Paradox

Contributor's Name David M. Weingold

Address % Synergy Research P.O. Box 372

City Woodmere

State N.Y.

Zip Code 11598

Program Description, Equations, Variables

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. If you imagine twins at age 21. One becomes an astronaut and volunteers for the first interstellar flight. He takes off and travels at a ponderous speed of say 2.994444444×10^8 meters per second. In this situation it is accurate enough to call C the speed of light, 3×10^8 . The astronaut travels for what he measures to be a year well past the sun 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 37 years old! That over 16 years had passed on Earth. The explanation as to why this happened involves very complicated non Euclidian geometry and relativistic considerations of accelerating frame of reference too complicated for this discussion, it suffices to say that in the event of tremendous accelerations such as the turning around of a space craft traveling near the speed of light that the order of magnitude of energy involved is extremely large and the consideration of it as it interrelates to space as time is conceived as a fourth physical

Operating Limits and Warnings

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Program Description I

Program Title Einsteins Twin Paradox

Contributor's Name David M. Weingold

Address % Synergy Research P.O. Box 372

City Woodmere

State New York

Zip Code 11598

Program Description, Equations, Variables

dimension of space, the Universe is then conceived as a giant four dimensional sphere with a three dimensional surface. The space craft in its turning travels relative to the Earth, not as far along that fourth dimension and hence the differential between the twins age. The equations for this case are quite simple and adequate for this case. They consist primarily of the Lorentz transform i.e., $\sqrt{1 - \frac{v^2}{c^2}}$, where v is the velocity of the space craft relative to the Earth, and c is the universal constant, 3×10^8 meters per second, the speed of light. The program inputs consist of speed of space craft in meters per second, time passed on Earth, time passed on board the craft, and the ages of the twins before the flights. With input T_E , time passed on Earth, the equation $T_S = T_E \sqrt{1 - \frac{v^2}{c^2}}$ gives T_S , ["time passed on board"] ship during journey. Input T_S , time passed on board ship, and the equation: $T_E = \frac{T_S}{\sqrt{1 - \frac{v^2}{c^2}}}$ gives you T_E , ["time passed on Earth"] during journey. The label A clears and initiates the program. Lbl B is the input for average velocity of the craft. Lbl C is the input for time passed on earth in years and outputs time passed on board ship by hitting fC Lbl D input time passed on board ship fD give appropriate time passed on earth the E's give ages.

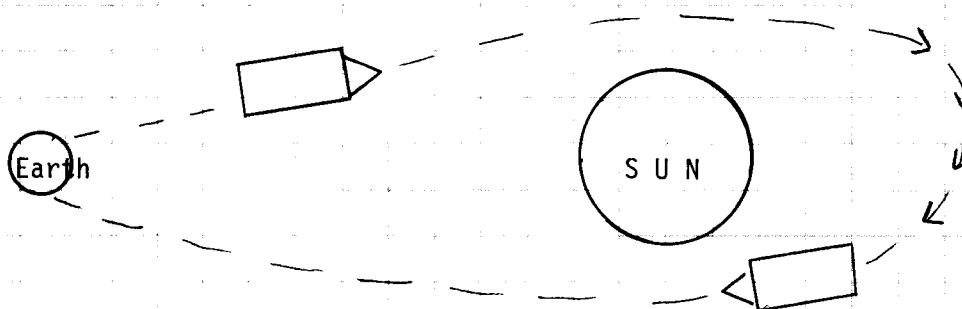
Operating Limits and Warnings Be certain that you enter the speed of the space craft in meters per second. All time and age entries must be in years. Outputs will be in years. Do not try to make the space travel at the speed of light, $\approx (3.00 \times 10^8 \text{ meters/second})$ as this will only show an error as should be and is implied by the theory of relativity.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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Program Description II

Sketch(es)



Sample Problem(s) Suppose two twins, age thirty, take part in this experiment the velocity of the ship will average 2.999111111×10^8 , if the twin on board travels a total of one year how much time will have passed on Earth? And given that 25 years passes on earth before return of the ship, how much time passed on board? What was the age differential in both cases?

Solution(s) Load side 1 and side 2
 [A] -----> -9.00×10^{16}
 2.999111111 [EEX] 8 [B]
 1 [D] [f] [D] -----> 41.08 years passed on Earth
 30 [E] -----> 71 twin on Earth's age
 Age differential is 40 years (71-31)
 [A]
 2.999111111 [EEX] 8 [B]
 25 [C] [f] [C] -----> .6085 years passed in space

30 [f] [E] -----> 30.6085 twin on board's age
 Age differential is 24.3015 (55-30.6085)

REFERENCE (S) Introduction to Special Relativity by James H. Smith (chp. 6)
 W.A. Benjam Inc., New York, Amsterdam 1965.

25



Always enter time in years, and speed in mtrs. per second, to go to new case i.e., new speed or different amounts of time or ages*. Hit [A], and then continue from step #3 with new values.

If time passed outputs are decimals,
multiplying by 365.25 converts to days

* The ages used in the [E] and [f] [E] subroutines need not be the same, our two "participants" need not be twins.

Time passed outputs, or age outputs can all be viewed in fixed mode by hitting fix key. i.e., 3.873+01→38.73, or 6.873+01→68.73

LABELS					FLAGS	SET STATUS		
A	B	C	D	E		FLAGS	TRIG	DISP
Initiate	Avg Ship Vel Ent	T. passed on Earth Ent	T. passed in space Ent	Earth Twin F. age	0			
$\sqrt{1 - \frac{v^2}{c^2}}$ routine		Earth T. to ship T.	Space T. to Earth T.	Space twin F. age	1	ON OFF		
0	1	2	3	4	2	0 ☐ ☒	DEG ☒	FIX ☐
						1 ☐ ☒	GRAD ☐	SCI ☒
						2 ☐ ☒	RAD ☐	ENG ☐
5	6	7	8	9	3	3 ☐ ☒		n <u>9</u>

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	X	-35	
002	CLRG	16-53		058	RCL1	36 01	Enter Time
003	SCI	-12		059	X	-35	Passed in Space
004	DSP9	-63 09		060	RCL2	36 02	CONVERT from
005	CLX	-51		061	X	-35	Years To Seconds
006	3	03		062	STOD	35 14	Store in RD
007	6	06		063	RTN	24	
008	0	00		064	*LBLd	21 16 14	
009	0	00		065	RCLD	36 14	
010	STO0	35 00		066	GSO0	23 00	
011	2	02		067	+	-24	
012	4	04		068	RCL0	36 00	
013	STO1	35 01		069	+	-24	
014	3	03		070	RCL1	36 01	
015	6	06		071	+	-24	
016	5	05		072	RCL2	36 02	
017	.	-62		073	+	-24	
018	2	02		074	STO4	35 04	
019	5	05		075	PSE	16 51	
020	STO2	35 02		076	SPC	16-11	
021	3	03		077	PRTX	-14	
022	EEX	-23		078	RTN	24	
023	28	08		079	*LBL0	21 00	
024	X	53		080	RCLB	36 12	
025	STOA	35 11		081	RCLA	36 11	
026	RTN	24		082	+	-24	
027	*LBLB	21 12		083	CHS	-22	
028	X ²	53		084	1	01	
029	STOB	35 12		085	+	-55	
030	RTN	24		086	√X	54	
031	*LBLC	21 13		087	RTN	24	
032	RCL0	36 00		088	*LBL E	21 15	
033	X	-35		089	RCL4	36 04	
034	RCL1	36 01		090	+	-55	
035	X	-35		091	PSE	16 51	
036	RCL2	36 02		092	SPC	16-11	
037	X	-35		093	PRTX	-14	
038	STOC	35 13		094	RTN	24	
039	RTN	24		095	*LBL e	21 16 15	
040	*LBLc	21 16 13		096	RCL3	36 03	
041	RCLC	36 13		097	+	-55	
042	GSO0	23 00		098	PSE	16 51	
043	X	-35		099	SPC	16-11	
044	RCL0	36 00		100	PRTX	-14	
045	÷	-24		101	RTN	24	
046	RCL1	36 01			R/S	51	
047	+	-24					
048	RCL2	36 02					
049	+	-24					
050	STO3	35 03					
051	PSE	16 51					
052	SPC	16-11					
053	PRTX	-14					
054	RTN	24					
055	*LBLD	21 14					
056	RCL0	36 00					

*initiate
store constants
clear registers
find C² and store
in RA.*

*Enter ship Avg. Velocity
Square and Store
in RB*

*Enter Time Passed
ON Earth in years
convert To seconds
Store in RC*

*Calculate
 $T_s = T_E \sqrt{1 - \frac{v^2}{c^2}}$
Store R3
Space and Print*

*Enter Time
Passed in Space
convert from
Years To Seconds
Store in RD*

*Calculate
 $T_E = \frac{T_s}{\sqrt{1 - \frac{v^2}{c^2}}}$
Store in R4*

*$\sqrt{1 - \frac{v^2}{c^2}}$
subroutine*

*Calculate
Earth Twin Final
Age*

*Calculate Space
Twin Final age*

REGISTERS									
0 3600	1 24	2 365.25	3 T _s	4 T _E	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A c²
B v²
C time passed Earth in sec.
D time passed rocket in sec.
E
F

Program Description I

Program Title Delta-V - Orbit Simulator

Contributor's Name Harold T. Coderre

Address 414 1915 Hall

City Princeton

State New Jersey

Zip Code 08540

Program Description, Equations, Variables 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:

$$\text{Energy: } E = \frac{1}{2} V_i^2 - \frac{GM}{R_i}$$

$$\text{Angular Momentum: } L = V R \sin(\alpha_i - \theta_i)$$

$$\text{Eccentricity: } e = \sqrt{1 + \frac{2 E L^2}{(GM)^2}}$$

$$R_0 = \frac{L^2}{GM}$$

$$\theta' = \theta_i + \cos^{-1}\left(\frac{R_0}{R_i} - 1\right)$$

$$R_{\min} = R_0 / (1 + e)$$

$$\text{Semimajor Axis: } a = R_0 / (1 - e^2)$$

$$\text{Semiminor Axis: } b = a \sqrt{1 - e^2}$$

$$\text{Period: } T = 2\pi \sqrt{\frac{a^3}{GM}}$$

$$\text{Distance to Asymptote Vertex } S = R_{\min} (1 - \frac{1}{e})$$

$$\text{Angle between Asymptotes and } \theta_a = \cos^{-1}\left(\frac{1}{e}\right)$$

Radius Vector

Given θ_{new} :

$$R_{\text{new}} = R_0 / (1 + e \cos(\theta_{\text{new}} - \theta'))$$

$$V_{\text{new}} = \sqrt{2(E + \frac{GM}{R_{\text{new}}})}$$

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

For a change in Velocity

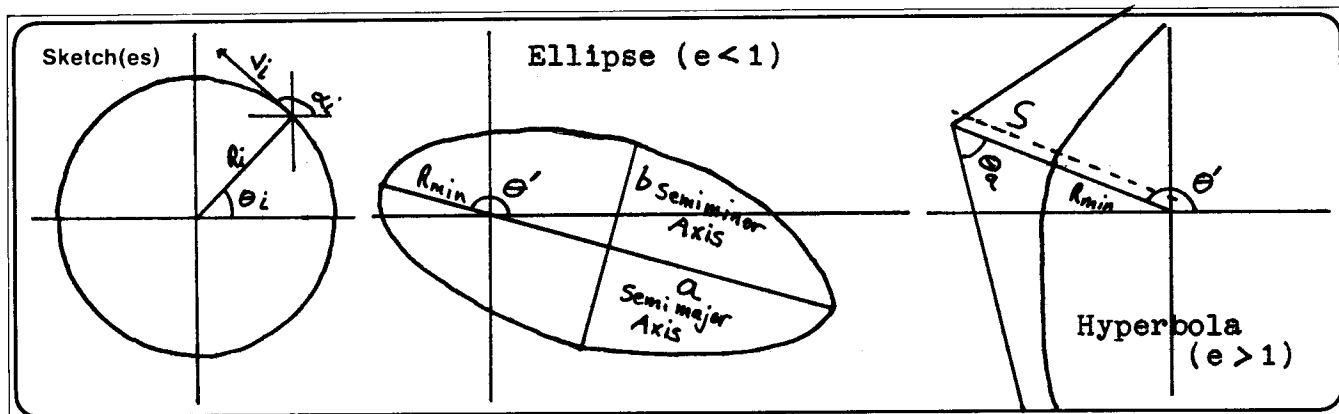
$$\vec{V}_{\text{new}} = \vec{V}_{\text{old}} + \Delta \vec{V}$$

Operating Limits and Warnings All angles should be $0 \leq \theta \leq 360$. If $\hat{\theta}(A)$ gives a negative radius for a hyperbolic orbit ($e > 1$) the orbit does not exist for the inputted θ . This program becomes ill-conditioned and inaccurate near degenerate conics (Circles, Parabolas and Straight lines). For added realism: avoid all orbits where $R_{\min} < \text{radius of the attracting body}$ (6.400×10^6 m for the Earth).

