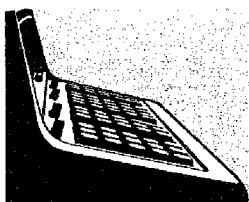


HEWLETT-PACKARD CALCULATOR

Model 9100A

Program Library



January 1, 1969

HEWLETT-PACKARD 9100A PROGRAM LIBRARY

Introduction

Here is the Program Library furnished with your 9100A Calculator. The purpose of the Program Library is to demonstrate calculator capability in many areas and to illustrate programming technique. We hope you will find the format, examples selected and the problem solutions useful, convenient, and easy to use.

The programs have been placed in the three-ring binder with category dividers so that changes, additions and reorganizations can be easily made. Each category has a corresponding part number and each program within a category is numbered consecutively according to the category part number. Additional binders may be purchased at a minimal cost to contain your programs.

The programs within the Program Library have been thoroughly tested and will yield accurate results. Each program includes a title, general description that includes formulas used in the program solution, reference, user instructions, and examples that you may use to test the operation of the program. Program steps are also included with each program. Comments have been placed by the program steps or flow charts have been included pointing out how problems were solved and programming techniques.

The program steps must be manually entered into the calculator step-by-step the first time. Then if you desire, you may record the program on a magnetic card furnished with your calculator. The use of the magnetic card eliminates the manual step-by-step entry. Programs recorded on the magnetic card may be entered instantly, using the ENTER button on the calculator. After entering the program steps into the calculator, it is suggested that you use the sample data to see if you get the test answers. If you do not get the correct answers, it is suggested that you carefully check each program step to see if the program is correctly entered into the appropriate location and/or re-read the user instructions. This may be done by comparing the step location and the code number to the printed program. You can do this very conveniently using the STEP PROGRAM key in the program mode.

The format of the programs is consistent, however, there are minor differences in the operation of the programs. Some programs are multiple-pass programs and others require re-entry before each set of test data, because they are "destructive" programs. A "destructive" program is one where we store data back into registers of the calculator that contain previously executed instructions. These program instructions have been destroyed. Before re-executing another problem and a different set of data, the program steps must be re-entered. This can be conveniently done by using the magnetic card. Record "destructive" programs on the magnetic card before trying any data, i.e., key the program steps into the calculator and record these on the magnetic card, then test the sample data.

We hope you find the 9100A Library a useful tool and guide for your computational work. To better serve you and other 9100A users, we welcome you to send us program solutions you have written. Please write them up in a similar format to the programs furnished in the Program Library and send them to us. Those having general interest will be published and added to the Library. Also send in any comments you might have on the 9100A Calculator and Program Library to our Applications Group. We at Hewlett-Packard look forward to serving you.

Sincerely,

HEWLETT-PACKARD COMPANY

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ApplicationsP.O. Box 301
Loveland, Colorado 80537



MATHEMATICS 09100-70000

70001 n!

Calculates $n!$ for positive integer n . ($n < 70$)

70002 - POLYNOMIAL EVALUATION

Evaluates polynomials of the form:

$$f(z) = C_n z^n + C_{n-1} z^{n-1} + \dots + C_1 z + C_0$$

for complex C_i , $i=1, \dots, n$ and complex z .

70003 - NUMERICAL INTEGRATION USING SIMPSON'S ONE-THIRD RULE

Uses Simpson's rule to obtain the area under a curve. The equation used is:

$$A = \frac{h}{3} (Y_0 + 4Y_1 + Y_2)$$

70004 - VECTOR CROSS PRODUCT $\vec{A} \times \vec{B}$

Calculates the vector cross product ($\vec{A} \times \vec{B}$) of two three-dimensional vectors of the form:

$$\vec{A} = a_1 \vec{i} + a_2 \vec{j} + a_3 \vec{k}$$

$$\text{and } \vec{B} = b_1 \vec{i} + b_2 \vec{j} + b_3 \vec{k}$$

70005 - ANGLE BETWEEN TWO THREE-DIMENSIONAL VECTORS

Calculates the angle between two three-dimensional vectors of the form:

$$\vec{A} = a_1 \vec{i} + a_2 \vec{j} + a_3 \vec{k}$$

$$\text{and } \vec{B} = b_1 \vec{i} + b_2 \vec{j} + b_3 \vec{k}$$

70006 - 1st ORDER DIFFERENTIAL EQUATIONS

Solves differential equations of the form:

$$y' = f(x, y)$$

70007 - RAISING A NUMBER TO A POWER

Solves the equation:

$$Z_3 = Z_1^{Z_2} \text{ where } Z_i = X_i + jY_i \quad i = 1, 2, 3$$

70008 - 2nd ORDER DIFFERENTIAL EQUATIONS

Solves differential equations of the form:

$$y'' = f(x, y, y')$$

70009 - QUADRATIC EQUATION

Solves $ax^2 + bx + c = 0$ for the roots.

70010 - FINITE DIFFERENCE INTERPOLATION USING GAUSS'S BACKWARD FORMULA

Uses Gauss's backward formula for interpolation in tabular data with equal abscissa spacing. The program fits a cubic equation through the tabular data.

70011 - CUBIC EQUATION

Solves $x^3 + px^2 + qx + r = 0$ for the real and complex roots.

MATHEMATICS (CONT.)

70012 - OCTAL $\leftrightarrow$ DECIMAL CONVERSIONS

Converts octal numbers to decimal or decimal numbers to octal.

70013 - FACTORS OF n

Gives all factors of an integer n.

70014 - REAL ROOTS OF f(x)

Calculates real roots for f(x) by starting from x_0 and incrementing until f(x) changes sign, then converges on the root. f(x) is programmed in by the user.

70015 - NUMERICAL INTEGRATION USING SIMPSON'S RULE WHEN f(x) IS KNOWN

The specific f(x) is programmed into the calculator by the user and is then used by the general solution to evaluate the integral. Execution time is dependent on the number of panels. Note f(x) should not have any singularities in the integration interval.

70016 - SIMULTANEOUS SOLUTION OF TWO EQUATIONS IN TWO UNKNOWNNS

The program solves two independent equations of the form:

$$\begin{aligned} ax + by &= e \\ cx + dy &= f \end{aligned}$$

x and y are the unknowns to be found.

70017 - n! (n < 10¹²)

Calculates n! for positive integer n.

70018 - CONVOLUTION

This program solves the convolution integral $\int_0^t f_1(t-\tau) f_2(\tau) d\tau$

70019 - 4TH OR 5TH DEGREE POLYNOMIAL ROOTS

Calculates the roots, real and/or complex, of 5th or 4th degree polynomials of the forms:

$$5th \quad x^5 + a_4x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

$$4th \quad x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

70020 - INTEGRAL OF THE FORM: $f(x) = \int_A^x f(u) du$

This program calculates the integral of a known function f(u) between any lower limit A and a successively incremented upper limit X. Simpson's rule is used to perform the integration.

70021 - POLYNOMIAL EVALUATION (1 ≤ n ≤ 10)

Repeatedly evaluates for a given x, a real polynomial of the form:

$$f(x) = A_n x^n + A_{n-1} x^{n-1} + \dots + A_1 x + A_0 \text{ for } 1 \leq n \leq 10$$

70022 - 3 x 3 MATRIX INVERSION OR SIMULTANEOUS SOLUTION OF THREE EQUATIONS IN THREE UNKNOWNNS

Solves three linear independent equations in three unknowns simultaneously or inverts a 3 x 3 matrix.

70023 - FOURIER SERIES

Calculates the Fourier Series coefficients that represent a periodic time function f(t) with period T. The specific f(t) is programmed into the calculator by the user.

70024 - GAMMA FUNCTION

Evaluates the gamma function $\Gamma(\nu)$ for $0 \leq \nu \leq 10^9$ where $\Gamma(\nu) = \int_0^\infty e^{-t} t^{\nu-1} dt$

70025 - BESSEL FUNCTION

Calculates the value of the Bessel function $J_n(x)$ of the first kind of integer order n where

$$J_n(x) = \left(\frac{x}{2}\right)^n \sum_{k=0}^{\infty} \frac{\left(-\frac{x^2}{4}\right)^k}{k! (n+k)!}$$

STATISTICS 09100-70800

70801 - MEAN AND STANDARD DEVIATION

Calculates the mean and standard deviation of n data points.

70802 - STANDARD DEVIATION AND MEAN OF GROUPED DATA

Calculates the mean and standard deviation of data points of certain frequencies.

70803 - LINEAR REGRESSION

Calculates the best fit of a set of data points to the line $y = ax + b$ i.e., the program computes the estimates $\hat{a}$ and $\hat{b}$. It also gives the correlation coefficient r .

70804 - NORMAL PROBABILITY INTEGRAL

Evaluates the integral under the normal density function.

70805 - χ^2 - CHI SQUARE DISTRIBUTION

Calculates the integral under the Chi Square distribution from 0 up to a value of χ^2 for a given number of degrees of freedom.

70806 - χ^2 - CHI SQUARE EVALUATION EXPECTED VALUES EQUAL ($E_i = E$)

Chi square calculation where the expected value of each observation is equal.

70807 - χ^2 - 2 x 2 CONTINGENCY TABLE

Calculates χ^2 for a 2 x 2 matrix.

70808 - χ^2 - CHI SQUARE EVALUATION EXPECTED VALUES UNEQUAL ($E_i \neq E_j$)

Chi square calculation where the expected values of the observations are not necessarily equal.

70809 - t - STATISTIC FOR MEANS OF TWO SAMPLES

Used for testing means of 2 samples with a normal distribution assuming the standard deviations are unknown but equal. $N_x + N_y - 2$ is the number of degrees of freedom where N_x is the number of samples in x and N_y is the number of samples in y .

70810 - WEIBULL DISTRIBUTION PARAMETER CALCULATION FOR FAILURE DATA

Calculates the parameters for the Weibull distribution and thus estimates of times to failure percentages may be made.

70811 - LEAST SQUARES FIT-POWER CURVE

Calculates coefficients fitting data points (x_i, y_i) to an equation of the form: $y = ax^b$

70812 - LEAST SQUARES FIT-EXPONENTIAL

Calculates coefficients fitting data points (x_i, y_i) to an equation of the form: $y = ae^{bx}$

70813 - POISSON DENSITY

Calculates the various summations associated with the Poisson density to give a probability based on an input parameter and summation endpoints.

70814 - MULTIPLE LINEAR REGRESSION

Calculates coefficients in the least squares sense, fitting data points (x_i, y_i, z_i) to a linear equation of the form:

$$z = a_0 + a_1x + a_2y$$

70815 - NON-LINEAR REGRESSION - LEAST SQUARES PARABOLA

Calculates coefficients fitting data points (x_i, y_i) to an equation of the form:

$$y = a_0 + a_1x + a_2x^2$$

70816 - RANDOM NUMBER GENERATOR

Random numbers (RN) in the range $0 \leq RN \leq 1$ are calculated; more than 10,000 random numbers may be generated before any previous value is repeated.

70817 - MEAN, DEVIATION AND PROBABLE ERROR

Calculates the mean, standard deviation, probable error, standard deviation from the mean, and the probable error of the mean.

ELECTRONICS 09100-71000

71001 - TCHEBYSHEFF FILTER DESIGN

Calculates component values for Tchebysheff low pass filters with equal terminations.

71002 - TCHEBYSHEFF FILTER DESIGN - FINITE TERMINATIONS

Calculates component values for Tchebysheff low pass filters with finite terminations (equal or unequal).

71003 - BUTTERWORTH FILTER DESIGN

Calculates component values for Butterworth low pass filters between equal terminations.

71004 - MINIMUM LOSS PADS

Calculates resistive minimum loss pad and gives resistor values and loss in dB.

71005 - TCHEBYSHEFF EVALUATION

Used to determine filter order or the frequency response of a particular Tchebysheff filter.

71006 - ATTENUATOR PADS T OR Π

Calculates resistor values for either T or Π pads.

71007 - BAND PASS FILTER DESIGN

Calculates ideal component values and evaluates the frequency response by the image parameter method for a band pass filter.

71008 - STUB MATCHED TRANSMISSION LINE

Calculates the distance from a load to a point where a shorted stub is to be placed and the length of the stub to match a transmission line.

71009 - TRANSMISSION LINE

Calculates the impedance at any point on a transmission line either toward the generator or toward the load, the voltage reflection (magnitude and phase) and the VSWR on the line.

71010 - WYE $\rightarrow$ DELTA AND/OR DELTA $\rightarrow$ WYE CONVERSION

Transforms impedances wired in delta configuration to the equivalent wye configuration and vice-versa. Loop and nodal analyses are used to perform the transformations.

71011 - S PARAMETER TO Y PARAMETER CONVERSION

Converts S parameters for linear (active or passive) circuits to Y parameters.

MECHANICS 09100-72000

72001 - MOMENT OF INERTIA OF A CIRCULAR SEGMENT

Given the radius of a segment of a circle and the central angle relative to a coordinate system located at the origin of the circle, this program calculates the distance to the center of gravity, the area of the segment, and the moment of inertia about both of the coordinate axes.

72002 - TRANSCENDENTAL EQUATION (ARC INVOLUTE IN GEAR DESIGN)

Solves for the angle ϕ in radians in the following expression

$$\text{INV}(\phi) = \tan \phi - \phi$$

where the INV (ϕ) is given. $1 \times 10^{-17} < \phi < 1 \times 10^6$ (ϕ is in radians).

72003 - SPRING DESIGN - COMPRESSION AND EXTENSION SPRINGS

This program calculates one of three variables (d - diameter of wire, N - number of turns of wire, and D - mean coil diameter), the remaining two being set, and calculates the maximum allowable stress. Other inputs are set to predetermined values.

72004 - STRESS AND STRAIN FROM A RECTANGULAR ROSETTE

Calculates the principal strains and stresses given rectangular rosette and strain gauge inputs.

BUSINESS 09100-73000

73001 - ANNUAL INTEREST

Calculates i that satisfies the equation:

$$R = \frac{P i (1 + i)^n}{(1 + i)^n - 1}$$

73002 - DEPRECIATION SCHEDULE-DECLINING BALANCE

Uses the declining balance technique for deriving the depreciation schedule for an asset.

73003 - DEPRECIATION SCHEDULE - SUM OF YEARS' - DIGITS

Uses the sum-of-years'-digits technique for deriving the depreciation schedule for an asset.

73004 - COMPOUND INTEREST

Uses compound interest factors to compute present and future worth and a uniform series of payments.

73005 - PRESENT VALUE OF A SERIES OF CASH FLOWS

Calculates the present value of a series of cash flows for any number of periods with a constant interest rate per period.

73006 - SINGLE AND DOUBLE EXPONENTIAL SMOOTHING AND FORECASTING

Uses single and double exponential techniques to smooth input data and subsequently predict future data on the basis of the past input data.