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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Program Description II



Sample Problem(s) Execute a transfer from Low Earth Orbit to Geosynchronous

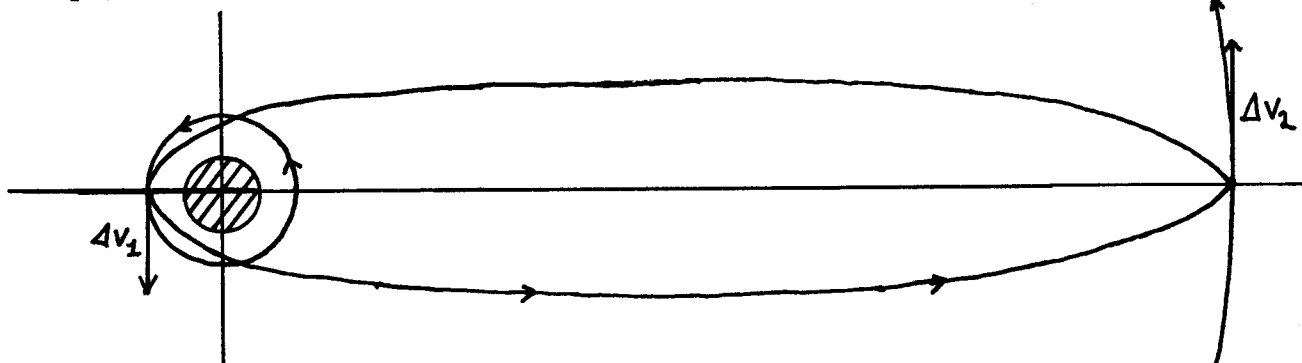
Step 1: Initialize $R_i = 7.1E6$ $\theta_i = 0$ $V_i = 7.4E3$ $\alpha_i = 90$

Step 2: Position Satellite at Perigee

Step 3: Accelerate to Synchronous Transfer

Step 4: Position Satellite at new Apogee

Step 5: Circularize



Solution(s) Keystrokes: (all underlined numbers are machine output)

Step 1: 7.10E6 ENT 0 F A

7.40E3 ENT 90 F B

Step 2: D 180.0 A 6.7462E6

Step 3: 2312 RCL 3 B 270.0

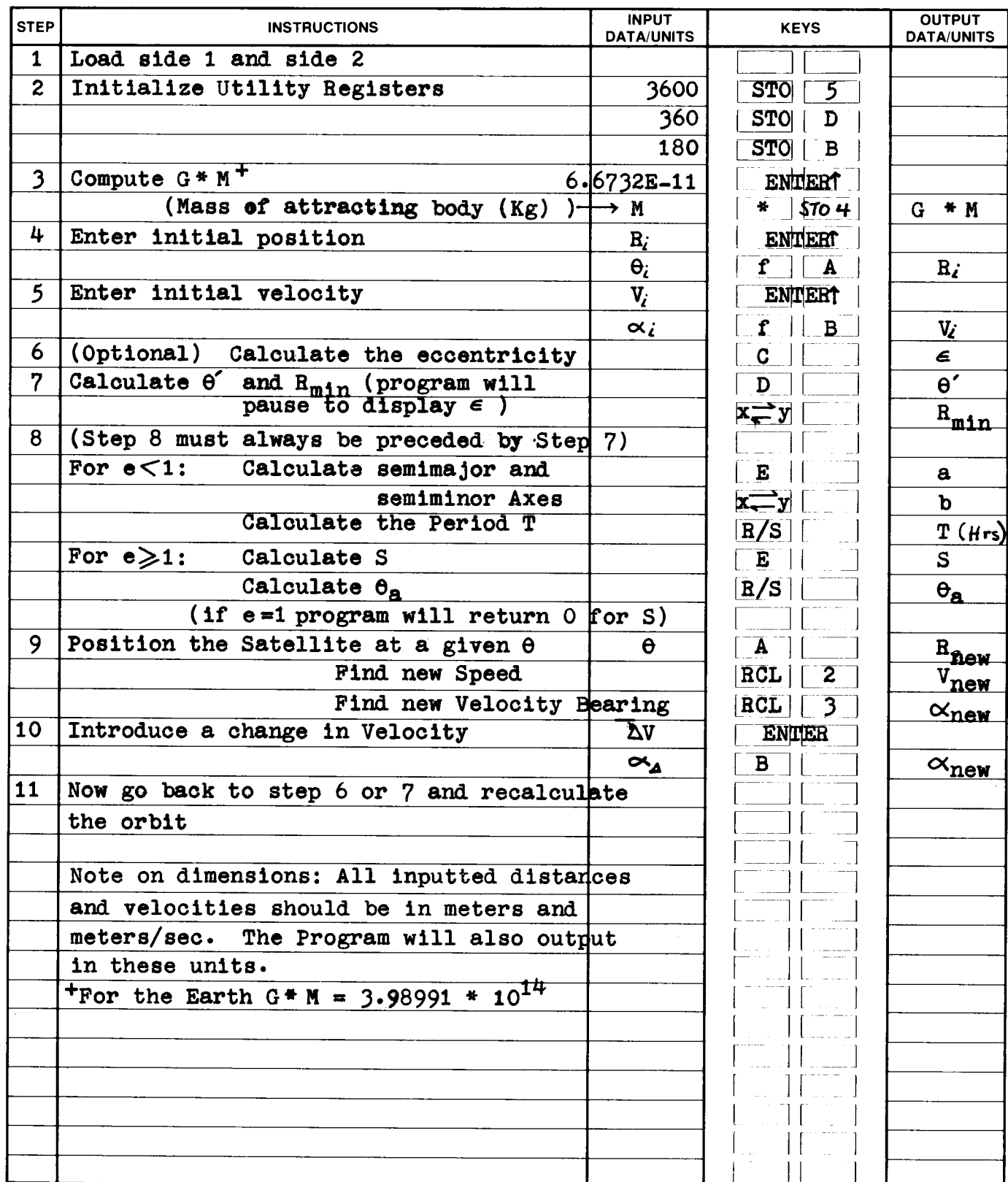
Step 4: D 180.0 180 + A 4.228688E7

Step 5: 1455 RCL 3 B 90.0 C 3.505809E-3 E 4.213916E7

R/S 23.90148 H→H.MS 23.54053 *****

Reference(s) Goldstein: Classical Mechanics Chapt 3

29



Note: All quantities listed below are per kilogram **Program Listing I**

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBL a	32 25 11	67		RCL 8	34 08	
	STO 1	33 01			÷	81	
	$x \Rightarrow y$	35 52			GSB d	32 22 14	
	STO 0	33 00		060	COS -1	32 63	
	RTN	35 22			RCL 3	34 03	
	LBL b	32 25 12			RCL 1	34 01	
	STO 3	33 03			-	51	
	$x \Rightarrow y$	35 52			COS	31 63	
	STO 2	33 02			LST X	35 82	
010	SF 1	35 51 01			SIN	31 62	
	RTN	35 22			*	71	
	LBL C	31 25 13			$x < 0$	31 71	
	RCL 2	34 02			GTO 7	22 07	
	X**2	32 54		070	R↓	35 53	
	2	02			CHS	42	
	+	81			R↑	35 54	
	RCL 4	34 04			LBL 7	31 25 07	
	RCL 0	34 00			R↓	35 53	
	+	81			+	61	
020	-	51			GSB e	32 22 15	
	STO 6	33 06	→ ENERGY		STO A	33 11	→ e'
	RCL 3	34 03			CLF 1	35 61 01	
	RCL 1	34 01			RCL 8	34 08	
	-	51		080	RTN	35 22	
	SIN	31 62			LBL D	31 25 14	
	RCL 0	34 00			TF 1	35 71 01	
	*	71			GSB C	31 22 13	
	RCL 2	34 02			RCL 8	34 08	
	*	71			Pause	35 72	
030	STO 7	33 07	→ ANGULAR MOMENTUM		1	01	
	X**2	32 54			+	61	
	2	02			1/X	35 62	
	*	71			RCL 9	34 09	
	RCL 6	34 06		090	*	71	→ R _{min}
	*	71			STO C	33 13	
	RCL 4	34 04			RCL A	34 11	
	X**2	32 54			RTN	35 22	
	+	81			LBL E	31 25 15	
	1	01			TF 0	35 71 00	
040	+	61			GTO 2	22 02	
	$\sqrt{x}$	31 54			RCL 9	34 09	ellipse section
	STO 8	33 08	→ ECCENTRICITY		1	01	
	1	01			RCL 8	34 08	
	CLF 0	35 61 00		100	X**2	32 54	
	$x \leq y$	32 71			-	51	
	STF 0	35 51 00			÷	81	
	RCL 1	34 01			STO E	33 15	→ Semimajor Axis
	RCL 7	34 07			LST X	35 82	
	X**2	32 54			$\sqrt{x}$	31 54	
050	RCL 4	34 04			*	71	→ Semiminor Axis
	+	81			RCL E	34 15	
	STO 9	33 09	→ R ₀		R/S	84	
	RCL 0	34 00			RCL E	34 15	
	+	81		110	X**2	32 54	
	1	01			LST X	35 82	
	-	51			*	71	

REGISTERS

0 Dist	1 BEARING	2 Speed	3 Speed Bearing	4 G * M	5 3600	6 Energy	7 A. M.	8 e	9 R ₀
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A e'	B 180	C R _{min}	D 360	E a	I				

67 Program Listing II

31

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS											
	RCL 4	34 04			RCL 1	34 01												
	$\frac{1}{x}$	81		170	RCL A	34 11												
	$\sqrt{x}$	31 54			-	51												
	2	02			SIN	31 62												
	*	71			*	71												
	π	35 73			$x > 0$	31 81												
	*	71			GTO 4	22 04												
120	RCL 5	34 05			CLX	44												
	+	81	→ Period (Hrs)		RCL B	34 12												
	RTN	35 22			-	51												
	LBL 2	31 25 02	Hyperbola Section	180	CHS	42												
	RCL C	34 13			R↑	35 54												
	1	01			LBL 4	31 25 04												
	RCL 8	34 08			R↓	35 53												
	1/X	35 62			RCL 1	34 01												
	-	51			+	61												
	$x \neq 0$	31 61	Output Zero for a Parabola		GSB e	32 22 15												
130	GTO 3	22 03			STO 3	33 03	→ α_{new}											
	RTN	35 22			RCL 0	34 00												
	LBL 3	31 25 03			RTN	35 22												
	+	81			LBL B	31 25 12												
	R/S	84	→ S	190	$x \Rightarrow y$	35 52												
	RCL 8	34 08			→ R	31 72												
	1/X	35 62			RCL 3	34 03												
	$\cos^{-1}$	32 63	→ θ_a		RCL 2	34 02												
	RTN	35 22			→ R	31 72												
	LBL A	31 25 11			$x \Rightarrow y$	35 52												
140	STO 1	33 01			R↓	35 53												
	RCL A	34 11			+	61												
	-	51			R↓	35 53												
	COS	31 63			+	61												
	RCL 8	34 08		200	R↑	35 54												
	*	71			→ P	32 72												
	1	01			STO 2	33 02												
	+	61			$x \Rightarrow y$	35 52												
	RCL 9	34 09			GSB e	32 22 15												
	+	81			STO 3	33 03												
150	1/X	35 62			SF 1	35 51 01												
	STO 0	33 00	→ R_{new}		RTN	35 22												
	RCL 4	34 04			LBL e	32 25 15												
	$x \Rightarrow y$	35 52			RCL D	34 14												
	+	81		210	+	81												
	RCL 6	34 06			FRAC	32 83												
	+	61			1	01												
	2	02			+	61												
	*	71			FRAC	32 83												
	$\sqrt{x}$	31 54			RCL D	34 14												
160	STO 2	33 02	→ V_{new}		*	71												
	RCL 7	34 07			RTN	35 22												
	RCL 0	34 00			LBL d	32 25 14												
	RCL 2	34 02			INT	31 83												
	*	71		220	$x \neq 0$	31 61												
	+	81			RTN	35 22												
	GSB d	32 22 14			CLX	44												
	$\sin^{-1}$	32 62			LST X	35 82												
	RCL 7	34 07			RTN	35 22												
LABELS				FLAGS		SET STATUS												
A	$\hat{\theta}$	B	$\Delta \vec{V}$	C	$\in$	D	$0, R_{min}$	E	Graph	F	$e \geq 1$	FLAGS			TRIG		DISP	
a	$\vec{R}_1$	b	$\vec{V}_1$	c		d	Adjust	e	Mod 360	1	Find e	ON OFF			DEG	☒	FIX	☐
0		1		2	-used-	3	-used-	4	-used-	2		0	☐	☒	GRAD	☐	SCI	☒
5		6		7	-used-	8		9		3		1	☐	☒	RAD	☐	ENG	☐
												2	☐	☒			n	6
												3	☐	☒				

Program Description I

Program Title EQUATIONS OF PARTICLE MOTION

Contributor's Name ERIK GOETZE

Address 1613 CAMULOS AVE.

City GLENDALE

State CALIF

Zip Code 91208

Program Description, Equations, Variables HERE ALL VARIABLES ARE IN y, BUT ALL y's COULD BE REPLACED WITH x's.

nr1 $y = \frac{1}{2}(V_{y0} + V_y)t$

nr2 $y = V_{y0}t + \frac{1}{2}a_y t^2$

nr3 $y = \frac{V_y^2 - V_{y0}^2}{2a_y}$

nr4 $t = \frac{V_y - V_{y0}}{a_y}$

nr5 $t = \frac{2y}{V_{y0} + V_y}$

nr6 $t = \frac{(-V_{y0} \pm \sqrt{V_{y0}^2 + 2a_y y})}{a_y}$

nr7 $V_y = V_{y0} + a_y t$

nr8 $V_y = \frac{2y}{t} - V_{y0}$

nr9 $V_y = \sqrt{V_{y0}^2 + 2a_y y}$

$V_{y0} = V_y - a_y t$ [nr10]

$V_{y0} = \frac{2y}{t} - V_y$ [nr11]

$V_{y0} = \frac{y}{t} - \frac{a_y t}{2}$ [nr12]

$V_{y0} = \sqrt{V_y^2 - 2a_y y}$ [nr13]

$a_y = \frac{V_y - V_{y0}}{t}$ [nr14]

$a_y = 2 \left(\frac{y - V_{y0}t}{t^2} \right)$ [nr15]

$a_y = \frac{V_y^2 - V_{y0}^2}{2y}$ [nr16]

y = DISTANCE COVERED BY PARTICLE IN TIME t

t = TIME IN WHICH PARTICLE MOVES

V_y = VELOCITY AT TIME t

V_{y0} = VELOCITY AT TIME 0

a_y = ACCELERATION (AVERAGE OVER TIME t) THAT PARTICLE IS EXPERIENCING IN TIME t

PROGRAM, GIVEN ANY THREE OUT OF THE ABOVE FIVE, WILL SOLVE THE ABOVE EQUATIONS FOR THE OTHER TWO.