73007 - TRIPLE EXPONENTIAL SMOOTHING AND FORECASTING

Uses triple exponential techniques to smooth input data and subsequently predict future data on the basis of the past input data.

73008 - AMORTIZED LOAN

Calculates the monthly payment on the principal of a loan for a specified term, the amount of payments toward principal and interest, and a running total of the amount of payments toward principal and interest to date.

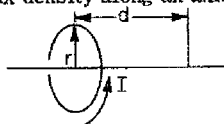
PHYSICS 09100-73200

73201 - BLOCK ON INCLINE (FRICTION PRESENT)

Gives acceleration, if any, of a block on an incline θ with coefficient of friction μ .

73202 - FLUX DENSITY

Calculates the flux density along an axis of a circular loop for a specified radius r , current I , and distance d .



73203 - VENTURI METER

Calculates flow Q by using Bernoulli's equation.

73204 - ORBITAL MECHANICS

Calculates the velocity of a satellite at apogee and perigee and the orbital time in seconds of a satellite orbiting a body in space.

THERMODYNAMICS 09100-73700

73701 - TEMPERATURE CONVERSION

Calculates the temperature equivalents of a temperature given in any of the three temperature scales -- Fahrenheit, Centigrade, and Kelvin (absolute).

SURVEYING 09100-74000

74001 - COORDINATE GEOMETRY

Traverses by bearing and distance and calculates coordinates and the following curve data:

- | | |
|-----------------|--|
| 1. Arc length | 3. Central angle in degrees, minutes and seconds |
| 2. Chord length | 4. Coordinates of tangent points |

74002 - ANGLE ACCUMULATION

Accumulates angles given in degrees, minutes and seconds.

74003 - INVERSE TRAVERSE FROM COORDINATES

Calculates bearing, distance, and quadrant code from end-point coordinates.

74004 - THREE POINT PROBLEM

Calculates the coordinates of an observer's position given coordinates of three other points and two reference angles to the observer's position.

74005 - LINE-TO-CURVE INTERSECTION

Calculates the length of a line intersecting a curve and the bearing of the radial line through the point of intersection.

74006 - TRUE MERIDIAN

Calculates the sun's bearing to within $\pm 2'$ by a single observation on the sun.

74007 - TRAVERSE WITH LAW OF SINES OPTION

Calculates coordinates of any number of points when traversing from point to point. The two distances between any series of three points may also be calculated using the law of sines option.

74008 - COORDINATE GEOMETRY AND ENCLOSED AREA

Traverses by bearing and distance and calculates coordinates, enclosed area, and the following curve data:

- | | |
|-----------------|-------------------------------------|
| 1. Arc length | 3. Central angle in decimal degrees |
| 2. Chord length | 4. Coordinates of tangent points |

74009 - TRIANGLE SOLUTION - SIDES GIVEN

Calculates the three included angles and area of any triangle where the side lengths are given.

74010 - CIRCULAR SECTOR

Given the radius and the included angle in degrees, minutes and seconds, calculates the arc length, chord length, and segment and sector areas of a circular sector.

74011 - TRAVERSE WITH COMPASS RULE ADJUSTMENT OPTION

Traverses by bearing and distance, calculates coordinates, closure error, total traverse distance and precision ratio. The program may then be used to distribute the closure error by the Compass Rule.

STRUCTURES 09100 - 74200

74201 - SHEAR COEFFICIENT - THIN-WALLED I SECTION

74202 - SHEAR COEFFICIENT - SPAR AND WEB SECTION OR THIN-WALLED BOX SECTION

74203 - CANTILEVER BEAM - INTERMEDIATE LOAD

Calculates shear, moment, and deflection.

74204 - CANTILEVER BEAM - TRIANGULAR LOAD

Calculates shear, moment, and deflection.

74205 - COORDINATES OF EQUALLY SPACED POINTS ON A CIRCLE

Computes the rectangular coordinates of equally spaced points on a circle given the center point coordinates, radius and offset angle of the circle, and the number of coordinate points desired on the circle.

FLUID MECHANICS 09100-75000

75001 - CHEZY-MANNING EQUATION

Finds channel flow when channel is circular pipe and flowing full.

75002 - CALCULATION OF FLOW CORRECTION (Δ) IN A SYSTEM OF PIPES
HARDY CROSS METHOD

For an assumed flow computes a correction Δ . The process may then be repeated.

75003 - RECTANGULAR WEIR

Calculates the rate of fluid flow over a rectangular weir.

75004 - WATER FLOW IN PIPE

Calculates the loss factor (f) and the head loss for a pipe of specified dimensions with a known flow rate.

LIFE SCIENCES 09100-75200

75201 - RADIOACTIVE DECAY

Calculates the mass loss between any two times given the half-life, initial mass and present mass; displays the decay curve; or calculates the age of the mass based upon the present mass.

CHEMICAL 09100-75500

75501 - ELEMENTAL PERCENTAGES AND MOLECULAR WEIGHT

Calculates elemental percentages and molecular weight of compounds containing 4 elements or less.

75502 - ELEMENTAL PERCENTAGE AND MOLECULAR WEIGHT - 6 ELEMENT

Calculates percentages and molecular weight of compounds containing 6 elements or less.

75503 - CHN ANALYSIS [K VALUES]

Calculates K values given C, H and N, blank values, and percentages for a known standard.

75504 - CHN PERCENTAGES

Given C, H, and N values and using previously calculated K values and known blank values, calculates C, H and N percentages.

75505 - MOLECULAR WEIGHT BY VPO

Calculates molecular weight for an unknown based on a series of vapor pressure osmometer (VPO) readings at various dilutions by extrapolating a least squares curve fit to infinite dilution.

75506 - MEMBRANE OSMOMETER

Determines the number-average molecular weight by extrapolating a least squares curve fit to infinite dilution.

SECONDARY EDUCATION 09100-75800

75801 - TIME KEEPER

Keeps time; any initial time (in hours, minutes, and seconds) may be entered.

75802 - PRIME NUMBERS

Calculates all prime numbers between any two numbers.

MISCELLANEOUS 09100-76000

76001 - DIAGNOSTIC PROGRAM

Checks all functions and operations of the calculator (9100A) and indicates by display whether or not the calculator is functioning properly.

76002 - POUNDS $\leftrightarrow$ DOLLARS CONVERSION

Converts British pounds and subdivisions thereof to American dollars and vice versa.

MISCELLANEOUS (CONT.)

76003 - NAVIGATIONAL COURSE CALCULATION

Calculates course settings for one or more adjoining legs of a proposed journey, the length of each leg, and the total distance covered on completion of the journey.

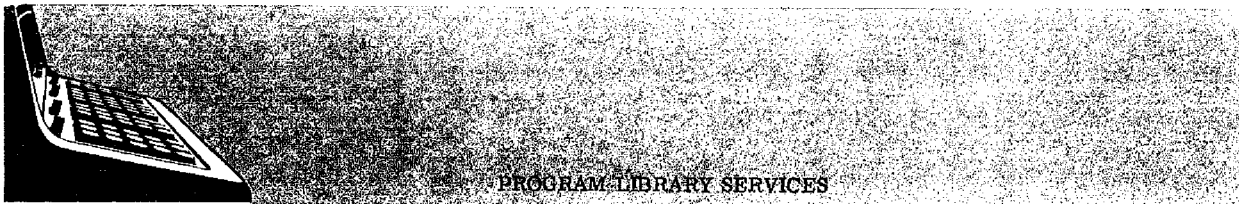
76004 - CIRCLE DETERMINED BY THREE POINTS

Calculates the radius and center point (in rectangular coordinates) of the circle defined by three given points.

76005 - AREA OF A RECTILINEAR SURFACE POLYGON

Calculates the area of any rectilinear polygon given the rectangular coordinates of the vertices.

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PROGRAM LIBRARY SERVICES

This Program Library is intended to illustrate practical problems which can be solved with the 9100A Calculator. Many programs are short enough so that they may be incorporated as subroutines in other programs. Each program consists of a description, equations (with references), examples and a list of the program steps.

A periodic program updating service is provided. Please return the Program Library card (in the pocket on the rear cover) indicating the Program Library disciplines in which you want to be informed of new programs. You are also invited to submit new programs to the Library. User submitted programs will be credited to the author and distributed as part of the updating service.

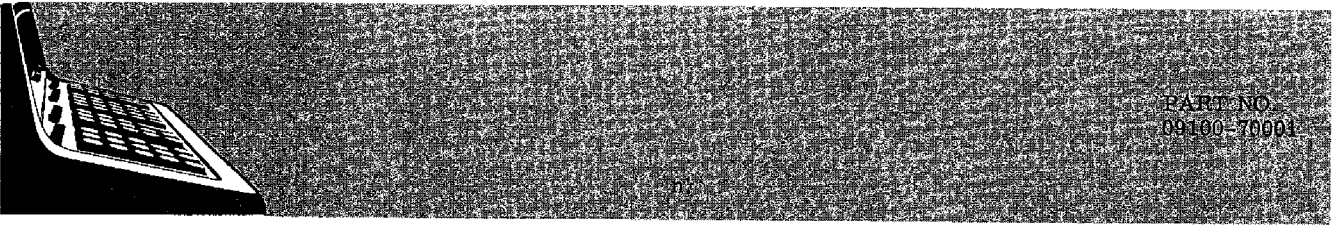
Selected programs will also be included in the Hewlett-Packard Keyboard, a periodic publication which will also include an index of other new programs.

PROGRAM LIBRARY CLASSIFICATIONS

HP Part No.	
09100-70000	Mathematics
09100-70800	Statistics
09100-71000	Electronics
09100-72000	Mechanics
09100-73000	Business
09100-73200	Physics
09100-73700	Thermodynamics
09100-74000	Surveying
09100-74200	Structures
09100-75000	Fluid Mechanics
09100-75200	Life Sciences
09100-75500	Chemical
09100-75800	Secondary Education
09100-76000	Miscellaneous

The following accessories are available:

HP Part No.	
09100-90000	Five Programming Pads
09100-90001	Operating and Programming Manual
09100-90002	Program Library
09100-90004	Diagnostic Card and envelope
5060-5919	Box of ten magnetic program cards
9320-1157	Pull-Out Instruction Card
4040-0350	Dust Cover



This program calculates $n!$ for integer n where $0 \leq n \leq 69$.

$$n! = n(n-1) \cdots 3 \cdot 2 \cdot 1$$

EXAMPLES

USER INSTRUCTIONS

0! = 1
6! = 720

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: n → X

PRESS: CONTINUE

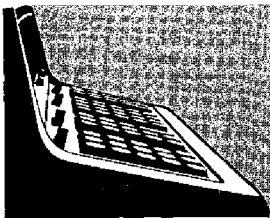
DISPLAY

0 ——— Z

n! ——— Y

n ——— X

[illegible]



PART NO.
09100-70002

POLYNOMIAL EVALUATION

This program evaluates polynomials of the form

$$f(Z) = C_n Z^n + C_{n-1} Z^{n-1} + \cdots + C_1 Z + C_0$$

for complex C_i , $i = 0, 1, \dots, n$ and complex Z .

EXAMPLES

$P(Z) = (3 + 4i)Z^2 + (-2 + i)Z^1 + (1 - i)$
 for $Z = 2 + i$ $\text{Re}Z = 2$ $\text{Im}Z = 1$
 $P(2 + i) = -11 + 23i$
 $P(Z) = 49.6Z^4 + 18Z^3 + 52.4Z^2 + 8Z + 12.8$
 for $Z = i$ $\text{Re}Z = 0$ $\text{Im}Z = 1$
 $P(i) = 10 - 10i$

GENERAL FORM

$$f(Z) = C_n Z^n + C_{n-1} Z^{n-1} + \dots + C_1 Z + C_0$$

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $n \rightarrow Z$, $\text{Im} Z \rightarrow Y$,
 $\text{Re} Z \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
n_i	—	Z

n_i is an indicator or
 coefficient entry number.
 When $n_i = 0$ enter C_0 .

ENTER DATA: $\text{Im} C_{n_i} \rightarrow Y$,
 $\text{Re} C_{n_i} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
$\text{Im} P(Z)$	—	Y
$\text{Re} P(Z)$	—	X

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1		01	DISPLAY 1 TO INDICATE FIRST DATA ENTRY							
	2	STOP	41	ReZ	ImZ	n	ENTER Z AND n				
	3	TO POLAR	62	[THE DEGREE OF P(Z)]							
	4	$x \rightarrow ()$	23								
	5	d	17								
	6	$y \rightarrow ()$	40								
	7	c	16	STORE DATA							
	8	ROLL $\uparrow$	22								
	9	$x \rightarrow ()$	23								
	a	b	14								
	b	CLEAR	20								
	c	b	14	RECALL n IN THE X REGISTER TO INDICATE COEFFICIENT TO BE ENTERED							
	d	STOP	41	ReCn	ImCn	0	ENTER Cn				
1	0	TO POLAR	62								
	1	$x \rightarrow ()$	23								
	2	a	13								
	3	$y \rightarrow ()$	40								
	4	9	11								
	5	b	14								
	6	$x \rightarrow y$	30	DECREMENT n_i							
	7	1	01								
	8	-	34								
	9	$\downarrow$	25								
	a	IF $x < y$	52								
	b	4	04	BRANCH WHEN $n_i = -1$							
	c	0	00								
	d	$x \rightarrow ()$	23								
2	0	b	14	RECALL n_i IN THE X REGISTER TO INDICATE COEFFICIENT TO BE ENTERED							
	1	STOP	41	ReCn _i	ImCn _i	0	ENTER Cn _i				
	2	ACC +	60								
	3	c	16								
	4	$\uparrow$	27								
	5	d	17								
	6	$\uparrow$	27								
	7	a	13								
	8	x	36								
	9	$x \rightarrow y$	30								
	a	$y \rightarrow ()$	24								
	b	9	11								
	c	ROLL $\downarrow$	31								
	d	+	33								

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD
FROM 3d

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	↓	25								
1	x↔y	30									
2	TO RECT	66	CALCULATE P(Z) BY USE OF THE EQUATION $P(Z) = \dots \{ [(C_n Z + C_{n-1}) Z + C_{n-2}] Z + C_{n-3} \} + \dots + C_0$								
3	ACC +	60									
4	RECALL	61									
5	TO POLAR	62									
6	x→()	23									
7	↔	13									
8	y→()	40									
9	9	11									
↔	CLEAR	20									
↔	GO TO () ()	44									
↔	1	01									
↔	5	05									
4	0	y↔()	24								
1	9	11	RECALL P(Z)								
2	↔	13									
3	TO RECT	66									
4	END	46	ReP(Z)	ImP(Z)	0	DISPLAY					
5											
6											
7											
8											
9											
↔											
↔											
↔											
↔											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
↔											
↔											
↔											
↔											

FROM IC

HEWLETT-PACKARD

HEWLETT-PACKARD

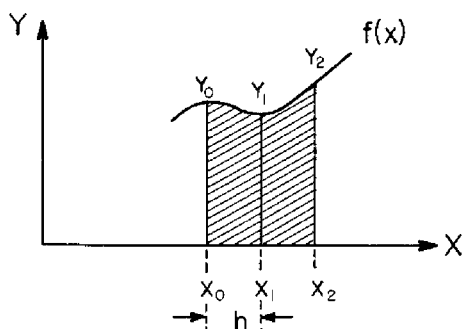
HEWLETT-PACKARD

This program evaluates the area under a curve represented by discrete points. The equation used is Simpson's One-Third Rule ie.,

$$\int_{x_0}^{x_2} f(x) dx = \frac{h}{3} (Y_0 + 4Y_1 + Y_2) - \frac{1}{90} h^5 f^{(4)}(\xi)$$

where $X_0 < \xi < X_2$

Graphically the integration is performed over two panels (each of width h) as shown below



The application of Simpson's Rule over $2n$ panels between $X_0 = a$, and $X_{2n} = b$ gives

$$\int_a^b f(x)dx = \frac{h}{3} (Y_0 + 4Y_1 + 2Y_2 + 4Y_3 + 2Y_4 + \dots + 4Y_{n-1} + Y_n) - \frac{1}{180} (b-a) h^4 f^{(4)}(\xi)$$

where $a < \xi < b$ and $f^{(4)}(\xi)$ is the fourth derivative of $f(x)$ evaluated at ξ .