Operating Limits and Warnings IF YOU ARE SOLVING FOR V-INITIAL, YOU MUST STORE THE VALUE YOU GET BY PRESSING [D] BEFORE SOLVING FOR THE OTHER UNKNOWN. THIS IS BECAUSE V_{y0} IS IN ALL THE OTHER EQUATIONS. IF THE DISPLAY COMES UP ERROR WHEN YOU ARE SOLVING FOR t , YOU HAVE AN IMAGINARY ROOT. SIMPLY SWITCH TO PROGRAM MODE, PRESS [SST] AND SWITCH BACK TO RUN AND PRESS [R/S]

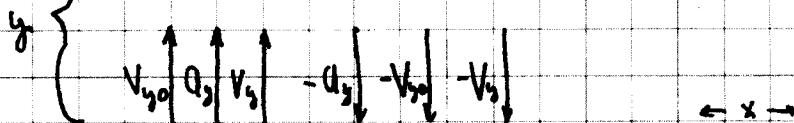
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Program Description II

33

Sketch(es)



Sample Problem(s) **TEST**
EACH EQTN. GIVEN
ON PREVIOUS SHEET.

Clear everything

Initial vel. 256.00 GSBD
Final vel. 17.00 GSBC
Time (seconds) 8.60 GSBB
Solve for y 1.00 GSBD

1173.96 ***

GSBe

159.00 GSBD

4.80 GSBB

g down $\downarrow$ -9.80 GSBE

Solve for dist. 1.00 GSBD

650.30 ***

GSBe

12.00 GSBC

19.00 GSBD

-9.80 GSBE

1.00 GSBD

11.07 ***

Solve for time

29.00 GSBD

0.00 GSBC

-32.30 GSBE

2.00 GSBD

0.90 ***

0.00 GSBe

47.00 GSBA

28.00 GSBD

7.00 GSBC

2.00 GSBD

2.69 ***

GSBe

Quad roots
pause $\rightarrow$

Solve for V_y

Solve for V_{y0}

88.00 GSBD

-32.30 GSBE

12.00 GSBA

2.00 GSBD

5.31 ***

0.14 ***

GSBe

15.00 GSBD

-9.80 GSBE

2.50 GSBB

3.00 GSBD

-9.50 ***

GSBe

7.00 GSBA

1.80 GSBB

12.00 GSBD

3.00 GSBD

-4.22 ***

GSBe

-9.80 GSBE

5.00 GSBA

23.00 GSBD

3.00 GSBD

20.76 ***

GSBe

19.00 GSBC

-9.80 GSBE

.30 GSBB

4.00 GSBD

22.72 ***

GSBe

14.80 GSBA

2.71 GSBB

0.00 GSBC

4.00 GSBD

10.92 ***

GSBe

118.00 GSBA

4.965 GSBB

-32.30 GSBE

4.00 GSBD

103.95 ***

GSBe

33.00 GSBC

-32.30 GSBE

15.70 GSBA

4.00 GSBD

45.86 ***

Solve for a

GSBe

24.70 GSBC

44.30 GSBD

2.00 GSBB

5.00 GSBD

-9.80 ***

y down $\downarrow$

GSBe

3.00 GSBA

18.00 GSBC

2.50 GSBB

5.00 GSBD

-13.44 ***

GSBe

17.00 GSBC

39.00 GSBD

9.00 GSBA

5.00 GSBD

-68.44 ***

Reference(s) **PHYSICS** BY **RESNICK AND HALLIDAY** CHAP 3 PAGE 49

97 Program Listing I

35

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	*LBL9	21 09	
002	1	01		058	RCL0	36 00	
003	CF0	16 22 00	NR OF REG DIS IS STORED AT	059	RCL5	36 05	
004	GT00	22 00		060	=	-24	
005	*LBLB	21 12		061	RTN	24	
006	2	02	NR OF REG TIME IS STORED AT	062	*LBL2	21 02	
007	CF1	16 22 01		063	RCL5	36 05	
008	GT00	22 00		064	Pi	16-24	
009	*LBLC	21 13		065	X=Y?	16-33	
010	3	03		066	GT06	22 06	
011	CF2	16 22 02		067	F0?	16 23 00	
012	GT00	22 00		068	GT07	22 07	
013	*LBLD	21 14		069	RCL4	36 04	
014	4	04		070	X²	53	
015	GT00	22 00		071	RCL5	36 05	
016	*LBLE	21 15		072	RCL1	36 01	
017	5	05		073	2	02	
018	*LBL0	21 00		074	x	-35	
019	ST01	35 46		075	x	-35	
020	R↓	-31		076	+	-55	
021	ST0i	35 45		077	JX	54	
022	RCL3	36 03		078	ST09	35 09	
023	X²	53		079	RCL4	36 04	
024	RCL4	36 04		080	CHS	-22	
025	X²	53		081	+	-55	
026	-	-45		082	LSTX	16-63	
027	2	02		083	RCL9	36 09	
028	=	-24		084	-	-45	
029	ST00	35 00		085	RCL5	36 05	
030	CLX	-51		086	=	-24	
031	RTN	24		087	PSE	16 51	
032	*LBL1	21 01		088	LSTX	16-63	
033	F1?	16 23 01		089	X²Y	-41	
034	GT09	22 09		090	R↓	-31	
035	F2?	16 23 02		091	=	-24	
036	GT08	22 08		092	RTN	24	
037	RCL4	36 04		093	*LBL7	21 07	
038	RCL3	36 03		094	RCL3	36 03	
039	+	-55		095	RCL4	36 04	
040	RCL2	36 02		096	-	-45	
041	x	-35		097	RCL5	36 05	
042	2	02		098	=	-24	
043	=	-24		099	RTN	24	
044	RTN	24		100	*LBL6	21 06	
045	*LBL8	21 08		101	RCL1	36 01	
046	RCL4	36 04		102	2	02	
047	RCL2	36 02		103	x	-35	
048	x	-35		104	RCL3	36 03	
049	RCL2	36 02		105	RCL4	36 04	
050	X²	53		106	+	-55	
051	RCL5	36 05		107	=	-24	
052	x	-35		108	RTN	24	
053	2	02		109	*LBL3	21 03	
054	=	-24		110	F0?	16 23 00	
055	+	-55		111	GT09	22 09	
056	RTN	24		112	F1?	16 23 01	

NR OF REG DIS IS STORED AT

NR OF REG TIME IS STORED AT

V FINAL NR REG

V INITIAL NR REG

ACC. NR REG

STORE NR. IN REG

CALCULATE $\frac{V_2^2 - V_0^2}{2}$

DONT HAVE TIME

DONT HAVE V FINAL

CALCULATE y USING FORMULA NR 1

CALCULATE y USING FORMULA NR 2

CALCULATE y USING FORMULA NR 3

NO Acc

NO y

QUAD ROOT EVALUATION FOR t USING FORMULA NR 6

CALCULATE T USING FORMULA NR 4

CALCULATE T USING FORMULA NR 5

NO y

REGISTERS

0	1	2	3	4	5	6	7	8	9
$V_2^2 - V_0^2$	DIST.	TIME	V FINAL	V INITIAL	ACCELER.				$\sqrt{b^2 - 4ac}$
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E					I NR OF LABEL + REG

97Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	GTOb	22 16 11	NO E	169	RCL5	36 05	CALCULATE V_{yo} USING FORMULA NR 13
114	RCL1	36 01	CALCULATE V_F USING FORMULA NR 8	170	RCL1	36 01	
115	2	02		171	2	02	
116	x	-35		172	x	-35	
117	RCL2	36 02		173	x	-35	
118	=	-24	CALCULATE V_F USING FORMULA NR 7	174	-	-45	CALCULATE V_{yo} USING FORMULA NR 11
119	RCL4	36 04		175	JX	54	
120	-	-45		176	RTN	24	
121	RTN	24		177	*LBL8	21 08	
122	*LBL9	21 09		178	RCL1	36 01	
123	RCL4	36 04	CALCULATE V_F USING FORMULA NR 9	179	2	02	CALCULATE Q USING FORMULA NR 15
124	RCL5	36 05		180	x	-35	
125	RCL2	36 02		181	RCL2	36 02	
126	x	-35		182	=	-24	
127	+	-55		183	RCL3	36 03	
128	RTN	24	CALCULATE V_F USING FORMULA NR 9	184	-	-45	CALCULATE Q USING FORMULA NR 14
129	*LBLa	21 16 11		185	RTN	24	
130	RCL4	36 04		186	*LBL5	21 05	
131	X ²	53		187	F0?	16 23 00	
132	RCL1	36 01		188	GT07	22 07	CALCULATE Q USING FORMULA NR 16
133	RCL5	36 05	CALCULATE V_{yo} USING FORMULA NR 12	189	F1?	16 23 01	
134	2	02		190	GT06	22 06	
135	x	-35		191	RCL1	36 01	
136	x	-35		192	RCL4	36 04	
137	+	-55	CALCULATE V_{yo} USING FORMULA NR 10	193	RCL2	36 02	RESET BY SETTING FLAGS, IT IN R ₅
138	JX	54		194	x	-35	
139	RTN	24		195	-	-45	
140	*LBL4	21 04		196	RCL2	36 02	
141	F0?	16 23 00		197	X ²	53	
142	GTOb	22 16 12	NO y	198	=	-24	CALCULATE VARIABLE i IN ROUTINE i
143	F1?	16 23 01	NO t	199	2	02	
144	GTOb	22 16 13	CALCULATE V_{yo} USING FORMULA NR 10	200	x	-35	
145	RCL5	36 05		201	RTN	24	
146	Pi	16-24		202	*LBL7	21 07	
147	X=Y?	16-33		203	RCL3	36 03	
148	GT08	22 08		204	RCL4	36 04	
149	RCL1	36 01	CALCULATE V_{yo} USING FORMULA NR 10	205	-	-45	CALCULATE VARIABLE i IN ROUTINE i
150	RCL2	36 02		206	RCL2	36 02	
151	=	-24		207	=	-24	
152	RCL5	36 05		208	RTN	24	
153	RCL2	36 02		209	*LBL6	21 06	
154	x	-35	CALCULATE V_{yo} USING FORMULA NR 10	210	RCL0	36 00	CALCULATE VARIABLE i IN ROUTINE i
155	2	02		211	RCL1	36 01	
156	=	-24		212	=	-24	
157	-	-45		213	RTN	24	
158	RTN	24		214	*LBLc	21 16 15	
159	*LBLb	21 16 12	CALCULATE V_{yo} USING FORMULA NR 10	215	SF0	16 21 00	CALCULATE VARIABLE i IN ROUTINE i
160	RCL3	36 03		216	SF1	16 21 01	
161	RCL5	36 05		217	SF2	16 21 02	
162	RCL2	36 02		218	Pi	16-24	
163	x	-35		219	ST05	35 05	
164	-	-45	CALCULATE V_{yo} USING FORMULA NR 10	220	0	00	CALCULATE VARIABLE i IN ROUTINE i
165	RTN	24		221	RTN	24	
166	*LBLc	21 16 13		222	*LBLd	21 16 14	
167	RCL3	36 03		223	ST01	35 46	
168	X ²	53		224	GT0i	22 45	

LABELS

SET STATUS

A STORE DIS	B STORE TIME	C STORE V_F	D STORE V_{IN}	E STORE A_{CL}	0 SET IF DIS HASN'T ENTERED	FLAGS	TRIG	DISP
a USED	b USED	c USED	d SOLVE	e RESET	1 SET IF TIME HASN'T ENTERED	ON OFF	DEG ☒	FIX ☒
0 STORAGE	1 CALL DIS	2 CALL TIME	3 CALL V_F	4 CALL V_{IN}	2 SET IF V_F HASN'T ENTERED	0 ☒ ☐	GRAD ☐	SCI ☐
5 CALL A_{CL}	6 USED	7 USED	8 USED	9 USED	3	1 ☒ ☐	RAD ☐	ENG ☐
						2 ☒ ☐		n <u>2</u>
						3 ☐ ☐		

Program Description I

Program Title Ballistics Trajectory Computations

Contributor's Name David M. Ivey

Address Scientific Atlanta, 3845 Pleasantdale Rd.

City Atlanta

State Ga.

Zip Code 30340

Program Description, Equations, Variables The Program computes remaining velocities, energies, flight times, rise and drops plus sight-in trajectories for bullets at user specified intervals. Computations technically apply to ICAO conditions which are satisfactory for most shooting conditions. The method uses a Mayevski drag formulation with different constants for the various velocity zones. The program automatically selects the correct zone. There are three programs combined on the one card. Note that data is stored on another card. LBL A: This program does the standard trajectory computations with outputs selected by two flags. LBL B: Knowing the velocities at two ranges enables one to compute the Ballistic Coefficient with Label B. LBL C: Given a "sight-in" range, this program calculates the actual bullet path. Label C represents the advanced capability of this program set.

Operating Limits and Warnings Be sure to use ballistics coefficient based on Ingall's Tables (presently all American bullets are). This system works best when the coefficient C_b is greater than 0.150 and velocities are above that of sound. Most importantly however, use range intervals no greater than 100yds, shorter intervals give better accuracy. Typically about 3% error occurs with this program relative to numeric integration techniques at 1000yds.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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BALLISTICS TRAJECTORY COMPUTATIONS

D. Ivey

Zone Data

The drag is computed according to the formula $A v^n$, where A and n are constants particular to a certain velocity zone. The constants A and n for each zone as well as the limits for a zone are best stored on a magnetic card.