Thus to use the program divide the abscissa into $2n$ panels. (The method requires an even number of panels of width h .) Since the error term is neglected, choose h (the distance between points) such that the error term is small. Usually $h \ll 1$ when $f^{(4)}(\xi)$ is unknown.

Reference: Numerical Analysis
by Kaiser S. Kunz

McGraw - Hill Book Co., Inc. 1957

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $h \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $X_0 \rightarrow X$

PRESS: CONTINUE

DISPLAY

A_{i-1}	—	Z
X_i	—	Y
0	—	X

Note: Subsequent X_i 's are calculated from X_0 and h and are not entered.

A - the area shows every other time starting after third y entry

(Corresponds to calcu-

ENTER DATA: $Y_i \rightarrow X$ lated X_i displayed in Y)

PRESS: CONTINUE (To restart a new problem PRESS: END, PRESS: CONTINUE)

To Change Increment (new h)

This can only be done if area or Z register is blank

ENTER DATA: $Y_i \rightarrow X$

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: new $h \rightarrow X$

PRESS: CONTINUE (Program branches to area display and ordinate entry. Proceed as before.)

EXAMPLES

INCREMENT CONSTANT

X	Y
0	2
.25	2.8
.50	3.8
.75	5.2
1.00	7.0
1.25	9.2
1.50	12.1
1.75	15.6
2.00	20

$$h = .25$$

$$\int_0^2 f(x) dx = 16.58$$

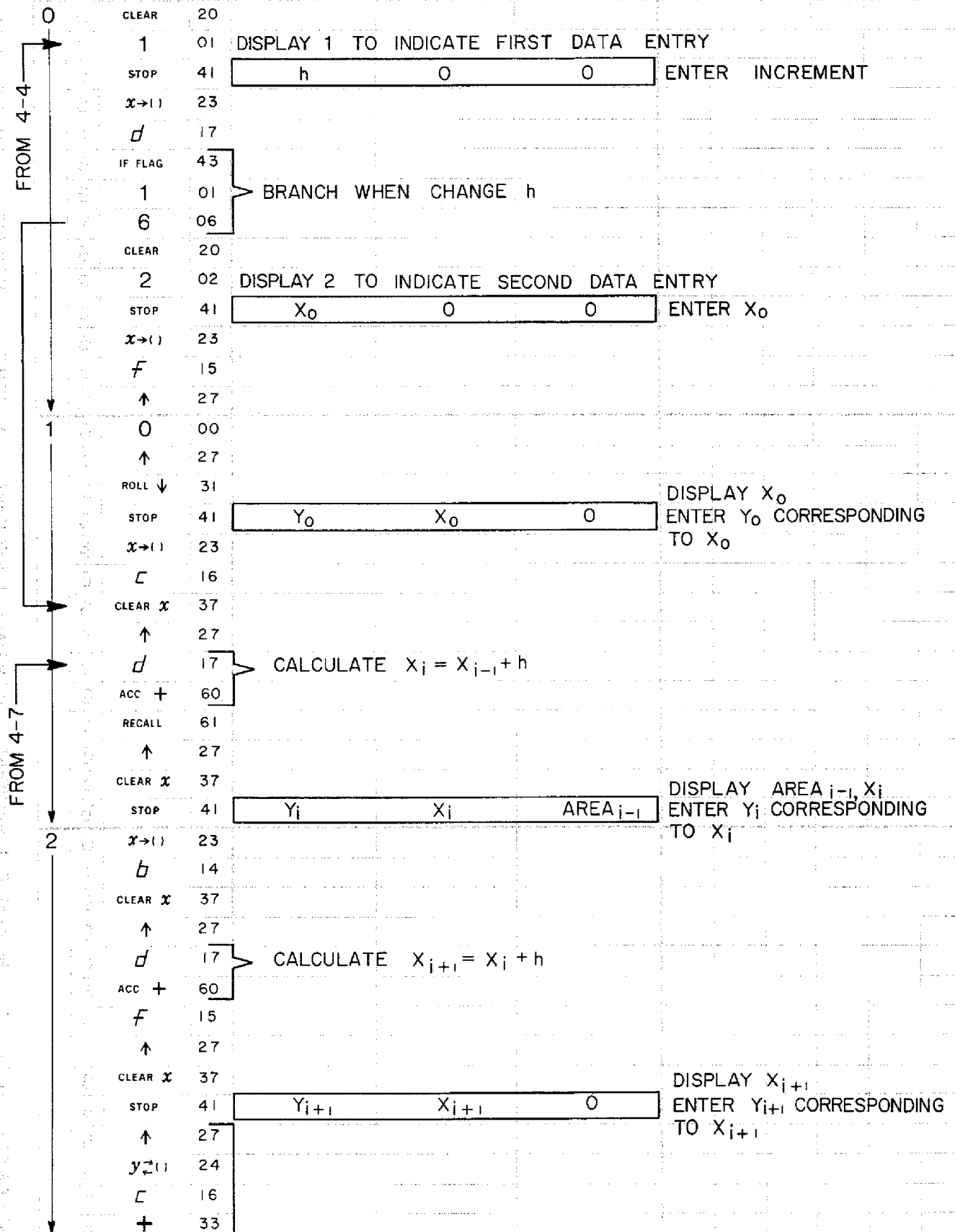
INCREMENT CHANGE

X	Y
0	2
.25	2.8
.50	3.8
.75	5.2
1.00	7.0
1.50	12.1
2.00	20

$$h = .25$$

$$h = .5$$

$$\int_0^2 f(x) dx = 16.62$$



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	b	14								
	1	↑	27								
	2	.4	04								
	3	x	36								
	4	0	00								
	5	ROLL ↓	31								
	6	+	33								
	7	3	03								
	8	÷	35								
	9	d	17								
	a	x	36								
	b	0	00								
	c	ACC +	60								
	d	ROLL ↓	31								
4	0	IF FLAG	43								
	1	SET FLAG	54								
	2	GO TO () ()	44								
	3	0	00								
	4	1	01								
	5	GO TO () ()	44								
	6	1	01								
	7	8	10								
	8	END	46								
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

CALCULATE $\left(\frac{Y_{i-1} + 4Y_i + Y_{i+1}}{3} \right) h = A$

SUM A TO PREVIOUS AREA

CHECK FOR FLAG, IF SET BRANCH TO h INPUT

BRANCH TO ENTER NEW ORDINATE AT SAME INCREMENT

PART NO.
09100-70004

VECTOR CROSS PRODUCT $\vec{A} \times \vec{B}$

This program calculates the Vector Cross Product by the equation

$$\begin{aligned}\vec{A} \times \vec{B} &= (a_2 b_3 - a_3 b_2) \vec{i} + (a_3 b_1 - a_1 b_3) \vec{j} + (a_1 b_2 - a_2 b_1) \vec{k} \\ &= c_1 \vec{i} + c_2 \vec{j} + c_3 \vec{k} \\ \text{where } \vec{A} &= a_1 \vec{i} + a_2 \vec{j} + a_3 \vec{k} \\ \text{and } \vec{B} &= b_1 \vec{i} + b_2 \vec{j} + b_3 \vec{k}\end{aligned}$$

Reference: Advanced Calculus
by Angus E. Taylor

Ginn and Co. 1955

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $a_3 \rightarrow Z$, $a_2 \rightarrow Y$,
 $a_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $b_3 \rightarrow Z$, $b_2 \rightarrow Y$,
 $b_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

c_3	—	Z
c_2	—	Y
c_1	—	X

$$\bar{A} = 2\bar{i} + 3\bar{j} + 4\bar{k}$$

$$\bar{B} = 1\bar{i} + 5\bar{j} + 2\bar{k}$$

$$\bar{A} \times \bar{B} = -14\bar{i} + 0\bar{j} + 7\bar{k}$$

$$\bar{A} = \bar{i} + \bar{j} - 2\bar{k}$$

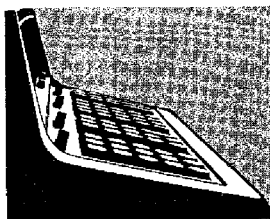
$$\bar{B} = 2\bar{i} - 3\bar{j} + \bar{k}$$

$$\bar{A} \times \bar{B} = -5\bar{i} - 5\bar{j} - 5\bar{k}$$

GENERAL FORM

$$\bar{A} = a_1\bar{i} + a_2\bar{j} + a_3\bar{k}$$

$$\bar{B} = b_1\bar{i} + b_2\bar{j} + b_3\bar{k}$$

PART NO.
09100-70005

ANGLE BETWEEN TWO THREE-DIMENSIONAL VECTORS

This program calculates the angle between two three-dimensional vectors of the form

$$\begin{aligned}\bar{A} &= a_1\bar{i} + a_2\bar{j} + a_3\bar{k} \\ \text{and} \\ \bar{B} &= b_1\bar{i} + b_2\bar{j} + b_3\bar{k}\end{aligned}$$

The equation used to calculate this angle is

$$\theta = \cos^{-1} \left\{ \frac{a_1 b_1 + a_2 b_2 + a_3 b_3}{\sqrt{a_1^2 + a_2^2 + a_3^2} \sqrt{b_1^2 + b_2^2 + b_3^2}} \right\}$$

Reference: Advanced Calculus
by Angus E. Taylor

Ginn and Co. 1955

USER INSTRUCTIONS

(Switch to Degrees or Radians
Depending on Desired Output, θ)

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

→ PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $a_3 \rightarrow Z$, $a_2 \rightarrow Y$,
 $a_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $b_3 \rightarrow Z$, $b_2 \rightarrow Y$,
 $b_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
θ	—	X

EXAMPLES

$$\bar{A} = 2.5\bar{i} + 2.6\bar{j} + 2.1\bar{k}$$

$$\bar{B} = 1.9\bar{i} + 1.4\bar{j} - 2.8\bar{k}$$

$$\theta = 1.406 \text{ radians} = 80.548 \text{ degrees}$$

$$\bar{A} = 0\bar{i} + \bar{j} + \bar{k}$$

$$\bar{B} = 0\bar{i} + \bar{j} - \bar{k}$$

$$\theta = 1.571 \text{ radians} = 90.000 \text{ degrees}$$

GENERAL FORM

$$\bar{A} = a_1\bar{i} + a_2\bar{j} + a_3\bar{k}$$

$$\bar{B} = b_1\bar{i} + b_2\bar{j} + b_3\bar{k}$$

Step	Key	Code	Display			Storage					
			x	y	z	F	E	D	C	B	A
3	0	d	17								
	1	x	36								
	2	d	17								
	3	+	33								
	4	↓	25								
	5	+	33								
	6	↓	25								
	7	$\sqrt{x}$	76								
	8	↑	27								
	9	C	16								
	a	↑	27								
	b	x	36								
	c	b	14								
	d	$y^2()$	24								
4	0	b	14								
	1	x	36								
	2	b	14								
	3	+	33								
	4	a	13								
	5	$y^2()$	24								
	6	a	13								
	7	x	36								
	8	a	13								
	9	+	33								
	a	↓	25								
	b	$\sqrt{x}$	76								
	c	x	36								
	d	F	15								
5	0	$x \div y$	30								
	1	÷	35								
	2	0	00								
	3	↑	27								
	4	ROLL ↑	22								
	5	ARC ↓	72								
	6	COS X	73								
	7	END	46	θ	0	0					
	8										
	9										
	a										
	b										
	c										
	d										

CALCULATE MAGNITUDE OF $\bar{A}$ CALCULATE $b_1^2 + b_2^2 + b_3^2$ CALCULATE MAGNITUDE OF $\bar{B}$ CALCULATE $\frac{a_1 b_1 + a_2 b_2 + a_3 b_3}{\sqrt{a_1^2 + a_2^2 + a_3^2} \sqrt{b_1^2 + b_2^2 + b_3^2}}$ CLEAR AND CALCULATE θ

DISPLAY

PART NO.
09100-70006

1ST ORDER DIFFERENTIAL EQUATIONS

This program may be used to solve a wide variety of first order (homogenous or non-homogenous, linear or non-linear) differential equations of the form $Y' = f(X, Y)$

The solution is a numerical solution which calculates Y_i for X_i . The X values are closely spaced with increment h over the desired range. Specifically the solution used in this program is a Runge-Kutta Method (third-order) which uses the equations,

$$Y_{i+1} = Y_i + \frac{1}{6} (p + 2q + 2r + s)$$

where

$$p = hf(X_i, Y_i)$$

$$q = hf\left(X_i + \frac{h}{2}, Y_i + \frac{p}{2}\right)$$

$$r = hf\left(X_i + \frac{h}{2}, Y_i + \frac{q}{2}\right)$$

$$s = hf(X_i + h, Y_i + r)$$

$$h = X_{i+1} - X_i$$

Reference: Numerical Analysis
by Kaiser S. Kunz

McGraw-Hill Book Co. Inc. 1957

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: (GO TO) (4) (a)

Place mode switch to PROGRAM

Starting at 4-a, enter the program steps which take the independent variable from the X register, the dependent variable from the Y register and calculate $f(X, Y)$. Place $f(X, Y)$ in the Y register and exit to location 8-b. Note there is a maximum of 57 steps (4-a through 8-a) available for storing and positioning $f(X, Y)$.

Place mode switch to RUN

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: (Initial conditions and increment)

$h \rightarrow Z, Y_0 \rightarrow Y, X_0 \rightarrow X$

PRESS: CONTINUE

The Calculator will display answers at every increment of the independent variable in the form

h	—	Z
Y_1	—	Y
X_1	—	X

To stop the solution at the next increment depress PAUSE until display. To restart press CONTINUE.

To start from a new set of initial conditions

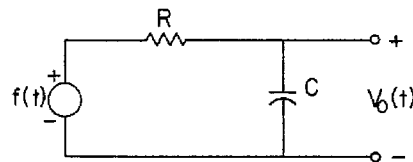
PRESS: STOP

PRESS: GO TO (0) (0) [or END]

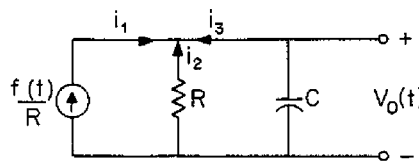
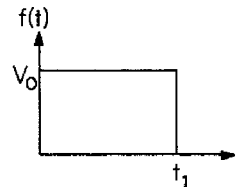
PRESS: CONTINUE

Enter initial conditions and increment as before.

EXAMPLES



$$\begin{aligned} V_O(0) &= 0 \\ t_0 &= 0 \\ h &= .01 \end{aligned}$$



$$i_1 + i_2 + i_3 = 0$$

$$\begin{aligned} \frac{f(t)}{R} - \frac{V_O(t)}{R} - C \frac{dV_O(t)}{dt} &= 0 \quad \left. \begin{array}{l} \text{Initial} \\ \text{Conditions} \end{array} \right\} \begin{array}{l} t_0 = 0 \\ V_O(0) = 0 \end{array} \\ \frac{dV_O(t)}{dt} &= -\frac{V_O(t)}{CR} + \frac{f(t)}{CR} \quad \text{Increment } h = .01 \end{aligned}$$

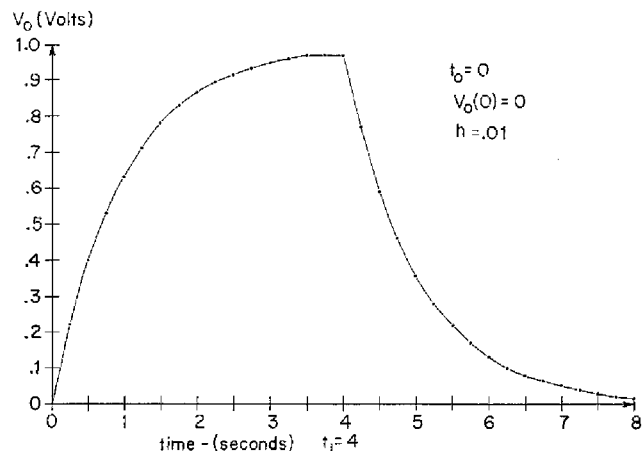
Let $V_0 = 1$ V, $C = 1$ F, $R = 1 \Omega$ and $t_1 = 4$ sec.

The equation becomes

$$\frac{dV_O(t)}{dt} = -V_O(t) + 1; \quad t \leq 4$$

$$\frac{dV_O(t)}{dt} = -V_O(t); \quad t > 4$$

The program steps that form $V_O' = f(t, V_O)$ appear on Page 1. See User Instructions.



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
4	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9		t	V ₀							
	a	↑ 27		t	V ₀						
	b	4 04	4								
	c	IF x < y 52									
	d	5 05									
5	0	9 11									
	1	ROLL ↑ 22	V ₀	4	t						
	2	CHG SIGN 32	-V ₀								
	3	↑ 27		-V ₀	4						
	4	1 01	1								
	5	+ 33		1-V ₀							
	6	GO TO () 44									
	7	8 10									
	8	b 14									
	9	ROLL ↑ 22	V ₀	4	t						
	a	CHG SIGN 32	-V ₀								
	b	↑ 27		-V ₀	4						
	c	GO TO () 44									
	d	8 10									
6	0	b 14									
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

COMPARE t TO 4 AND
BRANCH TO APPROPRIATE
DIFFERENTIAL EQUATION

$$t \leq 4$$

$$\frac{dV_0(t)}{dt} = -V_0(t) + 1$$

EXIT

$$t > 4$$

$$\frac{dV_0(t)}{dt} = -V_0(t)$$

EXIT

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	$x \rightarrow ()$	23									
2	b	14									
3	STOP	41	X_0	Y_0	h	ENTER INITIAL CONDITIONS AND INCREMENT					
4	$x \rightarrow ()$	23									
5	f	15									
6	$y \rightarrow ()$	40									
7	d	17									
8	ROLL $\uparrow$	22									
9	$x \rightarrow ()$	23									
a	c	16									
b	ROLL $\downarrow$	31									
c	PAUSE	57	X_i	Y_i	h	DISPLAY AT EACH INCREMENT					
d	GOTO () ()	44									
1	0	4	04	CALCULATE $p = hf(X_i, Y_i)$							
1	a	13									
2	$\downarrow$	25									
3	2	02									
4	$\div$	35									
5	d	17									
6	+	33									
7	c	16	CALCULATE $X_i + \frac{h}{2}, Y_i + \frac{p}{2}$								
8	$\uparrow$	27									
9	2	02	OR $X_i + \frac{h}{2}, Y_i + \frac{q}{2}$								
a	$\div$	35	IN THE X AND Y REGISTERS								
b	f	15	RESPECTIVELY								
c	+	33									
d	$\downarrow$	25									
2	0	IF FLAG	43								
1	CONTINUE	47									
2	SET FLAG	54									
3	GOTO () ()	44									
4	4	04	CALCULATE q OR r								
5	a	13									
6	$\downarrow$	25									
7	d	17									
8	+	33									
9	c	16									
a	$\uparrow$	27	CALCULATE $X_i + h$ IN THE X REGISTER								
b	f	15	AND $Y_i + r$ IN THE Y REGISTER								
c	+	33									
d	$\downarrow$	25									

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

FROM 4-9

FROM a-c

FROM 9-d

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	x→()	23								
	1	f	15								
	2	GOTO ()	44								
	3	4	04	CALCULATE S							
	4	a	13								
	5	E	12								
	6	↑	27								
	7	6	06								
	8	÷	35	CALCULATE $Y_i + \frac{1}{6}(p+2q+2r+s)$							
	9	d	17								
	a	+	33								
	b	f	15								
	c	y→()	40								
	d	d	17								
4	0	↑	27								
	1	0	00								
	2	x→()	23								
	3	b	14	REINITIALIZE POINTS FOR STARTING NEXT INCREMENT							
	4	x→()	23								
	5	E	12								
	6	c	16								
	7	IF FLAG	43								
	8	0	00								
	9	b	14	X	Y						
	a	CONTINUE	47	ENTER SPECIFIC DIFFERENTIAL EQUATION HERE. NOTE LOCATION 4-9 CONTAINS X IN THE X REGISTER AND Y IN THE Y REGISTER. USE THESE VARIABLES TO PROGRAM THE SPECIFIC EQUATION $Y' = f(X,Y)$. AFTER FORMING Y' , PLACE IT IN THE Y REGISTER IN LOCATION 8-b.							
	b										
	c										
	d										
5	0			FILL THE REMAINING AREA WITH CONTINUES TO ELIMINATE THE POSSIBILITY OF AN END AND THUS RECORDING AND ENTERING PROBLEMS.							
	1										
	2										
	3										
	4										
	5										
	6			SEE OPERATING MANUAL							
	7										
	8										
	9										
	a										
	b										
	c										
	d										

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
6	0	CONTINUE	47									
	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	a											
	b											
	c											
d												
7	0	CONTINUE	47									
	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	a											
	b											
	c											
d												
8	0	CONTINUE	47									
	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	a											
	b	c	16									
	c	x	36									
d	0	00										

Y¹

NOTE: Y¹ MUST BE IN THE Y REGISTER AT THIS TIME.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	IF FLAG	43								
	1	ACC +	60								
	2	SET FLAG	54								
	3	ACC +	60								
	4	SET FLAG	54								
	5	1	01								
	6	↑	27								
	7	b	14								
	8	+	33								
	9	y→()	40								
	a	b	14								
	b	3	03								
	c	IF x>y	53								
	d	a	13								
	a	0	13								
	1	IF x=y	50								
	2	a	13								
	3	7	07								
	4	GOTO()	44								
	5	3	03								
	6	5	05								
	7	IF FLAG	43								
	8	2	02								
	9	6	06								
	a	GOTO()	44								
	b	1	01								
	c	2	02								
	d	END	46								
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

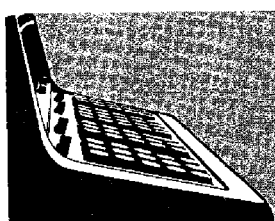
CALCULATE $p+2q+2r+s$ IN
THE E REGISTER

INCREMENT CONTENTS OF
STORAGE REGISTER b

BRANCH TO CALCULATE Y_i+1
AND REINITIALIZE ROUTINE

ZEROS FLAG AND BRANCHES
TO CALCULATE S

BRANCH TO CALCULATE
 q AND r



PART NO.
09100-70007

RAISING A NUMBER TO A POWER

This program solves the equation $Z_3 = Z_1^{Z_2}$

where Z_1 and Z_2 are given. Z_i may be real or complex ie. $Z_i = X_i + jY_i$ $i = 1, 2, 3$

The definitions $Z_1^{Z_2} = e^{Z_2 \ln Z_1}$ $Z_1 \neq 0$

$$\text{and } \ln Z = \ln(\sqrt{X^2 + Y^2}) + j\theta \quad (-\pi < \theta \leq \pi, \sqrt{X^2 + Y^2} > 0)$$

$$\theta = \text{TAN}^{-1} \frac{Y}{X}$$

are used.

The following equations are programmed

$$\begin{aligned} Z_3 &= e^{Z_2 \ln Z_1} \\ &= e^{(X_2 + jY_2)(\ln \sqrt{X_1^2 + Y_1^2} + j\theta_1)} \\ &= e^{X_2 \ln \sqrt{X_1^2 + Y_1^2} - Y_2 \theta_1} \left\{ \cos(Y_2 \ln \sqrt{X_1^2 + Y_1^2} + X_2 \theta_1) + \right. \\ &\quad \left. j \sin(Y_2 \ln \sqrt{X_1^2 + Y_1^2} + X_2 \theta_1) \right\} \end{aligned}$$

Reference: Complex Variable and Applications
by Churchill

McGraw-Hill 1960

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

SET: RADIANS

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $Y_1 \rightarrow Y$, $X_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $Y_2 \rightarrow Y$, $X_2 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
Y_3	—	Y
X_3	—	X

RESULT: $Z_3 = X_3 + jY_3$

$$Z_3 = (X_1 + jY_1)^{(X_2 + jY_2)}$$

$$1) \quad Z_3 = e^{(2 + j2)}$$

$$X_1 = e \quad Y_1 = 0$$

$$X_2 = 2 \quad Y_2 = 2$$

$$Z_3 = -3.075 + j6.719$$

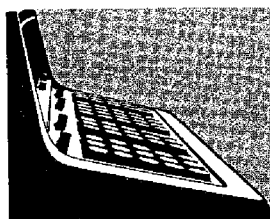
$$2) \quad Z_3 = (2 + j3)^{\cdot 5}$$

$$X_1 = 2 \quad Y_1 = 3$$

$$X_2 = .5 \quad Y_2 = 0$$

$$Z_3 = 1.674 + j.896$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0 0	CLEAR	20									
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	STOP	41	X_1	Y_1	0	ENTER X_1 AND Y_1					
3	$x \rightarrow ()$	23									
4	$\bar{a}$	13	STORE Z_1								
5	$y \rightarrow ()$	40									
6	b	14									
7	$\downarrow$	25									
8	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
9	STOP	41	X_2	Y_2	0	ENTER X_2 AND Y_2					
	$x \rightarrow ()$	23									
	$\bar{c}$	16	STORE Z_2								
	$y \rightarrow ()$	40									
	d	17									
1 0	b	14									
1	$\uparrow$	27									
2	$\bar{a}$	13	CALCULATE $\ln \sqrt{X_1^2 + Y_1^2}$ AND θ								
3	TO POLAR	62									
4	$\ln x$	65									
5	ROLL $\uparrow$	22									
6	$\bar{c}$	16									
7	$y \rightarrow ()$	40	STORE $\ln \sqrt{X_1^2 + Y_1^2}$								
8	e	12									
9	$\times$	36									
	ROLL $\uparrow$	22									
	$\bar{b}$	$\times$	CALCULATE $X_2 \ln \sqrt{X_1^2 + Y_1^2}$ AND $X_2 \theta_1$								
	$\bar{c}$	$y \rightarrow ()$									
	d	e									
2 0	$x \rightarrow y$	30									
1	$y \rightarrow ()$	24									
2	d	17	CALCULATE $Y_2 \ln \sqrt{X_1^2 + Y_1^2}$								
3	$x \rightarrow y$	30									
4	$\times$	36									
5	$y \rightarrow ()$	24									
6	d	17	CALCULATE $Y_2 \theta_1$								
7	$\times$	36									
8	ROLL $\downarrow$	31									
9	$-$	34	CALCULATE $X_2 \ln \sqrt{X_1^2 + Y_1^2} - Y_2 \theta$								
	$\bar{a}$	$y \rightarrow ()$									
	b	d									
	$\bar{c}$	e									
	d	$+$	33								



PART NO.
09100-70008

2nd ORDER DIFFERENTIAL EQUATIONS

This program may be used to solve a wide variety of second order differential equations of the form

$$Y'' = f(X, Y, Y')$$

The solution is a numerical solution which calculates Y_i and Y_i' for a set of closely spaced values of X_i over the desired range. The method used employs a Taylor series around the point X_i . The equations used are

$$Y_{i+1} = Y_i + hY_i' + \frac{h^2}{6} (4Y_i'' - Y_{i-1}'')$$

where the first term of the error is $-\frac{h^4}{8} Y^{(4)}$
and

$$Y_{i+1}' = Y_i' + \frac{h}{12} (5Y_{i-2}'' - 16Y_{i-1}'' + 23Y_i'')$$

where the first term of the error is $-\frac{3h^4}{8} Y^{(5)}$

where $h = X_{i+1} - X_i$

In order to start the solution the equations $Y_{-1}'' = Y_0'' - h \cdot Y_0'''$ with error of $-\frac{1}{2}h^2 Y^{(4)}$

and $Y_{-2}'' = Y_0'' - 2h \cdot Y_0'''$ with error of $-2h^2 Y^{(4)}$ are used.

X_0 , Y_0 , and Y_0' are known from the boundary conditions. Y_0'' is calculated from $f(X_0, Y_0, Y_0')$. Y_0''' is obtained by differentiating $f(X, Y, Y')$ and substituting in values X_0 , Y_0 , Y_0' , and Y_0'' . These initial conditions are required input.