Mayevski Velocity Zones

Range of V	n	A
3600-2600	1.55	$4.064882535 [10^{-3}]$
2600-1800	1.70	$1.247951766 [10^{-3}]$
1800-1370	2.00	$1.316 [10^{-4}]$
1370-1230	3.00	$9.569787630 [10^{-8}]$
1230-0970	5.00	$6.336817507 [10^{-14}]$

There are two more zones but memory space does not allow any more storage.

0	0.00
1	0.00
2	0.00
3	450240.00
4	40.00
5	0.00
6	2600.00
7	1800.00
8	1370.00
9	1230.00
A	0.00
B	0.00
C	0.00
D	0.00
E	0.00
F	0.00

Primary

P.S
REG

1	1.55
2	4.064882355-05
3	1.75
4	1.247951755-05
5	2.00
6	1.316000000-04
7	3.00
8	9.569767500-05
9	5.00
0	6.336817587-14
1	0.00
2	0.00
3	0.00
4	0.00
5	0.00
6	0.00
7	0.00
8	0.00
9	0.00

Secondary

BALLISTICS TRAJECTORY COMPUTATIONS

D. Ivey

List of equations and variables:

$$V_f = (V_i^2 - Z'D)^{\frac{1}{2}}$$

$$D = Av_i^n$$

$$Z' = 2\Delta x/C_b$$

$$t_f = 2\Delta x \sum (1/[v_i + v_f])$$

$$h = 48.26t_f^2$$

$$y_f = (4h/3)[1 + 2\sqrt{v_f/v_m}]$$

$$E_f = (w_b v_f^2)/450,240$$

$$C_b = (2\Delta x D)/(v_i^2 - v_f^2)$$

$$e_i = (x_i/x_o)(y_o + H) - y_i - H$$

$$x_f = x_i + \Delta x$$

v_i =initial velocity ft/sec

v_f =final velocity

v_m = muzzle velocity

D = Drag

n = Mayevski constant

A = Mayevski constant

C_b = Ballistic Coefficient
(Ingall's)

Δx = Range interval, ft.

t_f = flight time from v_i to v_f

h = maximum ordinate (rise)

y_f = drop at range x_f

E_f = energy of bullet at v_f

w_b = bullet weight in grains

x_o = sight in range

y_o = drop at sight in range

H = height of scope above bore

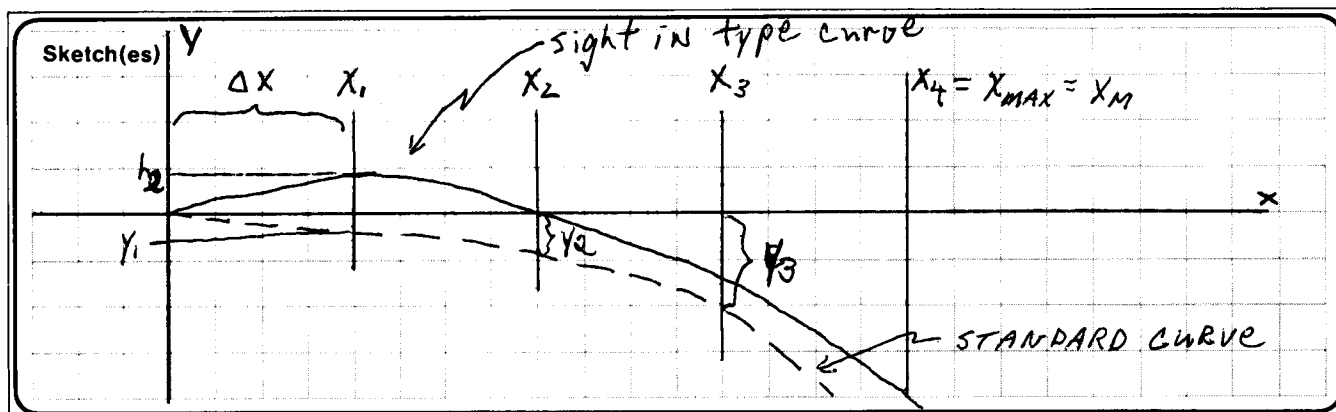
x_i = range at intermediate values

y_i = drop at intermediate values

x_m = maximum range

e_i = projectiles position at x_i

Program Description II



Sample Problem(s) LBL A problem: Compute the complete trajectory of a 30/06 cartridge where the bullet is a 165 gr. Sierra Boat Tail ($C_b=0.47$) at a muzzle velocity of 2800 ft/sec, in 100 yard increments out to 400 yards. Print the energy, flight time, maximum ordinate (rise) and drop.

2800.00 ST04
 .47 ST08
 300.00 ST06
 1200.00 ST00
 165.00 ST0E
 SF0
 SF1
 G3BH

Note: C_b is destroyed each time this program is run.

Initial
Data

$V_m = 2800.00$ ***
 $E_m = 2873.13$ ***
 $C_b = 0.47$ ***
 $w_b = 165.00$ ***

Range 100. ***

Velocity - 2588. ***V
 Energy - 2454. ***E
 time - 0.1114 ***t
 rise - 0.60 ***h
 drop - 2.33 ***y

At right is the output:

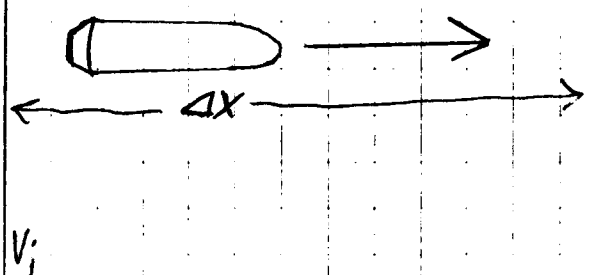
Solution(s) $V_m = 2800 \text{ ft/sec}$ ST0 A
 $C_b = 0.470$ ST0 B
 $\Delta x = 300 \text{ ft (100 yards)}$ ST0 C
 $X_m = 1200 \text{ ft (400 yards)}$ ST0 D
 $w_b = 165$ ST0 E
 Set flag one and
 two
 Press A

200. ***
 2385. ***
 2084. ***
 0.2320 ***
 2.60 ***
 9.86 ***
 300. ***
 2193. ***
 1762. ***
 0.3631 ***
 6.36 ***
 23.50 ***

~~XXXXXXXX~~ Remarks: Thus at 400 yards, we have lost 28% of our initial velocity and 48% of the energy.

400. ***
 2011. ***
 1487. ***
 0.5058 ***
 12.35 ***
 44.37 ***

Program Description II

Sketch(es)		$V_i = \text{initial velocity}$ $V_f = \text{final velocity}$ $V_i > V_f$
------------	---	---

Sample Problem(s) LBL B Problem Compute the ballistic coefficient for a 165gr. Sierra Boat Tail bullet if the initial interval velocity is 2588ft/sec. and the final interval velocity is 2385 ft/sec., assuming $x=300\text{ft.}$

NOTE: Due to the type of drag formulation used, different data sets yield different ballistic coefficients. This is especially true for the interval beginning at the muzzle. Several sets are shown, its best to average them.

Solution(s) $\Delta x=300$ STO C

V_i ENTER V_f Press B
 2588 enter 2385 B

2800.00 ENT
 2588.00 GSEB
 0.4751 ***

2588.0000 ENT
 2385.0000 GSEB
 0.4702 ***

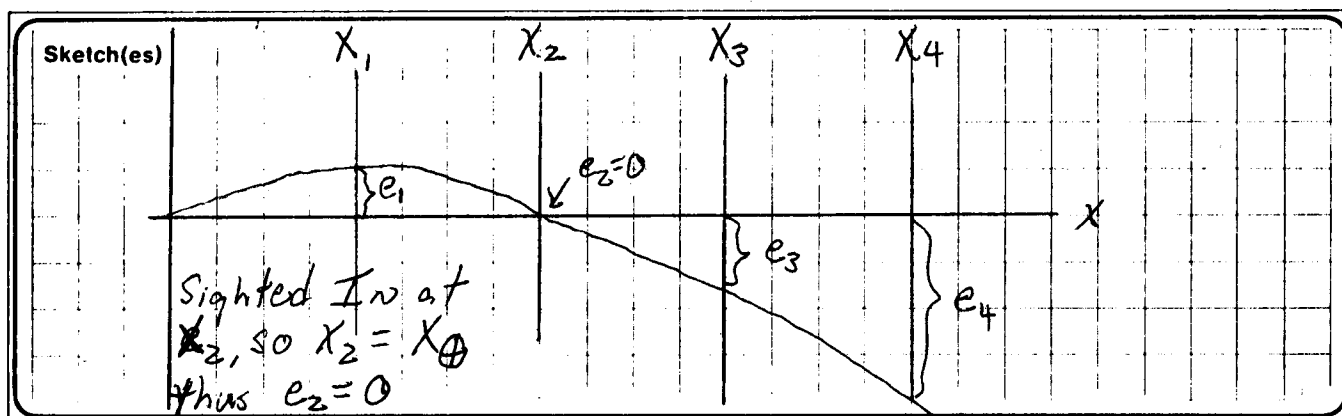
2385.0000 ENT
 2193.0000 GSEB
 0.4700 ***

2193.0000 ENT
 2011.0000 GSEB
 0.4661 ***

Average 0.4702 ***

Reference(s) This entire program set represents the first complete ballistic system without extensive numeric integration techniques ^{with} long tables. It was specifically developed for micro-computer applications. For more information regarding theoretical development or program usage, contact the author. Home phone: 404/ 448-5394 Bus: 404/ 449-2000

Program Description II



Sample Problem(s) LBL C Problem Assume we wish to sight a rifle in at 200yds with the parameters of Sample A. We want to know the bullet's position at each range increment to 400 yards. Using the data from Sample A, the drop at 200 yards is 9.86inches. Let our rifle scope be 1.5inches above the rifle bore.

Solution(s) 2800 STO A*
0.470 STO B
300 STO C*
1200 STO D*
9.86 STO 4
600.15 STO E (600=200yds in feet,)
Press " " (15=1.5 inches above bore)

2800.00 STOA
.47 STOB
300.00 STOC
1200.00 STOD
9.86 STOD
600.15 STOE
GSBC

2800.00 ***
200.00 ***
0.47 ***

100. ***

1.55 ***

200. ***

0.06 ***

300. ***

-7.36 ***

400. ***

-23.15 ***

* not necessary if entered with LBL A.

~~REMARKS~~ Remarks: From the output, to hit dead on at 400yds we need to hold 23.15 inches high. This program itself has great applications!

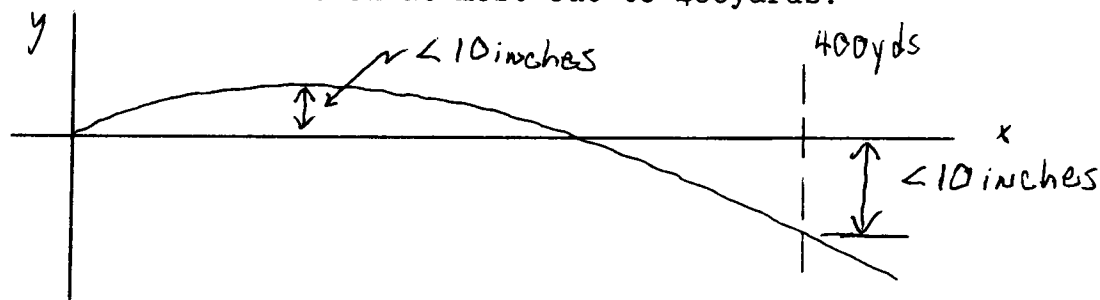
BALLISTICS TRAJECTORY COMPUTATIONS

D. Ivey

Special Comment on Program C:

Programs A and C can be used together to determine the optimum sight in range for a particular bullet/velocity combination.

Consider the 165gr. Sierra BT. What velocity and sight in range would yield a trajectory within ten inches of correction at most out to 400 yards?



From the sample with Program A, 2800ft/sec sighted at 200 yards is not adequate. Suppose we try a range of 300 yards for sight in? Then, using Program C we obtain a -12.54 inches drop at 400 yards. This is out of our design specs. Probably by increasing the powder charge to get 2900ft/sec we can succeed.