In cases where an increasing exponential predominates it may be necessary to reverse the direction of the independent variable. This may be done simply by making h negative.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: (GO TO) (5) (a)

PLACE MODE SWITCH TO PROGRAM

The general program has a blank section for storing your specific differential equation. Starting at 5-0, enter the program steps which take the independent variable from the b register, the dependent variable from the f register, and the derivative of the dependent variable in the e register, and calculate $f(X, Y, Y')$. Place $f(X, Y, Y')$ in the Y register and exit to location 9-3. Note there is a maximum of 59 steps (5-0 through 9-2) available for storing and positioning $f(X, Y, Y')$.

PLACE MODE SWITCH TO RUN

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0 — Z
0 — Y
1 — X

ENTER DATA: $Y_0'' \rightarrow Z$, $Y_0''' \rightarrow Y$,
 $h \rightarrow X$

PRESS: CONTINUE

DISPLAY

0 — Z
0 — Y
2 — X

ENTER DATA: $X_0 \rightarrow Z$, $Y_0' \rightarrow Y$,
 $Y_0 \rightarrow X$

PRESS: CONTINUE

The Calculator will display answers at every increment of the independent variable in the form

0 — Z
 Y_1 — Y
 X_1 — X

To stop the solution at the next increment depress PAUSE until display. To restart depress CONTINUE.

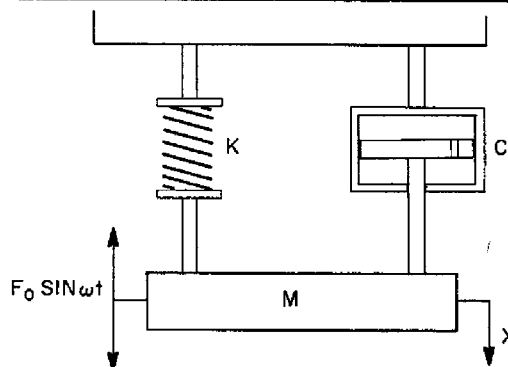
To start from a new set of initial conditions

PRESS: STOP

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

EXAMPLES



$$M\ddot{X} + C|\dot{X}|\dot{X} + KX = F_0 \sin \omega t$$

$$\begin{array}{llll} \underline{X(0) = 10} & C = .08 & \omega = 4\pi & m = .1 \\ \underline{\dot{X}(0) = 0} & F_0 = 100 & K = 25 & h = .001 \end{array}$$

$$\ddot{X} = -.8|\dot{X}|\dot{X} - 250X + 1000 \sin 4\pi t$$

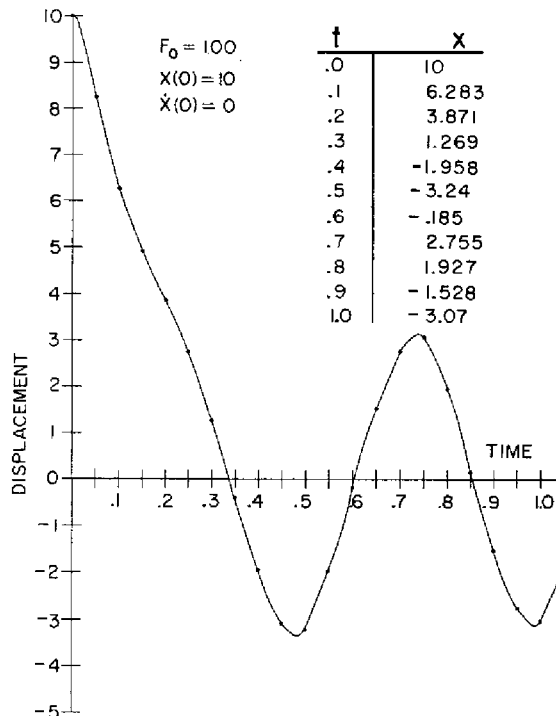
$$\underline{\dot{X}(0) = -2500}$$

$$\ddot{X} = -1.6|\dot{X}|\dot{X} - 250\dot{X} + 4000\pi \cos 4\pi t$$

$$\underline{\dot{X}(0) = 4000\pi}$$

NOTE: SET ☐ RADIANS

The program steps that form $\ddot{X} = f(t, X, \dot{X})$ appear on Page 1. See User Instructions.



[illegible]

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20	REGISTER CONTENTS →			Y_i	Y_i'	Y_i''	Y_{i-1}''	X_i	h
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY									
2	STOP	41	h	Y_0'''	Y_0''	ENTER INCREMENT AND INITIAL CONDITIONS						
3	$x \rightarrow ()$	23										
4	$\varnothing$	13										
5	X	36										
6	↓	25										
7	$y \rightarrow ()$	40										
8	d	17	CALCULATE Y_{i-1}''									
9	—	34										
10	$y \rightarrow ()$	40										
11	c	16										
12	—	34										
13	d	40	CALCULATE Y_{i-2}''									
14	b	14										
15	1	CLEAR	20									
16	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY									
17	STOP	41	Y_0	Y_0'	X_0	ENTER INITIAL CONDITIONS						
18	ACC +	60										
19	f	15										
20	ROLL ↓	31										
21	CLEAR x	37	RECALL AND POSITION FOR DISPLAY									
22	ROLL ↓	31										
23	PAUSE	57	X_i	Y_i	0	DISPLAY AT EACH INCREMENT						
24	$x \leftrightarrow y$	30										
25	$y \rightarrow ()$	24										
26	b	14										
27	d	05										
28	0	X	36									
29	1	c	16									
30	2	↑	27									
31	3	1	01									
32	4	6	06									
33	5	X	36									
34	6	↓	25									
35	7	—	34	CALCULATE $\frac{h}{12} (5Y_{i-2}'' - 16Y_{i-1}'' + 23Y_i'')$								
36	d	17										
37	↑	27										
38	2	02										
39	3	03										
40	X	36										
41	↓	25										

FROM 9-c

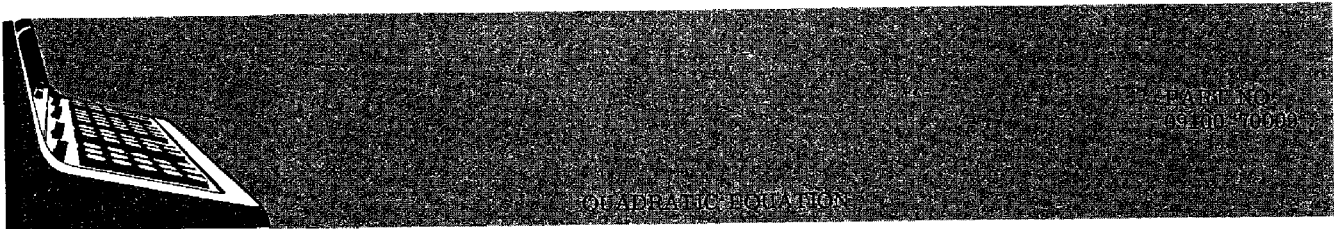
Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
3	0	+	33									
	1	a	13									
	2	x	36									
	3	1	01									
	4	2	02									
	5	÷	35									
	6	d	17									
	7	↑	27									
	8	4	04									
	9	x	36									
	a	c	16									
	b	-	34									
	c	a	13									
	d	x	36	CALCULATE $hY'_i + \frac{h^2}{6}(4Y''_i - Y''_{i-1})$								
4	0	6	06									
	1	÷	35									
	2	e	12									
	3	+	33									
	4	a	13									
	5	x	36									
	6	↓	25									
	7	ACC +	60	CALCULATE Y_{i+1} AND Y'_{i+1}								
	8	$y \rightarrow (1)$	24									
	9	b	14									
	a	a	13									
	b	+	33									
	c	$y \rightarrow (1)$	40	INCREMENT X_i								
	d	b	14									
5	0	CONTINUE	47	ENTER SPECIFIC DIFFERENTIAL EQUATION HERE. REGISTER b CONTAINS X , REGISTER f CONTAINS Y , AND REGISTER e CONTAINS Y' . USE THESE VARIABLES TO PROGRAM THE SPECIFIC EQUATION $Y''=f(X,Y,Y')$. AFTER FORMING Y'' PLACE IT IN THE Y REGISTER AND EXIT TO LOCATION 9-3.								
	1											
	2											
	3											
	4											
	5			FILL THE REMAINING AREA WITH CONTINUES TO ELIMINATE THE POSSIBILITY OF AN END AND THUS RECORDING AND ENTERING PROBLEMS.								
	6											
	7											
	8			SEE OPERATING MANUAL								
	9											
a												
b												
c												
d												

[illegible]

NEWLETT·PACKARD HEWLETT·PACKARD HEWLETT·PACKARD HEWLETT·PACKARD

FROM 5-0
THROUGH 9-2

[illegible]



QUADRATIC EQUATION

This program calculates the two roots X_1 and X_2 of the equation

$$ax^2 + bx + c = 0 \quad a \neq 0$$

The equation used to calculate the roots is:

$$X_1, X_2 = -\frac{b}{2a} \pm \frac{1}{2a} \sqrt{b^2 - 4ac}$$

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

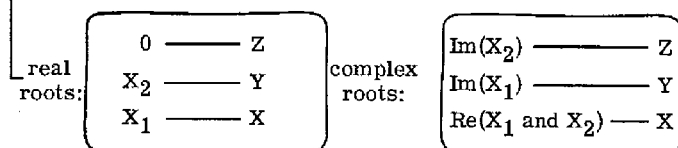
PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $a \rightarrow Z$, $b \rightarrow Y$, $c \rightarrow X$

PRESS: CONTINUE

DISPLAY



(Note Z contains zero)

EXAMPLES

GENERAL FORM

$$aX^2 + bX + c = 0$$

$$X^2 + X + 1.25 = 0$$

$$X_2 = -.5 + j1$$

$$X_1 = -.5 - j1$$

$$2X^2 + 5X + 3 = 0$$

$$X_2 = -1.5$$

$$X_1 = -1.0$$

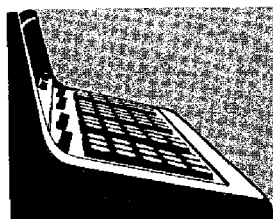
$$X^2 + 4 = 0$$

$$X_2 = j2$$

$$X_1 = -j2$$

[illegible]

[illegible]



PART NO.
09100-70010

FINITE DIFFERENCE INTERPOLATION USING GAUSS'S BACKWARD FORMULA

This program interpolates for data points in the region of tabulated data for uniformly spaced abscissas, with spacing h . The equation used is the backward-interpolation formula of Gauss which uses four pairs of data points and sets up the polynomial for cubic interpolation.

The equation used is:

$$Y = Y_0 + u \delta Y_{-1/2} + \frac{1}{2!} (u+1) \delta^2 Y_0 + \frac{1}{3!} (u+1)(u-1) \delta^3 Y_{-1/2}$$

The difference table is:

u	X	Y				
-2	X ₁	Y ₁				
-1	X ₂	Y ₂	Y ₂ - Y ₁			
0	X ₃	Y ₃	Y ₃ - Y ₂	Y ₃ - 2Y ₂ + Y ₁		
1	X ₄	Y ₄	Y ₄ - Y ₃	Y ₄ - 2Y ₃ + Y ₂	Y ₄ - 3Y ₃ + 3Y ₂ - Y ₁	

where $\delta Y_{-1/2} = Y_3 - Y_2$

$$\delta^2 Y_0 = Y_4 - 2Y_3 + Y_2$$

$$\delta^3 Y_{-1/2} = Y_4 - 3Y_3 + 3Y_2 - Y_1$$

and $u = \frac{X - X_3}{h}$

Reference: Introduction to Numerical Analysis
by F.B. Hildebrand

McGraw-Hill 1956

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $Y_1 \rightarrow Z$, $Y_2 \rightarrow Y$, $Y_3 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $Y_4 \rightarrow Z$, $X_3 \rightarrow Y$, $h \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER DATA: $X \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
Y(X)	—	Y
X	—	X

TO RESTART PRESS: END

PRESS: CONTINUE

EXAMPLES

GENERAL FORM: $Y(X)$

i	X_i	Y_i	
1	-1	-1	$Y(3.1) = 21.181$
2	1	1	$Y(2.5) = 10.375$
3	3	19	$Y(-2) = -11.000$
4	5	101	

 $h = 2$

i	X_i	Y_i	
1	0	-7	
2	.5	-6.75	$Y(.7) = -6.314$
3	1	-5	$Y(1.2) = -3.544$
4	1.5	-.25	

 $h = .5$

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1		01	DISPLAY 1 TO INDICATE FIRST ENTRY								
	2	STOP	41	Y_3	Y_2	Y_1	ENTER $Y_1, Y_2, Y_3,$					
	3	$x \rightarrow ()$	23	STORE Y_1, Y_2, Y_3								
	4	d	17									
	5	$y \rightarrow ()$	40									
	6	C	16									
	7	ROLL $\uparrow$	22									
	8	$x \rightarrow ()$	23									
	9	b	14									
	0	CLEAR	20									
	1	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	2	STOP	41	h	X_3	Y_4	ENTER Y_4, X_3, h					
	3	ACC +	60									
1	0	ROLL $\downarrow$	31									
	1	$y \rightarrow ()$	24									
	2	b	14									
	3	$\downarrow$	25									
	4	CHG SIGN	32									
	5	$\uparrow$	27									
	6	C	16									
	7	+	33									
	8	+	33									
	9	+	33	CALCULATE $\delta^3 Y_{-1/2}$								
	0	d	17									
	1	-	34									
	2	-	34									
	3	-	34									
2	0	b	14									
	1	+	33									
	2	$y \rightarrow ()$	40									
	3	b	14									
	4	$\uparrow$	27									
	5	d	17									
	6	-	34									
	7	-	34	CALCULATE $\delta^2 Y_0$								
	8	C	16									
	9	+	33									
	0	$y \rightarrow ()$	24									
	1	C	16									
	2	d	17									
	3	$y \rightarrow ()$	24									

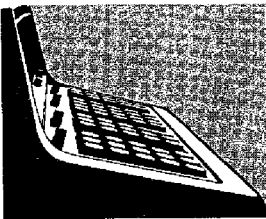
PAGE 2

PART NO. 09100-70010

Step	Key	Code	Display			Storage											
			x	y	z	f	e	d	c	b	a						
3	0	34	CALCULATE $\delta Y_{-1/2}$														
	1	40															
	2	13															
	3	37															
	4	27															
	5	27															
	6	03	DISPLAY 3 TO INDICATE THIRD ENTRY														
	7	41	X 0 0			ENTER X											
	8	31															
	9	25															
	0	12	CALCULATE u														
	1	34															
	2	15															
	3	35															
	4	22															
4	0	22	STORE X														
	1	23															
	2	11															
	3	25															
	4	01															
	5	30															
	6	33															
	7	36															
	8	36															
	9	27															
	0	36															
	1	31	CALCULATE $\frac{1}{3!} (u+1)(u)(u-1) \delta^3 Y_{-1/2}$														
	2	34															
	3	25															
5	0	30															
	1	34															
	2	06															
	3	35															
	4	14															
	5	36															
	6	13															
	7	22	CALCULATE $u \delta Y_{-1/2}$														
	8	36															
	9	31															
	0	33	FORM PARTIAL SUM														
	1	01															
	2	22															
	3	33															