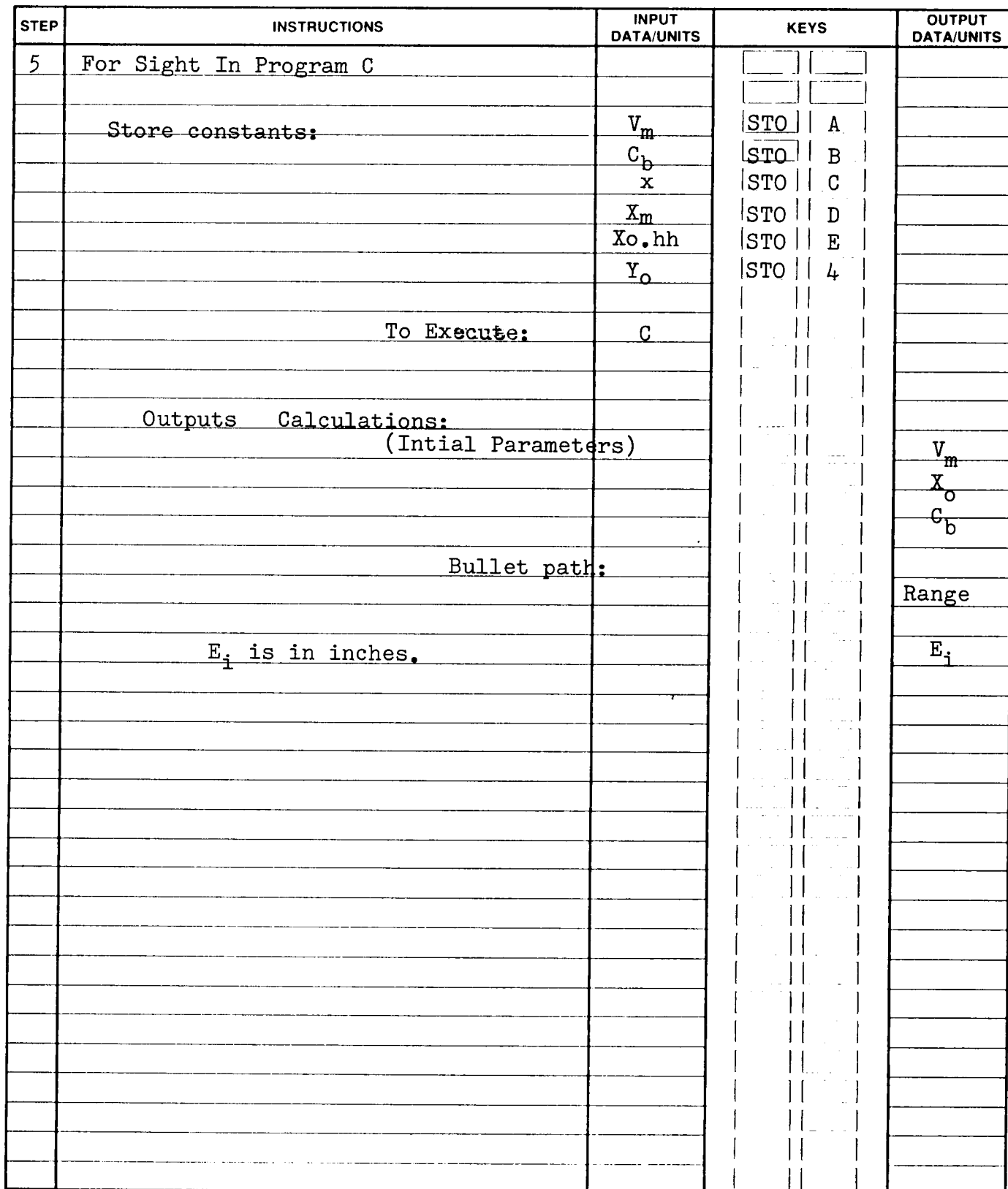
This example is one way the powerful Program C can be used. Also note that with Program A one can sight in using the rise data.

User Instructions

1 Ballistics Trajectory Computations F1 prints Energy
Regular C_b Sight In F2 prints rise, time

[illegible]

45



97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	Initialization and Setup.	057	*LBL5	21 05	Computes Flight time Rise and drop
002	DSP2	-63 02		058	RCL2	36 02	
003	GSB6	23 06		059	RCL5	36 05	
004	SPC	16-11		060	+	-55	
005	RCLA	36 11		061	1/X	52	
006	PRTX	-14		062	ST+0	35-55 06	
007	STO2	35 02		063	RCL5	36 05	
008	F1? 16	23 01		064	STO2	35 02	
009	GSB0	23 00		065	RCL0	36 00	
010	RCLB	36 12		066	RCLC	36 13	
011	PRTX	-14		067	X	-35	
012	RCLC	36 15		068	2	02	
013	X#0?	16-42		069	X	-35	
014	PRTX	-14		070	DSP4	-63 04	
015	RCLC	36 13		071	F0? 16	23 00	
016	RCLB	36 12		072	PRTX	-14	
017	=	-24		073	X?	53	
018	2	02		074	4	04	
019	X	-35		075	8	08	
020	STOB	35 12		076	.	-62	
021	*LBLa 21	16 11	Looping Label	077	2	02	
022	RCL1	36 01		078	6	06	
023	RCLD	36 14		079	X	-35	
024	X#Y?	16-35		080	DSP2	-63 02	
025	RTN	24		081	F0? 16	23 00	
026	GSB4	23 04		082	PRTX	-14	
027	RCL2	36 02		083	4	04	
028	GSB1	23 01		084	X	-35	
029	GSB3	23 03		085	3	03	
030	PRTX	-14		086	=	-24	
031	F1? 16	23 01	Computes Remaining Velocity	087	RCL5	36 05	Energy Calculations
032	GSB0	23 00		088	RCLA	36 11	
033	GSB5	23 05		089	=	-24	
034	PRTX	-14		090	JX	54	
035	STOa 22	16 11		091	2	02	
036	*LBL3 21	03		092	X	-35	
037	RCLB	36 12		093	1	01	
038	X	-35		094	+	-55	
039	CHS	-22		095	X	-35	
040	RCL2	36 02		096	RTN	24	
041	X?	53	Prints Range Intervals	097	*LBL0 21	00	
042	+	-55		098	ENT↑	-21	
043	JX	54		099	RCLC	36 15	
044	STO5	35 05		100	RCL3	36 03	
045	RTN	24		101	=	-24	
046	*LBL4 21	04		102	X#Y	-41	
047	RCLC	36 13		103	X?	53	
048	SPC	16-11		104	X	-35	
049	DSP0	-63 00		105	PRTX	-14	
050	ST+1 35-55	01		106	R↓	-31	
051	RCL1	36 01		107	RTN	24	
052	3	03		108	*LBL1 21	01	
053	=	-24		109	RCL6	36 06	
054	PRTX	-14		110	X#Y?	16-35	
055	SPC	16-11		111	STO2	22 02	
056	RTN	24		112	1	01	

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I				

97Program Listing II

47

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	2	02		169	SFC	16-11	
114	STOI	35 46		170	PRTX	-14	
115	RCL2	36 02		171	STO2	35 02	
116	RCL7	36 07		172	RCLC	36 15	
117	X&Y?	16-35		173	INT	16 34	
118	GT02	22 02		174	3	03	
119	1	01	Selects	175	+	-24	
120	4	04	Mayevski	176	PRTX	-14	
121	STOI	35 46		177	RCLB	36 12	
122	RCL2	36 02		178	PRTX	-14	
123	RCL8	36 08		179	RCLC	36 13	
124	X&Y?	16-35		180	RCLB	36 12	
125	GT02	22 02	Drag	181	+	-24	
126	1	01	Constants	182	2	02	
127	6	06		183	X	-35	
128	STOI	35 46		184	STOB	35 12	
129	RCL2	36 02		185	SFC	16-11	
130	RCL9	36 09		186	*LBLc	21 16 13	
131	X&Y?	16-35		187	RCL1	36 01	
132	GT02	22 02		188	RCLD	36 14	
133	1	01		189	X&Y?	16-35	
134	8	08		190	RTN	24	
135	STOI	35 46		191	GSB4	23 04	
136	*LBL2	21 02		192	RCL2	36 02	
137	R+	-31		193	GSB1	23 01	
138	RCL1	36 45		194	GSB3	23 03	
139	Y*	31		195	GSB5	23 05	
140	ISZI	16 26 45		196	RCLC	36 15	
141	RCL1	36 45		197	FRC	16 44	
142	X	-35		198	1	01	
143	DSZI	16 25 46		199	0	00	
144	RTN	24		200	X	-35	
145	*LBLB	21 12		201	+	-55	
146	STOA	35 11		202	CHS	-22	
147	R+	-31		203	LSTX	16-63	
148	STO2	35 02		204	RCL4	36 04	
149	GSB6	23 06		205	+	-55	
150	RCLA	36 11		206	RCL1	36 01	
151	GSB1	23 01		207	X	-35	
152	RCLC	36 13		208	RCLC	36 15	
153	X	-35		209	INT	16 34	
154	2	02		210	+	-24	
155	X	-35		211	+	-55	
156	RCL2	36 02		212	RND	16 24	
157	X²	53		213	PRTX	-14	
158	RCLA	36 11		214	GTOb	22 16 13	
159	X²	53		215	*LBL6	21 06	
160	-	-45		216	0	00	
161	÷	-24		217	STOB	35 02	
162	RTN	24		218	STOI	35 01	
163	*LBLC	21 13		219	1	01	
164	CF0	16 22 00		220	0	00	
165	CF1	16 22 01		221	STOI	35 46	
166	GSB6	23 06		222	RTN	24	
167	RCLA	36 11		223	R/S	51	
168	SFC	16-11					

Selects
Mayevski
Drag
Constants

Drag
Calculation

Initial
Setup

Looping
For
Prqm C

Register
clearance

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS		
a	b	c	d	e	1	TRIG		
0	1	2	3	4	2	DISP		
5	6	7	8	9	3			

Program Description I

Program Title ISOTOPE OVERLAP CORRECTIONS

Contributor's Name Lawrence I. Grossman

Address 206 Crest Ave.

City Ann Arbor

State MI

Zip Code 48103

Program Description, Equations, Variables 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. Program may be used with single isotope.

Isotopes X and Y are counted in machine channels A and B, respectively.

Let a = fractional spillover of isotope Y from channel B to A.

b = fractional spillover of isotope X from channel A to B.

C_x = 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 = $C_y (1 + a) = T_y$

Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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Program Description II

Sketch(es)

Sample Problem(s) 2 isotopes. Spillover $A \rightarrow B = 10\%$, $B \rightarrow A = 20\%$, $Bk_A = 10$ cpm, $Bk_B = 50$ cpm

For the following values of cts/min_A and cts/min_B, calculate corrected values and totals.

sample ^A	A	B
1	1000	500
2	2000	1000
3	1400	2200

Solution(s) Keystrokes

[F] [A]	→ 0.00	
0.2 ENTER 10 [D]	→ 0.20	
0.1 ENTER 50 [E]	→ 0.10	
/ [F] [C]	→ 1.00	
1000 [A] 500 [B] [C]	→ 1010	(T _x)
	→ 430	(T _y)
	→ 2	(next sample)
2000 [A] 1000 [B] [C]	→ 2020	(T _x)

	→ 920	(T _y)
	→ 3	(next)
1400 [A] 2200 [B] [C]	→ 1078	(T _x)
	→ 2462	(T _y)
	→ 4	(next)
[F] [B]	→ 4408	(ΣT _x)
	→ 3812	(ΣT _y)
	→ 0	(next)

Reference(s)

ISOTOPE OVERLAP CORRECTIONS

1

2 LABELS? $\rightarrow \epsilon_{Tx}, \epsilon_{Ty}$ $\uparrow$ # free. No.

CPM-A CPM-B $\rightarrow T_x, T_y$ $B \rightarrow A \uparrow B k_p$ $A \rightarrow B \uparrow B k_p$

2

[illegible]

67 Program Listing I

51

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL D	31 25 14			X	71	
	STO 0	33 00			STO +8	33 61 08	
	R+	35 53	store BKA, a		STO 9	33 09	
	STO 1	33 01		060	RCL 7	34 07	output Tx,
	RTN	35 22			-X-	31 84	Ty (if Fo set)
	*LBL c	32 25 13	store first sample no.		RCL 9	34 09	
	ST I	35 33			FO?	35 71 00	
	RTN	35 22			-X-	31 84	
	*LBL E	31 25 15			ISZ	31 34	
010	STO 2	33 02	store BKB, b		RC I	35 34	
	R+	35 53			RTN	35 22	
	STO 3	33 03			*LBL a	32 25 11	SFO for 2 labels
	RTN	35 22			SFO	35 51 00	
	*LBL A	31 25 11	enter counts/min for A	070	RTN	35 22	
	RCL 0	34 00	channel, subtract BKA,		*LBL b	32 25 12	output total x for
	-	51	store.		RCL 6	34 06	all samples, total y
	STO 4	33 04			-X-	31 84	(if Fo set). CFO.
	RTN	35 22			RCL 8	34 08	Clear accumulation
	*LBL B	31 25 12	enter counts/min for B		FO?	35 71 00	registers.
020	RCL 2	34 02	channel, subtract BKB,		-X-	31 84	
	-	51	store		CFO	35 61 00	
	STO 5	33 05			0	00	
	RTN	35 22			STO 6	33 06	
	*LBL C	31 25 13		080	STO 8	33 08	
	RCL 4	34 04	Calculate Cx, Cy,		ST I	35 33	
	RCL 1	34 01	Tx, Ty		RTN	35 22	
	RCL 5	34 05					
	X	71					
	-	51					
030	I	01					
	RCL 1	34 01					
	RCL 3	34 03					
	X	71					
	-	51					
	÷	81					
	I	01					
	RCL 3	34 03					
	+	61					
	X	71					
040	STO +6	33 61 06					
	STO 7	33 07					
	DSP 0	23 00					
	RCL 5	34 05					
	RCL 3	34 03					
	RCL 4	34 04					
	X	71					
	-	51					
	I	01					
	RCL 1	34 01					
050	RCL 3	34 03					
	X	71					
	-	51					
	÷	81					
	I	01					
	RCL 1	34 01					
	+	61					

LABELS				
A counts/min A	B counts/min B	C output Tx, Ty	D a↑ Backg. A	E b↑ Backg. B
a 2 labels	b Total cpm	c 1st sample No.	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS		SET STATUS		
0 Set for 2 isotopes		FLAGS	TRIG	DISP
1	ON OFF	0 ☒	DEG ☒	FIX ☒
2	1 ☐	GRAD ☐	SCI ☐	
3	2 ☐	RAD ☐	ENG ☐	
	3 ☐			n. 0

REGISTERS									
0 Background A	1 a	2 Background B	3 b	4 CA	5 CB	6 ΣC_x	7 Cx	8 ΣC_y	9 Cy
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I	sample Number			

Program Description I

Program Title Critical Reactor Code

Contributor's Name Richard D. Hyman

Address 23822 80th W.