FROM 7-3

[illegible]



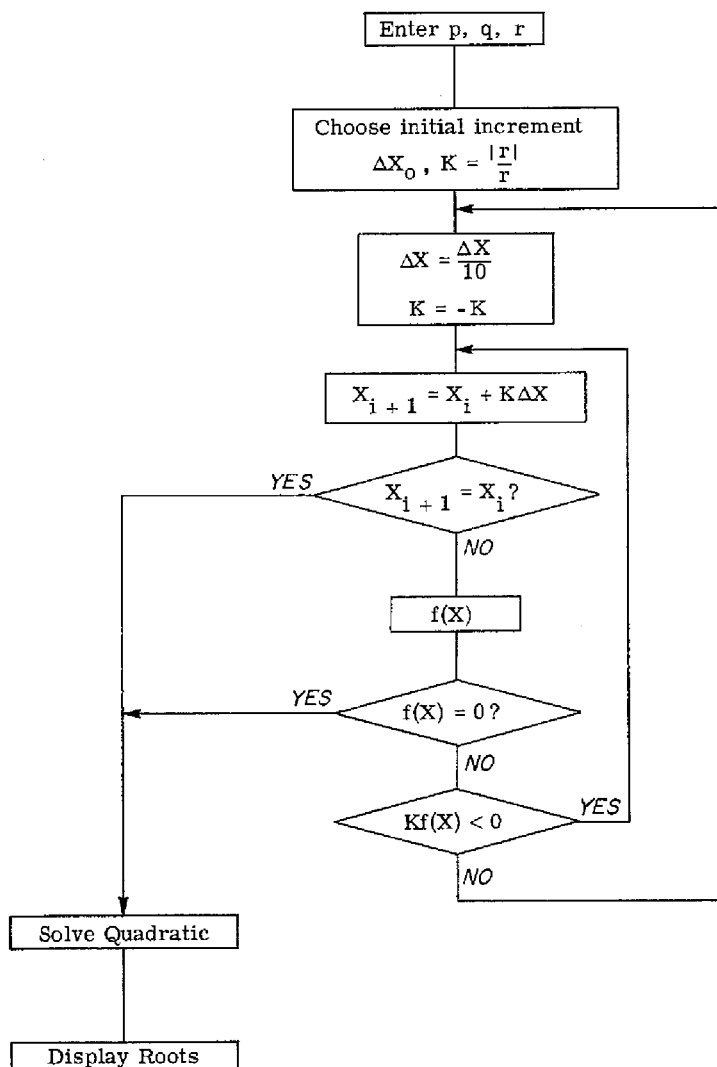
PART NO.
09100-70011

CUBIC EQUATION

This program solves

$$X^3 + pX^2 + qX + r = 0$$

for real and complex roots.



USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $p \rightarrow Z$, $q \rightarrow Y$, $r \rightarrow X$

PRESS: CONTINUE

DISPLAY:

3 real roots

0	—	Z
0	—	Y
3	—	X

1 real
2 complex
roots

0	—	Z
0	—	Y
1	—	X

PRESS: CONTINUE

DISPLAY:

real
roots:

X_3	—	Z
X_2	—	Y
X_1	—	X

complex
roots:

$(X_3) - Z$
$\text{Im}(X_1 \text{ and } X_2) - Y$
$\text{Re}(X_1 \text{ and } X_2) - X$

General Form

$$X^3 + pX^2 + qX + r = 0$$

Example 1

$$X^3 + 3X^2 + 3X + 1$$

$$X_3 = -1$$

$$X_2 = -1$$

$$X_1 = -1$$

Example 2

$$X^3 - X^2 + X - 1$$

$$X_3 = 1$$

$$X_1, X_2 = \pm i$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20									
1	1 STOP	41	r	q	p	ENTER p,q,r					
2	2 ACC +	60									
3	3 ↓	25									
4	4 y→()	40									
5	5 d	17									
6	6 y	55									
7	7 f	15									
8	8 x↔y	30									
9	9 y	55									
a	+	33									
b	ENTER EXP	26									
c	CHG SIGN	32									
d	2	02									
1	0 ↑	27									
1	1	01									
2	0	00									
3	X	36									
4	↓	25									
5	IF x<y	52									
6	1	01									
7	0	00									
8	x→()	23									
9	c	16									
a	CLEAR X	37									
b	↑	27									
c	f	15									
d	↑	27									
2	0 y	55									
1	÷	35									
2	y→()	40									
3	b	14									
4	c	16									
5	x↔y	30									
6	.	21									
7	1	01									
8	X	36									
9	y→()	40									
a	c	16									
b	b	14									
c	CHG SIGN	32									
d	x→()	23									

STORE DATA

STORE INITIAL INCREMENT Δx_0

CALCULATE K

CALCULATE $\frac{\Delta x}{10}$

CALCULATE -K

FROM 5-8

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	b	14								
1	↓	25									
2	c	16									
3	↑	27									
4	b	14									
5	x	36									
6	↓	25									
7	+	33									
8	↓	25									
9	IF x=y	50									
a	5	05									
b	9	11									
c	↑	27									
d	↑	27									
4	0	d	17								
1	+	33									
2	↓	25									
3	x	36									
4	e	12									
5	+	33									
6	↓	25									
7	x	36									
8	f	15									
9	+	33									
a	CLEAR x	37									
b	IF x=y	50									
c	5	05									
d	9	11									
5	0	b	14								
1	x	36									
2	CLEAR x	37									
3	IF x>y	53									
4	3	03									
5	1	01									
6	GO TO ()	44									
7	2	02									
8	4	04									
9	↓	25									
a	y→()	40									
b	b	14									
c	d	17									
d	ROLL ↑	22									

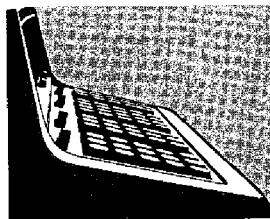
CALCULATE $X_{i+1} = X_i + K\Delta X$ BRANCH IF $X_{i+1} = X_i$ CALCULATE $f(X)$ BRANCH IF $f(X)=0$ COMPARE $Kf(X)$ TO ZERO

BRANCH TO INCREMENT CHANGE

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	+	33								
	1	↑	27								
	2	↓	25								
	3	x	36								
	4	E	12								
	5	+	33								
	6	↓	25								
	7	CHG SIGN	32								
	8	ROLL ↓	31								
	9	2	02								
	E	CHG SIGN	32								
	b	÷	35								
	c	↓	25								
	d	↑	27								
7	0	x	36								
	1	ROLL ↓	31								
	2	+	33								
	3	ENTER EXP	26								
	4	CHG SIGN	32								
	5	1	01								
	6	0	00								
	7	ROLL ↑	22								
	8	x	36								
	9	y	55								
	a	ROLL ↓	31								
	b	CHG SIGN	32								
	c	IF x > y	53								
	d	9	11								
8	0	1	01								
	1	SET FLAG	54								
	2	CHG SIGN	32								
	3	IF x > y	53								
	4	CLEAR x	37								
	5	x	36								
	6	↓	25								
	7	√x	76								
	8	-	34								
	9	ROLL ↑	22								
	E	+	33								
	b	↓	25								
	c	GO TO () ()	44								
	d	9	11								

SOLVE REDUCED QUADRATIC EQUATION

[illegible]



PART NO.
09100-70012

OCTAL $\rightleftharpoons$ DECIMAL CONVERSIONS

Many computer program dumps are in octal. Debugging such a dump is aided by converting octal $\rightleftharpoons$ decimal numbers on the 9100A.

This program converts numbers in the X register from one base to the other. The Y and Z registers are not affected by the conversions so that arithmetic operations may be carried out by first converting from octal to decimal, then performing the desired arithmetic operations in decimal and, finally converting the answer from decimal to octal. The A and B registers may be used for auxiliary storage. Conversion limits are:

OCTAL $\rightarrow$ DECIMAL

$$8^{-99} \leq |\text{OCTAL NUMBER}| < 8^{100}$$

DECIMAL $\rightarrow$ OCTAL

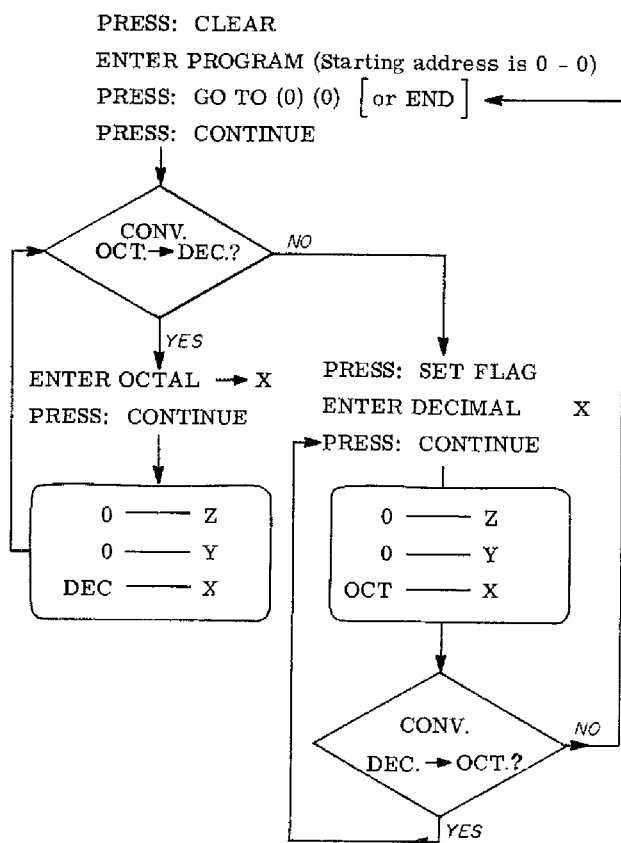
$$10^{-89} \leq |\text{DECIMAL NUMBER}| \leq 10^{90}$$

Decimal numbers are expressed as standard floating point numbers; however, the exponent on octal numbers is listed in decimal rather than octal i.e.,

$$1.234 \quad 19 \text{ means } 1.234_8 \times 8^{19_{10}}$$

USER INSTRUCTIONS

EXAMPLES



To reset octal → decimal, without losing X, Y or Z,

PRESS: END

PRESS: CONTINUE

NOTE: Contents of Y and Z remain unchanged after conversion.

DEGREES

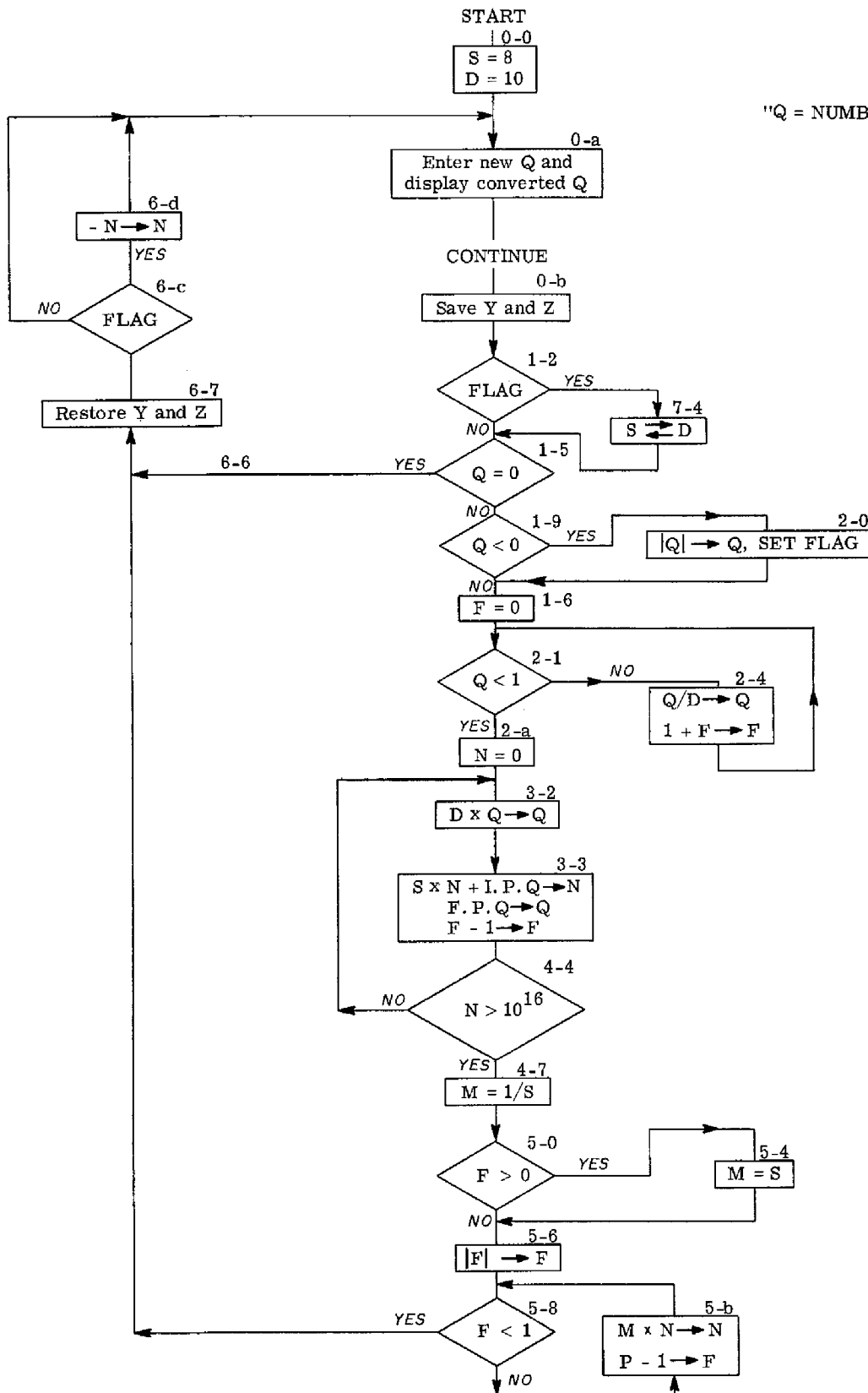
$$24_8(\sin -36_8^\circ) + 144.4_8 = 132.4_8$$

Following the steps listed above:

1. PRESS: CLEAR
2. PRESS: END
3. PRESS: CONTINUE
4. { PRESS: CHANGE SIGN
PRESS: 3 (Converts to -30°)
PRESS: 6
5. PRESS: CONTINUE
6. PRESS: SIN X ($\sin 30^\circ = -.5$)
7. PRESS: ↑ (-0.5 to Y)
8. { PRESS: 2 (Converts to 20_{10})
PRESS: 4
9. PRESS: CONTINUE
10. PRESS: X ($20_{10} (-0.5) = -10$ in Y)
11. { PRESS: 1
PRESS: 4
PRESS: 4 (Converts to 100.5_{10})
PRESS: .
PRESS: 4
12. PRESS: CONTINUE
13. PRESS: + 90.5 IN Y
14. PRESS: ↓ 90.5 IN X
15. PRESS: SET FLAG Set up Decimal → Octal
16. PRESS: CONTINUE

Answer, 132.4_8 , IN X

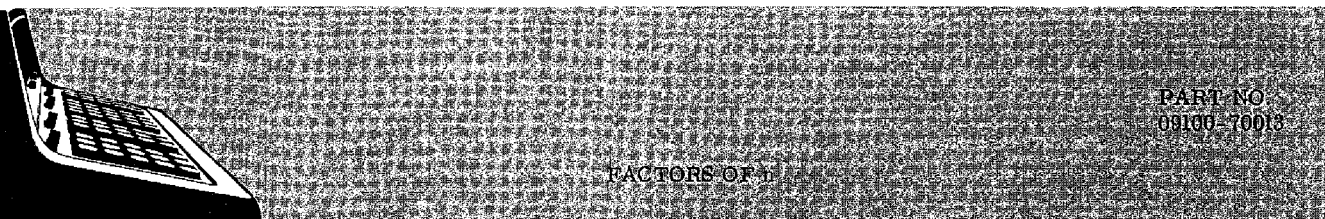
"Q = NUMBER ENTRY"





[illegible]

HEWLETT-PACKARD
HEWLETT-PACKARD
HEWLETT-PACKARD
HEWLETT-PACKARD
HEWLETT-PACKARD
HEWLETT-PACKARD



This program gives the factors of any positive integer n.

All repeated factors are given.

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

→ PRESS: CONTINUE

DISPLAY

0	——	Z
0	——	Y
0	——	X

ENTER DATA: No. to be factored → X

DISPLAY

0	——	Z
0	——	Y
n	——	X

→ PRESS: CONTINUE

DISPLAY

n	——	Z
remaining factor	——	Y
Factor	——	X

FINAL DISPLAY

n	——	Z
1	——	Y
Factor	——	X

(A)

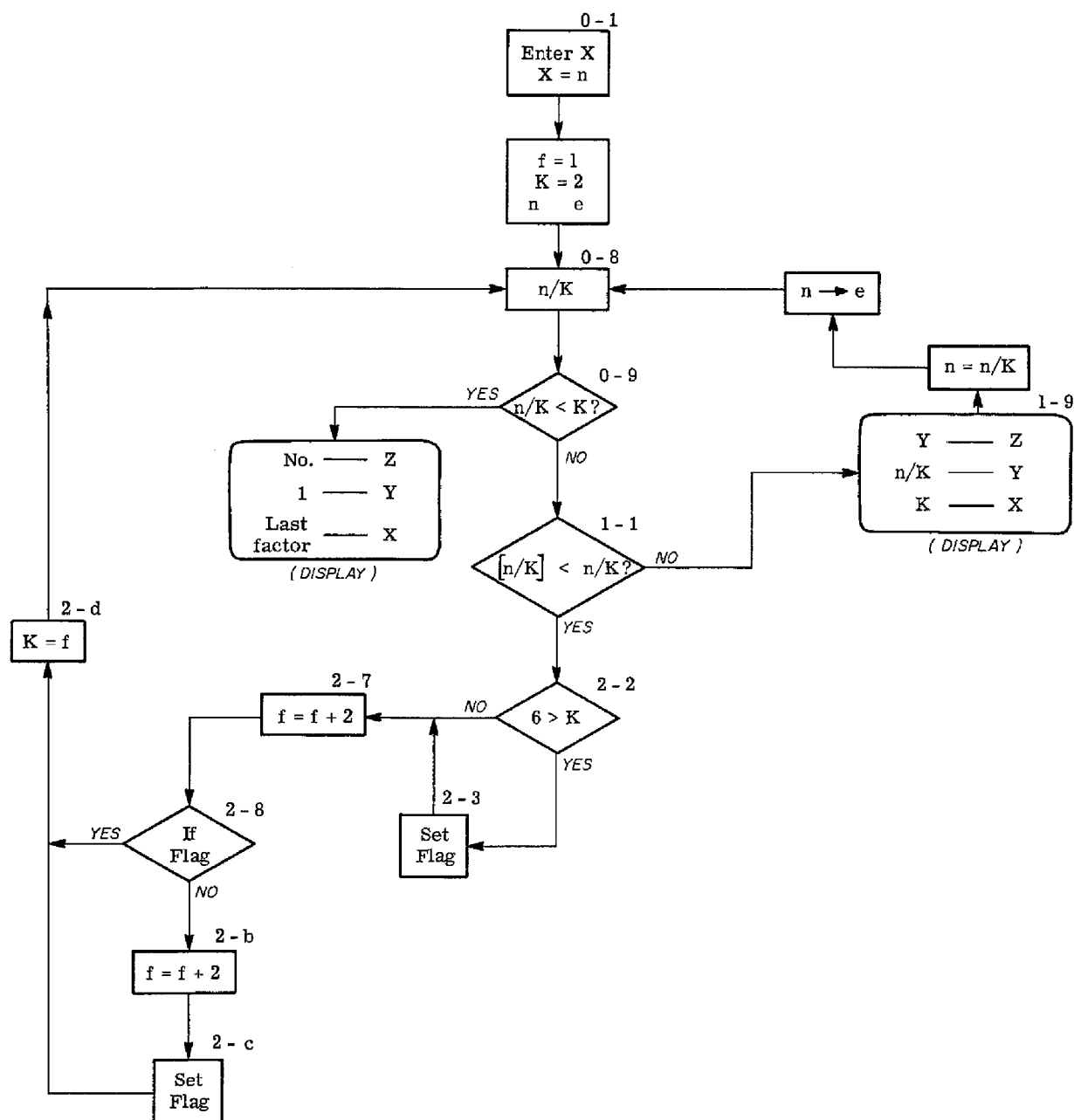
$n = 50$

Factors are: 2, 5, 5

(B)

$n = 2.9393939 \times 10^7$

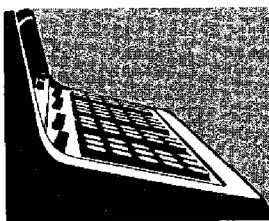
Factors are: 2.9393939×10^7
(n is a prime number)





Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	STOP	41	X	0	0					
	2	$x \rightarrow ()$	23								
	3	d	17	STORE X							
	4	↑	27								
	5	1	01	STORE 1 AND X							
	6	ACC +	60								
	7	2	02								
	8	÷	35	CALCULATE X/K							
	9	IF $x > y$	53								
	a	3	03	BRANCH FOR FINAL DISPLAY							
	b	3	03								
	c	$x \neq y$	30								
	d	↑	27								
1	0	int x	64	COMPARE $\left[\frac{n}{k}\right]$ TO K AND BRANCH IF							
	1	IF $x < y$	52	K IS NOT A FACTOR							
	2	1	01								
	3	d	17								
	4	ROLL ↓	31								
	5	d	17								
	6	ROLL ↓	31	POSITION DISPLAY AND STORE UNFACTORED PORTION							
	7	$y \rightarrow ()$	40								
	8	E	12								
	9	STOP	41	K	n/k	n					
	a	GOTO ()	44								
	b	0	00	BRANCH TO CONTINUE FACTORING							
	c	8	10								
	d	CLEAR x	37								
2	0	ROLL ↓	31								
	1	6	06								
	2	IF $x > y$	53								
	3	SET FLAG	54	SET FLAG IF $6 > K$							
	4	CLEAR x	37								
	5	↓	25								
	6	2	02	CALCULATE $f+2$							
	7	ACC +	60								
	8	IF FLAG	43								
	9	2	02	BRANCH WHEN FLAG IS SET							
	a	d	17								
	b	ACC +	60	CALCULATE $f+2$ AND SET FLAG							
	c	SET FLAG	54								
	d	RECALL	61	SET $K=f$							

[illegible]



PART NO.
09100-70014

REAL ROOTS OF $f(x)$

This program finds the real roots of equations of the form $f(x) = 0$. The solution evaluates $f(x)$ at a specified starting point x_0 and at successive x 's by replacing x with $x + \Delta x$ (the initial Δx is also specified by the user). When $f(x)$ changes sign, Δx is replaced with $-\Delta x/10$.

The search continues until $f(x)$ is driven to zero. The value of x such that $f(x) = 0$ is a root of the equation. $f(x)$ must change sign for the technique to converge.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

SET: PROGRAM

Starting at (6) (0) enter the program steps which take the independent variable from the X register and program $f(x)$, (x is also contained in the d register). Place $f(x)$ in the X register and exit to location 0-6. The last four steps of the $f(x)$ subroutine should be:

GO TO
0
6
END

Note: Registers 6, 7, 8, 9, a, b, c, e, and f are available for programming and storage of $f(x)$. Register d and the flag are unavailable.

SET: RUN

PRESS: END

Store initial conditions (when applicable).

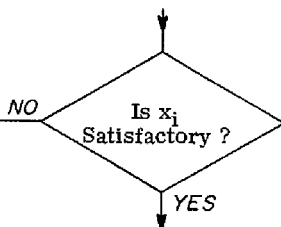
ENTER: $x_i \rightarrow X$ (x_i is initial x from which search is to begin.)

PRESS: CONTINUE

DISPLAY

$\pm f(x_{i-1}) \cdot f(x_i)$	— Z
$f(x_i)$	— Y
x_i	— X

Note:
 $f(x_{i-1})$ is random
the first pass and
product is mean-
ingless



ENTER: $\Delta x \rightarrow x$. (Δx is the searching increment. $+\Delta x$ searches right, $-\Delta x$ searches left)

USER INSTRUCTIONS (con't)

PRESS: CONTINUE

The real roots of $f(x)$ program successively evaluates $f(x)$.

PAUSE DISPLAY

$\pm f(x_{i-1}) \cdot f(x_i)$	— Z
$f(x_i)$	— Y
x_i	— X

The calculation stops when x_i is a root, x_i is successively replaced by $x_i \pm \Delta x$. (See flow-chart). If calculation is not converging, press: PAUSE, press: END and enter a new estimate as before.

TO ENTER A NEW PROBLEM:

PRESS: END

PRESS: GO TO (0) (0)

ENTER NEW DATA AS BEFORE

EXAMPLES

1. FIND ROOT OF $x = \cos x$ SET: RADIANS ENTER DATA: $x_i = 0 \rightarrow X$

PRESS: END

PRESS: CONTINUE

DISPLAY

(JUNK)	— Z
-1.000	— Y
0	— X

(Y contains $f(x)$)(X contains x)ENTER DATA: $x = 0.1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	— Z
0	— Y
0.7390851332	— X

(X contains root)

EXAMPLES (con't)

EXAMPLES (con't)

2.

$$y = \frac{\pi^2 \sqrt{x}}{1 + \cos \frac{\pi}{2} x}$$

Given the initial x
condition $y = 4$,
find x.

Rewrite equation as

$$f(x) = y(1 + \cos \frac{\pi}{2} x) - \pi^2 \sqrt{x}$$

User subroutine assumes y is in a (it will be
manually entered into a as an initial condition)

SET: RADIANS

ENTER DATA: $y = 4 \rightarrow X$

PRESS: $X \rightarrow (a)$ to satisfy initial condition that
y is in a.

PRESS: END

ENTER DATA: Initial $x_1 = 0$ X

PRESS: CONTINUE

DISPLAY

(JUNK) — Z	
8.00 — Y	f(x, 4) in Y
0 — X	(x in X)

Instead of entering Δx , evaluate $f(x)$ at a
new value x_1

PRESS: END

ENTER DATA: $x_1 = 1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

(JUNK) — Z	
-5.87 — Y	f(x, 4) in Y
1.0 — X	(x in X)

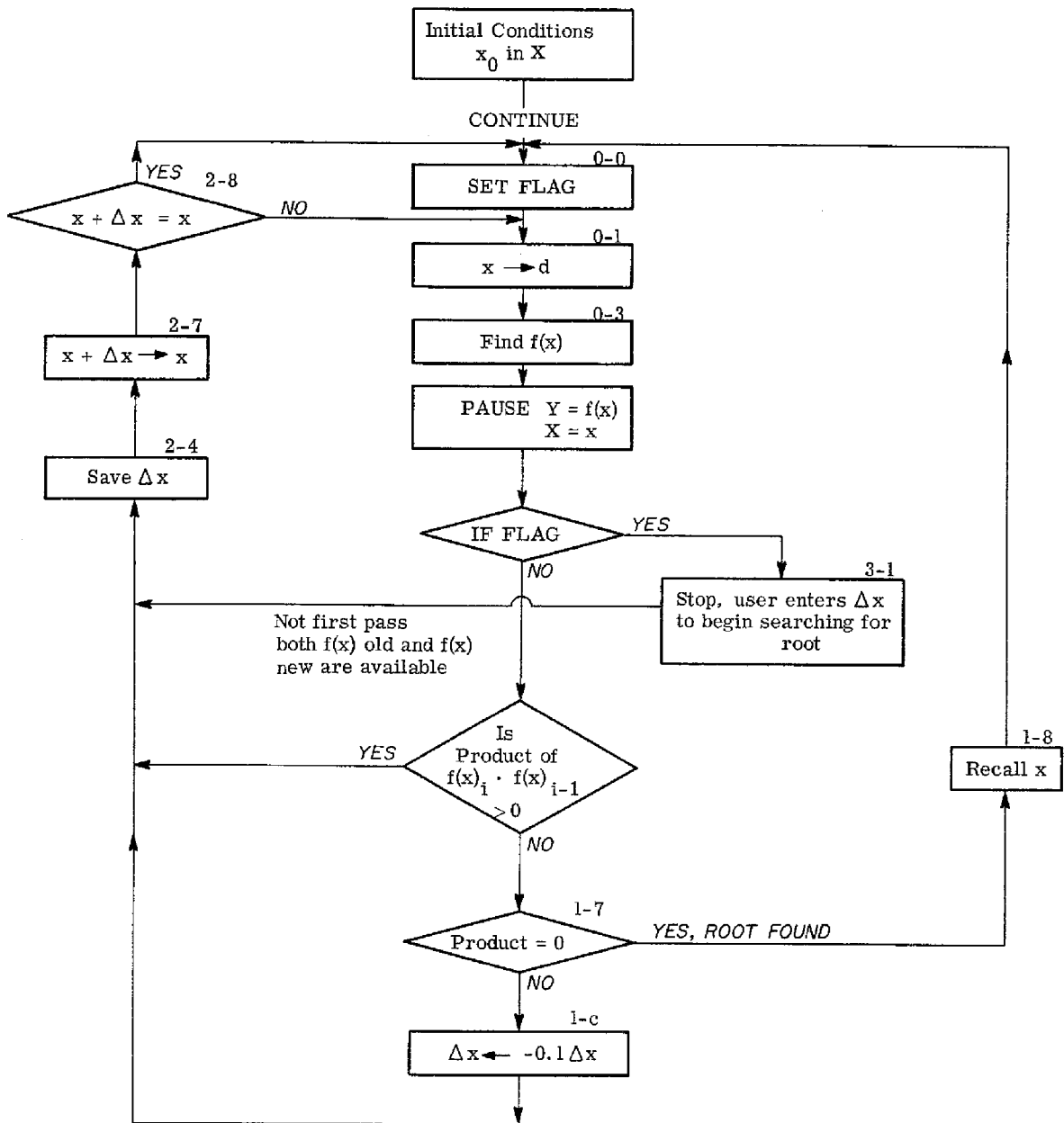
A root has been crossed between $f(0)$ and $f(1)$
because $f(x)$ changed sign. Begin search to the
left by entering

$x = -0.1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

4×10^{-22}	
-2	-11 f(x, 4) in Y
4.868292372	-01 X contains root



[illegible]

[illegible]

[illegible]

[illegible]

NUMERICAL INTEGRATION USING SIMPSON'S
RULE WHEN f(x) IS KNOWN

PART NO
09100-7001

This program evaluates the integral of a known f(x) using Simpson's rule. The equation used is:

$$\int_a^b f(X) dX \cong \frac{\Delta X}{3} \left[f(a) + 4f(a + \Delta X) + 2f(a + 2\Delta X) + \dots + 2f\{a + (n-2)\Delta X\} + 4f\{a + (n-1)\Delta X\} + f(b) \right]$$

for n panels (n must be even) where $\Delta X = \frac{b-a}{n}$

The specific f(x) is programmed into the calculator by the user and is then used by the general solution to evaluate the integral. Execution time is dependent on the number of panels. Note f(x) should not have any singularities in the integration interval.