City Edmonds

State Washington

Zip Code 98020

Program Description, Equations, Variables The program estimates the parameters of a reactor with different fuels, moderator, fuel to moderator ratios, size, and shapes of the reactor. Its most important use is in indicating trends in certain changes of mod. etc.

$$\eta = \frac{\gamma_{235} \Sigma_f(235)}{\Sigma_a(235) + \Sigma_a(238)} = \gamma \frac{\sigma_f}{\sigma_a}$$

$$f = \frac{\Sigma_a F}{\Sigma_a t} = \frac{\Sigma_a m}{\Sigma_a F} \frac{V_m}{V_F} F + E$$

$$F(x) = 1 + \frac{1}{2} \left(\frac{x}{2}\right)^2 - \frac{1}{12} \left(\frac{x}{2}\right)^4 + \frac{1}{48} \left(\frac{x}{2}\right)^6 : x = a/LF$$

$$E(y, z) = 1 + \frac{z^2}{2} \left[\frac{z^2}{z^2 - y^2} \ln\left(\frac{z}{y}\right) - \frac{3}{4} + \frac{y^2}{4z^2} \right] : \begin{matrix} z = b/LM \\ y = a/LM \end{matrix}$$

$$\rho = \exp - \left[\frac{N_F V_F I}{\Sigma_m \Sigma_{sm} V_m} \right] \quad I = A + C / \sqrt{ap}$$

$$B^2 = \left(\frac{\pi}{R}\right)^2 \text{ sphere}$$

$$\epsilon = 1 + .3 \left(\frac{V_F}{V_m}\right)$$

$$P_L = \frac{1}{1 + B^2 L_T}$$

$$B^2 = 3 \left(\frac{\pi}{R}\right)^2 \text{ cube}$$

Operating Limits and Warnings This program works best for low enrichment fuel, (-7²-5)% this is much like a power reactor. The accuracy is only to be taken as an estimate. But the trends are good. Note: Radius of reactor is stored in S-6 register to change this you must change [P↔S] [STO 6] [P↔S]

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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New data cards can be made for U^{235} Pu^{239} fuels & H_2O , C, on D_2O moderators. The information needed on these cards can be found in John R. Lamarsh, Introduction to Nuclear Engineering.

- P-0 = ρ - Density of Fuel
- P-1 = MW - Molecular weight of fuel
- P-2 = Atom density of fuel
- P-3 = $\Sigma_a F$ - Microscopic cross section of fuel (abs.)(cm⁻¹)
- P-4 = Microscopic cross section of mod. (abs.) (cm⁻¹)
- P-5 = Const A
- P-6 = Const C
- P-7 = $\Sigma_m \Sigma_{sm}$
- P-8 = Microscopic fission cross section of fuel (in barns)
- P-9 = # of neutrons emitted per fission
- S-8 = Diffusion length of moderator (cm)
- S-9 = Diffusion length of fuel (cm)
- A = Enrichment % of fissile fuel
- B = Microscopic abs - cross section of fissile fuel (in barns)
- C = Microscopic abs cross section of U^{238} (in barns)
- D = Radius of fuel pin (cm)
- E = Radius of fuel

All these must be set for different fuel + moderators this is why it is best to record this on a card.

Values for Diff. Fuel + Moderators

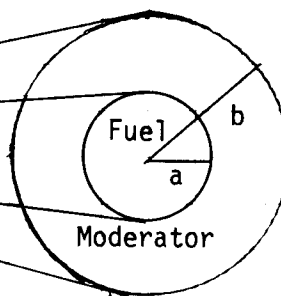
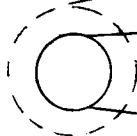
	U^{235}	Pu^{239}	H_2O	D_2O	C
ρ	19.1	21.45			
MW	238	239			
NF	.04833	.04938			
ΣaF					
Σam			.0222	2.9×10^{-5}	.0002728
A	3.0	3.0			
C	38	38			
$\Sigma m \Sigma sm$			1.46	.178	.0608
σ_f	580	742.5			
γ	2.6	2.98			
L_m			2.85	170	59
L_F	1.55	2.0			
σ_{afiss}	680	1011.3			
σ_{a238}	2.7	2.7			

Program Description II

Sketch(es)



Nuclear Fuel Lattice



Sample Problem(s)

What are the parameters of the reactor and is it critical if it is filled graphite moderated with a fuel pin radius of 1.02 cm and a of 25.4 cm. The reactor is a sphere of radius 5 meters.

$\eta = 1.33$	= # of neutrons produced per neutron abs in fuel
$f = .811$	= # of neutrons abs in fuel per neutron abs
$\rho = .98$	= probability a neutron is not abs, in ^{238}U uranium
$\epsilon = 1.0002$	= fast fission factor (from U^{238} fission)
$PL = .879$	= <u>non</u> leakage probability
$k = .936$	= <u>neutrons in generation n</u> neutrons in generation n-1

$k < 1$ so reactor is subcritical

Solution(s) Keystrokes assuming data has been stored.

A -----> 1.33

B -----> .811

C -----> .98

D -----> 1.0002

SF,1 → E -----> .879

```
fE -----> .936
```

Reference(s) See Introduction to Nuclear Engineering.

John R. Lamarsh, Volume 1 pag 188, 198, 203, 202, 204, 227, 229-235, Addison-Wesley Publishing Co., 1975.

97 Program Listing I

57

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	6	06	
002	1	01		058	YX	31	
003	0	00		059	4	04	
004	0	00		060	8	08	
005	RCLA	36 11		061	1/X	52	
006	-	-45		062	X	-35	
007	RCLA	36 11		063	RCLI	36 46	
008	=	-24	Calculates n	064	4	04	
009	RCLC	36 13		065	YX	31	
010	X	-35		066	1	01	
011	RCLB	36 12		067	2	02	
012	+	-55		068	1/X	52	
013	RCL8	36 08		069	X	-35	
014	RCL9	36 09		070	CHS	-22	
015	X	-35		071	+	-55	
016	X*Y	-41		072	RCLI	36 46	
017	=	-24		073	X ²	53	
018	P*S	16-51		074	.	-62	
019	ST00	35 00		075	5	05	
020	ST05	35 05		076	X	-35	
021	P*S	16-51		077	+	-55	
022	RTN	24		078	1	01	
023	*LBLB	21 12		079	+	-55	
024	RCL0	36 00		080	RCLC	36 15	
025	RCL1	36 01		081	X ²	53	
026	=	-24		082	ST01	35 46	
027	.	-62		083	RCLD	36 14	
028	6	06	Calculates f	084	X ²	53	
029	0	00		085	-	-45	
030	2	02		086	RCLI	36 46	
031	3	03		087	=	-24	
032	X	-35		088	X	-35	
033	ST02	35 02		089	P*S	16-51	
034	RCLA	36 11		090	RCL4	36 04	
035	%	55		091	RCL3	36 03	
036	RCLB	36 12		092	=	-24	
037	X	-35		093	X	-35	
038	1	01		094	P*S	16-51	
039	0	00		095	ST01	35 01	
040	0	00		096	RCLC	36 15	
041	RCLA	36 11		097	RCL8	36 08	
042	-	-45		098	=	-24	
043	RCL2	36 02		099	ST01	35 46	
044	X*Y	-41		100	RCLD	36 14	
045	%	55		101	RCL8	36 08	
046	RCLC	36 13		102	=	-24	
047	X	-35		103	=	-24	
048	+	-55		104	LN	32	
049	ST03	35 03		105	RCLI	36 46	
050	P*S	16-51		106	X ²	53	
051	RCLD	36 14		107	RCLD	36 14	
052	RCL9	36 09		108	RCL8	36 08	
053	=	-24		109	=	-24	
054	2	02		110	X ²	53	
055	=	-24		111	-	-45	
056	ST01	35 46		112	RCLI	36 46	

REGIS

0	ρ	1	MW fuel	2	N fuel	3	ΣaF	4	Σam	5	A	6	C	7	Σ _{sm} Σ _{sm}	8	σ _{f25}	9	γ
S0	η	S1	f	S2	ρ	S3	ε	S4	P _L	S5	K	S6	Radius (cm)	S7		S8	L _M	S9	L _F
A	enrich %	B	σ _a fiss. fuel	C	σ _a non fiss fuel	D	a (cm)	E	b (cm)	I	used								

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	X ²	53		169	e ^x	33	
114	X ² Y	-41		170	P ² S	16-51	
115	÷	-24		171	ST02	35 02	
116	x	-35		172	STx5	35-35 05	
117	.	-62		173	P ² S	16-51	End of p
118	7	07		174	RTN	24	
119	5	05		175	*LBLD	21 14	
120	-	-45		176	RCLD	36 14	
121	RCLD	36 14		177	X ²	53	
122	RCL8	36 08		178	ST01	35 46	
123	÷	-24		179	RCLE	36 15	
124	4	04		180	X ²	53	Calculates
125	÷	-24		181	RCLI	36 46	ε
126	RCLI	36 46		182	-	-45	
127	÷	-24		183	÷	-24	
128	RCLI	36 46		184	.	-62	
129	÷	-24		185	1	01	
130	+	-55		186	x	-35	
131	RCLI	36 46		187	1	01	
132	X ²	53		188	+	-55	
133	x	-35		189	P ² S	16-51	
134	2	02		190	ST03	35 03	
135	÷	-24		191	STx5	35-35 05	
136	1	01		192	P ² S	16-51	
137	+	-55		193	RTN	24	
138	RCL1	36 01		194	*LBL E	21 15	
139	+	-55		195	P ² S	16-51	
140	1/X	52		196	Pi	16-24	Calculates
141	ST01	35 01	End of f	197	RCL6	36 06	
142	STx5	35-35 05		198	÷	-24	P _L
143	P ² S	16-51		199	X ²	53	
144	RTN	24		200	F1?	16 23 01	
145	*LBLC	21 13		201	GT01	22 01	
146	RCL0	36 00		202	3	03	
147	RCLD	36 14		203	x	-35	
148	x	-35		204	*LBL1	21 01	
149	√x	54		205	ST01	35 46	
150	RCL6	36 06	Calculates	206	RCL8	36 08	
151	X ² Y	-41	p	207	GSB9	23 09	
152	÷	-24		208	ST04	35 04	
153	RCL5	36 05		209	STx5	35-35 05	
154	+	-55		210	P ² S	16-51	
155	RCLD	36 14		211	RTN	24	
156	X ²	53		212	*LBL9	21 09	
157	x	-35		213	X ²	53	
158	RCL2	36 02		214	x	-35	
159	x	-35		215	1	01	
160	RCL7	36 07		216	+	-55	
161	÷	-24		217	1/X	52	
162	RCLE	36 15		218	RTN	24	
163	X ²	53		219	*LBL e	21 16 15	
164	RCLD	36 14		220	P ² S	16-51	Recall K
165	X ²	53		221	RCL5	36 05	
166	-	-45		222	P ² S	16-51	
167	÷	-24		223	RTN	24	
168	CHS	-22					

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS	TRIG	DISP
η	f	p	ε	P _L	1	ON OFF		
a	b	c	d	e	1	0 ☐ ☒	DEG ☒	FIX ☒
0	1	2	3	4	2	1 ☒ ☒	GRAD ☐	SCI ☐
5	6	7	8	9	3	2 ☐ ☒	RAD ☐	ENG ☐
						3 ☒ ☐		n <u>5</u>

Program Description I

Program Title Semi-Empirical Nuclear mass Formula

Contributor's Name Dan Shapira

Address Physics Division, Oak Ridge National Laboratory, Bldg. 5500 X-10

City Oak Ridge **State** Tennessee **Zip Code** 37830

Program Description, Equations, Variables 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 $-N$.

Definitions: 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

$M(N,Z)$ = 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

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

$$E_v = -a_1 * A, \quad E_s = a_2 * A^{2/3}, \quad E_c = a_3 * Z^2/A^{1/3}$$

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

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

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

Operating Limits and Warnings 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.

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Program Description II

Sketch(es)

Sample Problem(s) Which one of the mass-25 isobars (Nuclei with same number of protons+neutrons) is stable.

A=25 isobars are nuclei that can have N(#of neutrons) = 10, 11, 12, 13, 14 etc.
and at the same time Z(#of protons) = 15, 14, 13, 12, 11 respectively

The most stable Isobar will be the one that is most strongly bound nucleus.

The experimental observation is that the only stable Isobar of A=25 is the element Mg (Magnesium) which has Z=12 and N=13

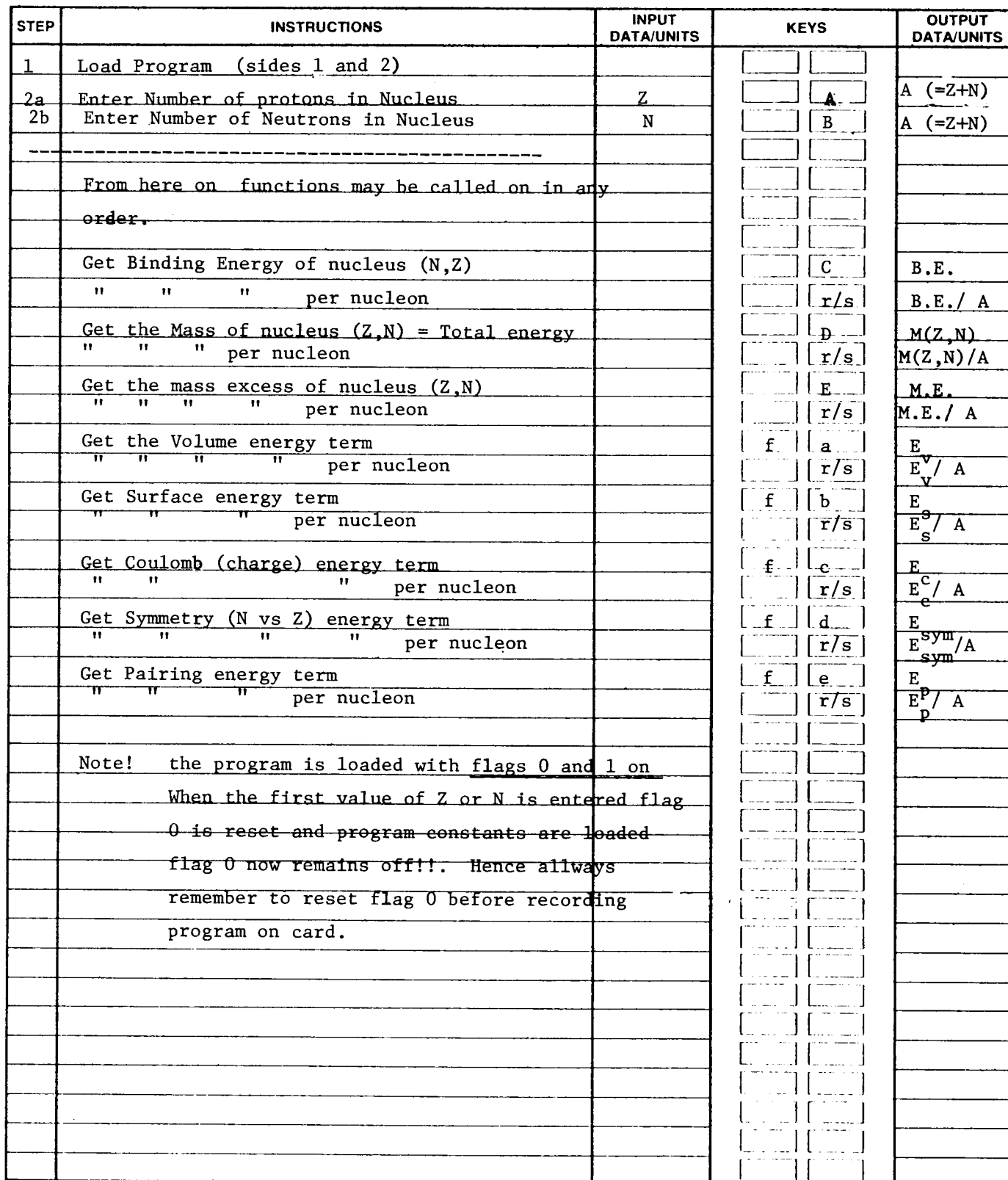
One can make use of the semiempirical mass formula in predicting this result

For each Z and N in this group we shall calculate the binding energies (all the binding energies will be negative numbers) the largest number (in this case the most negative one) will belong to the most stable Isobar.

SOLUTION(S)	KEYSROKES	DISPLAY	COMMENTS
	10, A	10	enter Z of Isobar
	15, B	25	N of Isobar(mass displ.)
	C	-180.69	Display Binding energy
	11, A	26	new Z entered
	14, B	25	new N entered
	C	-193.53	Display binding energy
	12, A, 13, B	25	enter new Z and N
	C	-196.88	Display new binding energy
	13, A, 12, B	25	New Z, N
	C	-190.75	Display new binding energy
	14, A, 11, B	25	New Z, N
	C	-175.14	New binding energy

From the results displayed - the Z=12, N=13 combination has the highest value of binding energy.

Reference(s) De Shalit and Feshbach Theoretical Nuclear Physics



REGISTERS

A	Z	N						-a.m.u.	M_p
S0 $M_{(m)}$	S1 $-a_1$	S2 a_2	S3 a_3	S4 a_4	S5 $-a_5$	S6	S7	S8 $I \times M_p$	S9 $N \times M_n$
A E_V	B E_S	C E_c	D E_{sym}	E E_{pair}	I				

67 Program Listing II

63

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
	GSB4	31 22 04			6	06	
	GTO7	22 07		170	GSB8	31 22 08	
	LBL E	31 25 15			1	01	
	GSB1	31 22 01			5	05	
	1	01			.	83	
	6	06			6	06	
	STI	35 33			8	08	
120	GSB4	31 22 04			CHS	42	
	LBL7	31 25 07			GSB8	31 22 08	
	RIS	84			1	01	
	RCL 0	34 00			8	08	
	÷	81		180	.	83	
	RTN	35 22			5	05	
	LBL4	31 25 04			6	06	
	0	00			GSB8	31 22 08	
	STO6	33 06			.	83	
	LBL5	31 25 05			7	07	
130	ISZ	31 34			1	01	
	RCL	35 34			7	07	
	2	02			GSB8	31 22 08	
	5	05			2	02	
	-	51		190	8	08	
	X=0	31 51			.	83	
	GTO6	22 06			1	01	
	RCL(1)	34 24			GSB8	31 22 08	
	STO+6	33 01 06			1	01	
	GTO5	22 05			7	07	
140	LBL6	31 25 06			CHS	42	
	RCL6	34 06			GSB8	31 22 08	
	RTN	35 22			CFO	35 61 00	
	LBL9	31 25 09			RCL 0	34 00	
	7	07		200	RTN	35 22	
	STI	35 33			LBL8	31 25 08	
	9	09			ISZ	31 34	
	3	03			STO(2)	33 24	
	1	01			RTN	35 22	
	.	83					
150	5	05					
	0	00					
	4	04					
	CHS	42					
	GSB8	31 22 08		210			
	9	09					
	3	03					
	8	08					
	.	83					
	7	07					
160	9	09					
	3	03					
	GSB8	31 22 08		220			
	9	09					
	3	03					
	9	09					
	.	83					
	5	05					
	7	07					

LABELS					FLAGS	SET STATUS		
A ENTER	B ENTER	C B.E.	D M(Z,N)	E H. EXCESS	0	FLAGS	TRIG	DISP
Z	N				↘	ON OFF		
→ E _v	→ E _s	→ E _c	→ E _{sym}	→ E _{par}	1	0 ☒ ☐	DEG ☐	FIX ☐
0	1	2	3	4	2	1 ☒ ☐	GRAD ☐	SCI ☒
5	6	7	8	9	3	2 ☐ ☐	RAD ☐	ENG ☐
						3 ☐ ☐		n 4

Program Description I

Program Title	Clebsch-Gordon Coefficients and 3j Symbols Evaluation
---------------	---

Contributor's Name G. Richard Scott

Address 110 Donelsonwood Drive

City **Nashville**

State Tennessee

Zip Code 37214

Program Description, Equations, Variables This program will evaluate all valid Clebsch-Gordan 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;

$$\underbrace{\begin{pmatrix} j_1 & j_2 & J \\ m_1 & m_2 & -M \end{pmatrix}}_{3j \text{ SYMBOL}} = (-1)^{j_1-j_2+M} \sqrt{\Delta(j_1, j_2, J)} \sqrt{(j_1+m_1)! (j_1-m_1)! (j_2+m_2)! (j_2-m_2)! (J+M)! (J-M)!}$$

with $\Delta(j_1, j_2, \bar{j}) \equiv [(j_1 + j_2 - \bar{j})! (j_2 + \bar{j} - j_1)! (\bar{j} + j_1 - j_2)!] \div (j_1 + j_2 + \bar{j} + 1)!$

SUBJECT TO THE RESTRAINTS

$$\textcircled{1} |j_1 - j_2| \leq J \leq |j_1 + j_2|$$

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

THE CLEBSCH-GORDAN COEFFICIENT, $\langle j_1 j_2 m_1 m_2 | JM \rangle = \frac{\sqrt{2J+1}}{(-1)^{j_1-j_2+m}} \begin{pmatrix} j_1 & j_2 & J \\ m_1 & m_2 & -M \end{pmatrix}$

Operating Limits and Warnings If any one term in the Racah formula is greater than 69, an error message will result (or else the calculator will display all 9's in the x-register). If illegitimate values are entered for j_1 , j_2 , and J or for m_1 , m_2 , and M , spurious results (ie, non-zero) may be obtained or the the calculator may get caught in a "loop" which will not terminate until the "t" value in the

Racah formula exceeds 69.

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Program Description II

Sketch(es)

Sample Problem(s) ① SUPPOSE THE G.G. COEFFICIENT $\langle j_1 j_2 m_1 m_2 | JM \rangle$ IS NEEDED WITH $j_1 = \frac{3}{2}$, $j_2 = 2$, $J = \frac{5}{2}$; $m_1 = \frac{1}{2}$, $m_2 = 0$, $M = \frac{1}{2}$.

NOTE FOR SOLUTIONS: j_1 is "entered" by pressing "A"

j_2	"	"	"	"	B
J	"	"	"	"	C
m_1	"	"	"	"	f[A]
m_2	"	"	"	"	f[B]

M is keyed in as -M and is "entered" by pressing f[C]

② IF THE 3J SYMBOL $\begin{pmatrix} j_1 & j_2 & J \\ m_1 & m_2 & -M \end{pmatrix}$ was desired, IT IS STORED IN REGISTER E.

Solution(s) ① 1.5 [A] 2 [B] 2.5 [C] .5 f[A] 0. f[B] - .5 f[C]
completes entry of data

[D] starts program $\rightarrow 2.927700221-01$
(DIMENSIONLESS)

② [RCL] [E] $\rightarrow 1.195228610-01$
(DIMENSIONLESS)

Reference(s) MESSIAH, ALBERT, QUANTUM MECHANICS,
VOLUME II, pp 1054-1058, NORTH-HOLLAND
PUBLISHING CO. (AMSTERDAM) AND JOHN WILEY
& SONS (NEW YORK), 1958.
(translated from the French edition)

97 Program Listing I

67

			COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	C L E A R S R E G I S T E R S A N D S T O R E S J ₁	057	JX	54	S T O R E S $\sqrt{\Delta(J_1, J_2, J)}$ C O M P U T E S
002	CLRG	16-53		058	ST04	35 04	
003	P=S	16-51		059	1	01	
004	CLRG	16-53		060	1	01	
005	ST01	35 01		061	ST01	35 46	
006	RTN	24	S T O R E S J ₂	062	RCL1	36 01	$\sqrt{(j_1+m_1)! (j_1-m_1)! (j_2+m_2)! (j_2-m_2)! (J+W)! (J-W)!}$ C O M P U T E S $(-1)^{j_1-j_2+M}$
007	*LBLB	21 12		063	RCLi	36 45	
008	ST02	35 02		064	+	-55	
009	RTN	24		065	N!	16 52	
010	*LBLC	21 13		066	RCL1	36 01	
011	ST03	35 03	S T O R E S J	067	RCLi	36 45	
012	P=S	16-51	S T O R E S m ₁	068	-	-45	
013	RTN	24		069	N!	16 52	
014	*LBLD	21 16 11		070	x	-35	
015	ST01	35 01		071	ST05	35 05	
016	RTN	24		072	ISZ1	16 26 46	
017	*LBLB	21 16 12	S T O R E S m ₂	073	RCL2	36 02	
018	ST02	35 02	S T O R E S -M	074	RCLi	36 45	
019	RTN	24		075	+	-55	
020	*LBLD	21 16 13		076	N!	16 52	
021	ST03	35 03		077	RCL2	36 02	
022	P=S	16-51		078	RCLi	36 45	
023	RTN	24	B E G I N S C O M P U T A T I O N S $\Delta(J_1, J_2, J)$ I S C O M P U T E D I N S T E P S 25-57	079	-	-45	
024	*LBLD	21 14		080	N!	16 52	
025	RCL1	36 01		081	x	-35	
026	RCL2	36 02		082	STX5	35-35 05	
027	RCL3	36 03		083	ISZ1	16 26 46	
028	-	-45	C O M P U T E S $(-1)^{j_1-j_2+M}$	084	RCL3	36 03	
029	+	-55		085	RCLi	36 45	
030	N!	16 52		086	+	-55	
031	ST04	35 04		087	N!	16 52	
032	RCL2	36 02		088	RCL3	36 03	
033	RCL3	36 03		089	RCLi	36 45	
034	RCL1	36 01		090	-	-45	
035	-	-45		091	N!	16 52	
036	+	-55		092	x	-35	
037	N!	16 52		093	STX5	35-35 05	
038	STX4	35-35 04		094	RCL5	36 05	
039	RCL3	36 03		095	JX	54	
040	RCL1	36 01		096	ST05	35 05	
041	RCL2	36 02		097	RCL1	36 01	
042	-	-45	M U L T I P L I E S C O M P U T E D S Q. R O O T S T O G E T H E R; M U L T I P L I E S B Y $(-1)^{j_1-j_2+M}$ S T O R E S A D	098	RCL2	36 02	
043	+	-55		099	RCLi	36 45	
044	N!	16 52		100	+	-55	
045	STX4	35-35 04		101	-	-45	
046	1	01		102	1	01	
047	RCL1	36 01		103	CHS	-22	
048	RCL2	36 02		104	X*Y	-41	
049	RCL3	36 03		105	YX	31	
050	+	-55		106	ST06	35 06	
051	+	-55		107	RCL4	36 04	
052	+	-55		108	RCL5	36 05	
053	N!	16 52		109	RCL6	36 06	
054	RCL4	36 04		110	x	-35	
055	X*Y	-41		111	x	-35	
056	÷	-24		112	ST0D	35 14	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	USED	USED	USED	USED	USED	USED	USED	USED	USED
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
	USED	USED	USED						
A	B	C	D	E	I	3J VALVE			
USED	USED	USED	USED	USED					USED

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	CLX	-51		169	+	-55	
114	SF0	16 21 00	COMPUTES	170	RCLI	36 46	
115	STOI	35 46		171	-	-45	
116	P=S	16-51	SUMMATION	172	X<0?	16-45	
117	RCL1	36 01	IN	173	GT03	22 03	
118	STOA	35 11		174	N!	16 52	
119	RCL2	36 02	RACAH	175	ST08	35 08	
120	STOB	35 12		176	CF0	16 22 00	
121	RCL3	36 03	FORMULA	177	RCL4	36 04	
122	STOC	35 13		178	RCL5	36 05	
123	P=S	16-51	(STEPS	179	RCL6	36 06	
124	*LBL2	21 02	113-198)	180	X	-35	
125	RCL3	36 03		181	X	-35	
126	RCLI	36 46		182	RCL7	36 07	
127	RCLA	36 11		183	RCL8	36 08	
128	+	-55		184	X	-35	
129	+	-55		185	X	-35	
130	RCL2	36 02		186	RCLI	36 46	
131	-	-45		187	N!	16 52	
132	X<0?	16-45		188	X	-35	
133	GT03	22 03		189	1/X	52	
134	N!	16 52		190	1	01	
135	ST04	35 04		191	CHS	-22	
136	RCL3	36 03		192	RCLI	36 46	
137	RCLI	36 46		193	Y*	31	
138	+	-55		194	X	-35	
139	RCL1	36 01		195	ST+9	35-55 09	
140	RCLB	36 12		196	ISZI	16 26 46	
141	+	-55		197	GT02	22 02	
142	-	-45		198	GT02	22 02	
143	X<0?	16-45		199	*LBL3	21 03	
144	GT03	22 03		200	ISZI	16 26 46	
145	N!	16 52		201	F0?	16 23 00	
146	ST05	35 05		202	GT02	22 02	
147	RCL1	36 01		203	RCL9	36 09	
148	RCL2	36 02		204	RCLD	36 14	
149	+	-55		205	X	-35	
150	RCL3	36 03		206	STOE	35 15	
151	RCLI	36 46		207	1	01	
152	+	-55		208	CHS	-22	
153	-	-45		209	RCL1	36 01	
154	X<0?	16-45		210	RCLC	36 13	
155	GT03	22 03		211	-	-45	
156	N!	16 52		212	RCL2	36 02	
157	ST06	35 06		213	-	-45	
158	RCL1	36 01		214	Y*	31	
159	RCLI	36 46		215	RCL3	36 03	
160	RCLA	36 11		216	2	02	
161	+	-55		217	X	-35	
162	-	-45		218	1	01	
163	X<0?	16-45		219	+	-55	
164	GT03	22 03		220	JX	54	
165	N!	16 52		221	X	-35	
166	ST07	35 07		222	RCLC	36 15	
167	RCL2	36 02		223	X	-35	
168	RCLB	36 12		224	RTN	24	

CHECKS TO
SEE IF $\frac{t}{t}$ finished;
IF SO, COMPUTES
3J VALUE,
STORES IN
REGISTER E

COMPUTES
CLEBSCH-
GORDON
COEFFICIENT

LABELS					FLAGS	SET STATUS		
A	B	C	D	E		FLAGS	TRIG	DISP
f	J ₁	J	D → C.G		0	ON OFF		
a	M ₁	m ₂	-M		1	0 ☒ ☐	DEG ☒	FIX ☐
0	1	2	calc	3	2	1 ☐ ☒	GRAD ☐	SCI ☒
5	6	7		8	3	2 ☐ ☒	RAD ☐	ENG ☐
				9		3 ☐ ☒		n <u>9</u>

Program Description I

Program Title **32-P REMAINING ON MM.DDYYYY GIVEN MCI ON
EARLIER MM.DDYYYY**
 Contributor's Name **GARY G. ALTMAN**
 Address **3307 NORTHBROOK DRIVE**
 City **MIDDLETON** State **WISCONSIN** Zip Code **53562**

Program Description, Equations, Variables

1. JULIAN DAY NUMBER IS CALCULATED AS DESCRIBED IN THE HP-67 STANDARD PAC, PAGE 04-01;
THE NUMBER OF DAYS BETWEEN DATE 1 AND DATE 2 IS ALSO CALCULATED AS DESCRIBED IN THE HP-67 STANDARD PAC.
2. RADIOACTIVE DECAY: $(\text{INITIAL mCi})(0.5)^n = \text{mCi ON DATE 2}$, WHERE $n = 14.3 / \Delta \text{DAYS} = \text{THE NUMBER OF HALF-LIVES OF } ^{32}\text{P WHICH HAVE OCCURRED}$.
3. SUBROUTINE D YIELDS: mCi ON DATE 2 ;
 $(\text{mCi ON DATE 2})(2.2 \times 10^9 \text{ DPM}) = \text{DPM ON DATE 2}$;
AND $(0.3)(\text{DPM}) \approx \text{CPM ON DATE 2}$
[ASSUMES 30% COUNTING EFFICIENCY AND NO QUENCHING]
4. SUBROUTINE F C YIELDS:
 $(0.5)^n (\text{CPM ON DATE 1}) = \text{CPM ON DATE 2}$; AND
 $[(2.2 \times 10^9 \text{ DPM / mCi}) / (\text{CPM / 1.3})]^{-1} = \text{mCi ON DATE 2}$

Operating Limits and Warnings **PROGRAM FAILS IF DATE 1 = DATE 2 OR
IF DATE 1 IS MORE RECENT THAN DATE 2.**

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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Program Description II

Sketch(es)

Sample Problem(s) 1. HOW MANY DPM (AND CPM) REMAIN OF A 0.135 mCi ^{32}P SAMPLE? GIVEN: DATE OF SPECIFIC RADIOACTIVITY RATING AS FEB 2, 1977; AND TODAY'S DATE APRIL 22, 1977.

2. HOW MANY CPM (AND mCi) REMAIN OF A 3.2×10^6 CPM SAMPLE OF ^{32}P AS MEASURED BY CHERENKOV RADIATION ON AUGUST 11, 1976?

Solution(s) 1. 2.071977 A (DISPLAY: 2443182) 4.221977 B (DISPLAY: 2443256.) C (DISPLAY: 74., THE NUMBER OF DAYS BETWEEN FEB 7 AND APR 22) 0.135 D (DISPLAY: 8.2220×10^6 , 2.466×10^6 - THE DPM AND THE CPM REMAINING)
2. 8.111976 A (2443002.) 4.221977 B (2443256.) C (254. = ΔDAYS) 3.2 EEX 6 F C (ANSWERS: 14., 2.18×10^{-8} - 14 CPM REMAINING, 2.18×10^{-8} mCi REMAINING.)

Reference(s) CALENDAR FUNCTIONS, PAGE 04-01 IN HP-67 STANDARD PAC, AND CHASE, G.D. & J.L. RABINOWITZ, PRINCIPLES OF RADIOISOTOPE METHODOLOGY, BURGESS, MINNEAPOLIS, MN (1962).

71

[illegible]

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS		
001	F LBL A	31 25 11		57	STO 7	33 07	CALC		
2	F FIX	31 23	CALC ΔDAYS	58	RCL A	34 11	DAY OF MONTH		
3	DSP 2	23 02	AND PUT CONTROL	59	h X2Y	35 52			
4	RCL 4	34 04	3 IN DISPLAY	060	RCL 6	34 06			
5	RCL C	34 13		61	X	71			
6	-	51		62	F INT	31 83			
7	3	03		63	-	51			
8	GTO 0	22 00		64	STO 6	33 08			
9	F LBL B	31 25 12		65	RCL 7	34 07	BUILD (M'-1).DD		
010	RCL 3	34 03	CALCULATE	66	1	01	PART OF DISPLAY		
11	RCL C	34 13	ΔDAYS AND PUT	67	RCL 8	34 08			
12	+	61	4 IN DISPLAY	68	F %	31 82			
13	4	04		69	-	51			
14	F LBL 0	31 25 00		070	-	51			
15	h STO i	35 33	STORE CONTROL	71	RCL 7	34 07	CORRECT M'-1		
16	h RV	35 53	CODE	72	1	01	AND Y' TO M		
17	3	03	STORE	73	4	04	AND Y.		
18	6	06	CONSTANTS	74	÷	81			
19	5	05		75	GSR 2	31 22 02			
020	.	83		76	RCL 9	34 09	FINISH BUILDING		
21	2	02		77	EEY	43	MM.DDYYYY		
22	5	05		78	6	06	RESULT AND DISPLAY		
23	STO 5	33 05		79	÷	81	ANSWER.		
24	3	03		080	+	61			
25	0	00		81	DSP 6	23 06			
26	.	83		82	h RTN	35 22			
27	6	06		83	F LBL 1	31 25 01	BREAK DATE		
28	0	00		84	h RV	35 53	INPUT INTO THE		
29	0	00		85	↑	41	INDIVIDUAL		
030	1	01		86	F INT	31 83	COMPONENTS OF		
31	STO 6	33 06		87	STO 7	33 07	MM, DD, YYYY.		
32	h RV	35 53	RETURN ΔDAYS	88	-	51			
33	h RV	35 53	TO DISPLAY	89	EEY	43			
34	h F 3?	35 71 03	IF DATA INPUT	090	2	02			
35	GTO 1	22 01	GO TO 1	91	X	71			
36	h ST i	33 24	STORE ΔDAYS	92	↑	41			
37	1	01	ACCORDING TO	93	F INT	31 83			
38	2	02	CONTROL MODE	94	STO 8	33 08			
39	2	02		95	-	51			
040	.	83	CALC Y'.	96	EEY	43			
41	1	01		97	4	04			
42	-	51		98	X	71			
43	RCL 5	34 05		99	STO 9	33 09			
44	÷	81		100	RCL 7	34 07	M+1		
45	F INT	31 83		101	1	01			
46	STO 9	33 09	CALC M'.	102	+	61			
47	RCL 5	34 05		103	↑	41			
48	X	71		104	h 1/X	35 62	M+1 → M'		
49	F INT	31 83		105	.	83			
050	h RCL i	34 24		106	7	07			
51	-	51		107	+	61			
52	CHS	42		108	CHS	42			
53	STO A	33 11		109	GSR 2	31 22 02			
54	RCL 6	34 06		110	RCL 6	34 06	COMPUTE		
55	÷	81		111	X	71	JULIAN DAY		
56	F INT	31 83		112	F INT	31 83	NUMBER		
REGISTERS									
0	1	2	3 DAY 1	4 DAY 2	5 365.25	6 30.6001	7 MM	8 DD	9 YYYY
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A USED		B		C Δ DAYS		D		E I CONTROL	

67 Program Listing II

73

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCL 9	34 09		169	RCL 2	34 02	
114	RCL 5	34 05		170	$\div$	81	
115	X	71		171	h y ^x	35 63	$(\frac{1}{2})^n$
116	F INT	31 83		172	h 1/x	35 62	
117	+	61		173	RCL 0	34 00	
118	RCL 8	34 08		174	RCL 1	34 01	
119	+	61		175	X	71	
120	h STI	33 24		176	X	71	
121	1	01		177	g sci	32 23	
122	7	07		178	DSP 4	23 04	
123	2	02		179	f-x-	31 84	DISPLAY DPM
124	0	00		180	$\uparrow$	41	
125	9	09		181	.	83	
126	8	08		182	3	03	
127	2	02		183	X	71	
128	+	61		184	f-x-	31 84	DISPLAY CPM
129	DSP 0	23 00		185	h RTN	35 22	
130	h RTN	35 22		186	g 16LC	32 25 13	
131	FLBL 2	31 25 02	IF INPUT TO THIS ROUTINE HAS ABS VALUE OF 1 OR >	187	STO A	33 11	STORE CPM
132	F INT	31 83	Y = Y ± 1	188	RCL C	34 13	
133	STO + 9	33 61 09	M = M ± 12	189	RCL 2	34 02	
134	1	01	(+ FOR PLUS INPUT)	190	$\div$	81	$\Delta \text{DAYS} = n$
135	2	02		191	.	83	$\frac{1}{14.3} = n$
136	X	71		192	5	05	
137	-	51		193	h x ² y	35 52	
138	h RTN	35 22		194	h y ^x	35 63	$(\frac{1}{2})^n$
139	FLBL C	31 25 13	STORE INPUT	195	RCL A	34 11	
140	DSP 0	23 00		196	X	71	
141	STO C	33 13		197	f-x-	31 84	DISPLAY CPM
142	h F3	35 71 03	IF INPUT FLAG TRUE, THEN STOP	198	.	83	
143	h RTN	35 22		199	3	03	
144	RCL 4	34 04	COMPUTE Δ DAYS AND STOP	200	$\div$	81	
145	RCL 3	34 03		201	RCL 1	34 01	
146	-	51		202	$\div$	81	
147	STO C	33 13		203	h RTN	35 22	DISPLAY mCi
148	h RTN	35 22					
149	h F3	35 71 03					
150	STO 4	22 04					
151	FGTO C	31 22 13	COMPUTE Δ DAYS				
152	DSP 1	23 01					
153	FLBL D	31 25 14	STORE CONSTANTS				
154	STO 0	33 00					
155	1	01					
156	4	04					
157	.	83					
158	3	03					
159	STO 2	33 02					
160	2	02					
161	.	83					
162	2	02					
163	EEX	43					
164	9	09					
165	STO 1	33 01					
166	FLBL E	31 25 15					
167	2	02					
168	RCL C	34 13	$\Delta \text{DAYS} = n$ 14.3				

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS		TRIG
DATE 1	DATE 2	Δ DAYS	mCi → CPM			ON	OFF	DISP
a	b	CPM → mCi	d	e	1	0	☐	DEG ☒
0	1	2	3	4	2	1	☐	GRAD ☐
5	6	7	8	9	3	2	☐	RAD ☐
						3	☐	VARIES
								FIX ☐
								SCI ☐
								ENG ☐
								n

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Industrial Engineering
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EINSTEIN'S TWIN PARADOX

DELTA-V—ORBIT SIMULATOR

EQUATIONS OF PARTICLE MOTION

BALLISTICS TRAJECTORY COMPUTATIONS

ISOTOPE OVERLAP CORRECTIONS

CRITICAL REACTOR CODE

SEMI-EMPIRICAL NUCLEAR MASS FORMULA

CLEBSCH-GORDON COEFFICIENTS AND $3j$ SYMBOLS EVALUATION

32-P REMAINING ON MM.DDYyyy GIVEN MCI ON EARLIER
MM.DDYyyy



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