Reference:

Numerical Analysis
by
Kaiser S. Kunz

McGraw-Hill Book Company, Inc.
(1957)

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (6) (0)

SET: PROGRAM

Enter the program steps that take X from the X register (X is also in the e register) and calculate $f(X)$. Place $f(X)$ in the Y register and exit to location 1 - 5, i.e. finish with the steps GO TO () (), (1), (5), END. Registers 6, 7, 8, 9, and a are available for storing and calculating $f(X)$. The flag is unavailable.

SET: RUN

PRESS: END

→PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: n panels (must be an even number) → Z, b → Y, a → X

PRESS: CONTINUE

DISPLAY

AREA	—	Z
b	—	Y
a	—	X

To calculate the integral of another $f(X)$, repeat the instructions.

PRESS: GO TO (6) (0)

and proceed as before.

EXAMPLES

$$\int_e^{e^2} \frac{1}{X (\ln X)^3} dX = \frac{3}{8}$$

1. Let n panels = 30 (must be even)

$$b = e^2$$

$$a = e$$

$$\int_a^b \frac{1}{X (\ln X)^3} dX \cong .3750098$$

2. Let n panels = 100

$$b = e^2$$

$$a = e$$

$$\int_a^b \frac{1}{X (\ln X)^3} dX \cong .3750001$$

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	1	01									
2	STOP	41	a	b	n PANELS	ENTER n PANELS (n MUST BE EVEN), b AND a					
3	y→()	40									
4	d	17									
5	x→()	23									
6	b	14									
7	—	34									
8	ROLL ↓	31									
9	x↔y	30									
a	÷	35									
b	y→()	40									
c	C	16									
d	ROLL ↑	22									
1	0	23									
1	E	12									
2	GOTO () ()	44									
3	6	06									
4	0	00									
5	E	12									
6	↑	27									
7	b	14									
8	IF x=y	50									
9	4	04									
a	2	02									
b	d	17									
c	—	34									
d	y	55									
2	0	26									
1	9	11									
2	CHG SIGN	32									
3	IF x>y	53									
4	4	04									
5	8	10									
6	E	12									
7	x↔y	30									
8	d	17									
9	IF x<y	52									
a	4	04									
b	8	10									
c	C	16									
d	ROLL ↑	22									

STORE DATA

CALCULATE Δx BRANCH TO CALCULATE $f(x)$

RECALL a AND BRANCH FOR INITIAL POINT

COMPARE $|a_i - b|$ TO 10^{-9} AND STOP
INTEGRATION IF $|a_i - b| < 10^{-9}$ COMPARE a_i TO b AND STOP
INTEGRATION IF $a_i > b$

FROM 5-9

FROM 4-1 & 4-7

[illegible]

[illegible]

SIMULTANEOUS SOLUTION OF
TWO EQUATIONS IN TWO UNKNOWNNS

PART NO
09100-70016

This program solves two independent equations simultaneously for the two unknowns.

The two equations are of the following form:

$$ax + by = e$$

$$cx + dy = f$$

where x and y are the two unknowns to be found.

The solution is obtained by normalizing the coefficient of x to 1, yielding the equations:

$$x = e/a - (b/a)y \quad (1)$$

$$x = f/c - (d/c)y \quad (2)$$

Subtracting gives the solution for y:

$$y = \frac{(e/a - f/c)}{(b/a - d/c)}$$

The value of x is then found by substituting the value of y back into the second equation.

Reference:

Numerical Analysis

by

Kaiser S. Kunz

McGraw-Hill, 1st edition

(1957)

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM: (Starting Address is (0) (0))

→ PRESS: GO TO (0) (0) or [END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: a → Z, b → Y, e → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: c → Z, d → Y, f → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
y	_____	Y
x	_____	X

→ TO RESET PROBLEM:

Solve the following equations simultaneously for x and y.

$$(1) \quad 2x + y = 6$$

$$(2) \quad 2x + 3y = 1$$

Data to be entered:

2	→	Z	
1	→	Y	(1)
6	→	X	
2	→	Z	
3	→	Y	(2)
1	→	X	

Solution:

$$\begin{aligned} x &= 4.25 \\ y &= -2.50 \end{aligned}$$

General Form:

$$\begin{aligned} ax + by &= e \\ cx + dy &= f \end{aligned}$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	SET FLAG	54									
2	ACC +	60									
3	CLEAR X	37									
4	↑	27									
5	↑	27									
6	STOP	41	e	b	a						
7	ROLL ↑	22									
8	÷	35									
9	ROLL ↑	22									
a	x↔y	30									
b	÷	35									
c	↓	25									
d	IF FLAG	43									
1	0	00									
1	2	02									
2	ACC -	63									
3	x↔y	30									
4	y↔1	24									
5	E	12									
6	f	15									
7	÷	35									
8	E	12									
9	x↔y	30									
a	X	36									
b	ROLL ↓	31									
c	-	34									
d	CLEAR X	37									
2	0	ROLL ↓	31								
1	END	46	x	y	0						
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

CLEAR OUT STORAGE AND
SET THE FLAG

ENTER DATA: (COEFFICIENTS
AND CONSTANT OF FIRST
EQUATION)

CALCULATE e/a AND b/a ON THE FIRST PASS;
 f/c AND d/c ON THE SECOND PASS

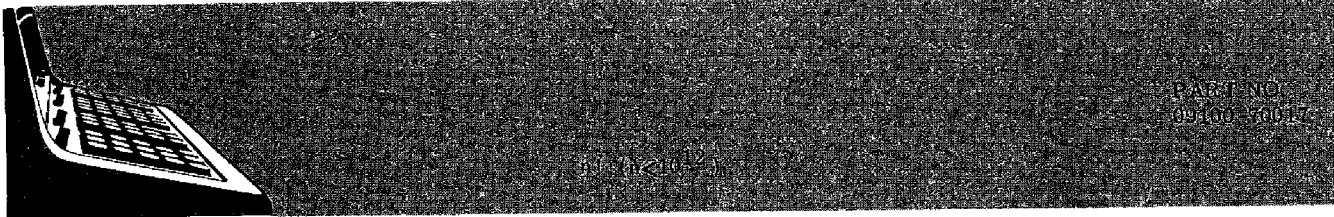
BRANCH TO STORE e/a AND b/a AND ENTER COEFFICIENTS
AND CONSTANT OF SECOND EQUATION

CALCULATE $(b/a - d/c)$ AND $(e/a - f/c)$

CALCULATE y

CALCULATE x

[illegible]



PART NO.
09100-70017

This program calculates $n!$ for integer n where $0 \leq n < 10^{12}$

$$n! = n (n - 1) \dots 3 \cdot 2 \cdot 1$$

No Reference

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM: (Starting Address is (0) (0))

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA:

n → X

PRESS: CONTINUE

DISPLAY

Exponent of 10	_____	Z
Decimal Number of n!	_____	Y
n	_____	X

TO RESET PROBLEM:

DATASOLUTIONTIME

A) n = 0	n! = 1	
B) n = 7	n! = 5.040 x 10 ³	1 sec.
C) n = 1000	n! = 4.0239 x 10 ²⁵⁶⁷	16 sec.
D) n = 10 ⁴	n! = 2.8463 x 10 ³⁵⁶⁵⁹	2 min. 53 sec.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	STOP	41	n	0	0	ENTER n					
2	$x \rightarrow ()$	23	STORE n								
3	d	17									
4	$\uparrow$	27									
5	1	01									
6	$x \leftrightarrow y$	30									
7	ROLL $\uparrow$	22									
8	ACC +	60									
9	IF $x=y$	50	BRANCH IF $n=0$ TO SET $n!=1$								
a	2	02									
b	c	16	FORM $n \cdot (n-1) \cdot (n-2) \cdots 3 \cdot 2 \cdot 1$								
c	$\downarrow$	25									
d	x	36									
1	0	ENTER EXP	26								
1	9	11									
2	0	00									
3	IF $x > y$	53	BRANCH IF $n! \text{ (PARTIAL)} < 10^{90}$ TO DECREMENT $(n-k)$ BY 1								
4	2	02									
5	3	03	REDUCE EXPONENT OF $n! \text{ (PARTIAL)}$ BY 90's AND SUM THE VALUE OF THE EXPONENT OVERFLOW IN F								
6	ENTER EXP	26									
7	CHG SIGN	32									
8	9	11									
9	0	00									
a	x	36									
b	0	00									
c	$\uparrow$	27									
d	9	11									
2	0	00									
1	ACC +	60									
2	$\downarrow$	25									
3	1	01	DECREMENT $(n-k)$ BY 1								
4	$\uparrow$	27									
5	CLEAR x	37									
6	ACC -	63									
7	RCL	61									
8	CLEAR x	37									
9	GOTO ()	44	BRANCH TO MULTIPLY THE PARTIAL FACTORIAL BY $(n-k-1)$								
a	0	00									
b	9	11									
c	$\downarrow$	25									
d	ENTER EXP	26									

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

FROM 3-c

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	9	11								
1	IF $x > y$	53									
2	3	03									
3	d	17									
4	ENTER EXP	26									
5	CHG SIGN	32									
6	9	11									
7	X	36									
8	9	11									
9	ACC +	60									
a	GO TO () ()	44									
b	2	02									
c	d	17									
d	1	01									
4	0	00									
1	IF $x > y$	53									
2	4	04									
3	c	16									
4	.	21									
5	1	01									
6	X	36									
7	1	01									
8	ACC +	60									
9	GO TO () ()	44									
a	3	03									
b	d	17									
c	f	15									
d	xzy	30									
5	0	↑	27								
1	d	17									
2	END	46	n	DEC. NO. (n!)	EXP. OF 10	DISPLAY					
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

REDUCE EXPONENT OF $n!$ BY 9's AND
SUM THE VALUE OF EXPONENT OVERFLOW IN f

BRANCH TO COMPARE $n!$ TO 10^9

BRANCH IF ARGUMENT $(n!) < 10^{12}$ TO RECALL
RESULTANT EXPONENT AND DISPLAY

REDUCE EXPONENT OF $n!$ BY 1's AND SUM
THE VALUE OF EXPONENT OVERFLOW IN f

BRANCH TO COMPARE $n!$ TO 10^9

RECALL n AND EXPONENT OF $n!$

n DEC. NO. (n!) EXP. OF 10 DISPLAY

09100-70018

CONVOLUTION

This program uses the convolution integral to find the response of any system to an arbitrary forcing function. The forcing function and the response of the system to an impulse must be known.

Development:

The convolution integral is: $e(t) * h(t) = y(t) = \int_0^t e(\tau) h(t-\tau) d\tau$

where $e(t)$ is the forcing function.

$y(t)$ is the circuit response due to the forcing functions.

$h(t)$ is the impulse response.

It is assumed that the forcing function is zero prior to time equal zero.

Reference: Transform & State Variable Methods in Linear Systems --
Someshwar C. Gupta
Publisher - John Wiley & Sons, Inc.
Copyright - 1966, 1st Edition

USER INSTRUCTIONS

SET:

ENTER PROGRAM: Starting Address is (0-0)

PRESS: GO TO(7)(c)

SET:

Enter program steps to form $e(\tau) \cdot h(t-\tau)$ and place this quantity in the Y register. τ is in the X register and in storage register e. t is in storage register d.

The last four steps must be:

GO TO
3
4
END

NOTE: Steps 7-c, 7-d and registers 8 and 9 are available for forming the function to be integrated.

SET:

PRESS: GO TO(0)(0)[or END]

PRESS: CONTINUE

DISPLAY

0 — Z
0 — Y
1 — X

ENTER DATA: Panels/unit time $\rightarrow$ Y
Time increment (Δt) $\rightarrow$ X

PRESS: CONTINUE

DISPLAY

y(t) — Z
t — Y
0 — X

NOTE: Each successive depression of the CONTINUE button increments t by the amount Δt and calculates $y(t)$ for the incremented value of t .

TO RESET PROBLEM for a different Δt .TO RESET PROBLEM for a different $e(\tau)$

EXAMPLES

- (A) Find the response of a circuit with an impulse response of e^{-t} to a forcing function of $u(t)$ -- for $0 \leq t \leq \infty$.

Therefore: $e(\tau) = u(\tau) = 1$ for $0 \leq \tau \leq \infty$

$$h(t-\tau) = e^{-(t-\tau)} = e^{\tau-t}$$

Program Steps Code No.

7-c	↑	27
7-d	d	17
8-0	-	34
8-1	↓	25
8-2	e^x	74
8-3	↑	27
8-4	GO TO	44
8-5	3	03
8-6	4	04
8-7	END	46

Integrating analytically, the result is:

$$\int_0^t e(\tau) h(t-\tau) d\tau = \int_0^t e^{(\tau-t)} d\tau = 1 - e^{-t} \text{ for } t > 0$$

Data: $\Delta t = 1$, Panels / (unit time) = 100Results: t $y(t)$

1	.63212
2	.86466
3	.95021
4	.98168
5	.99326

- (B) Find the response of a circuit with an impulse response of e^{-t} to a forcing function of $\sin t$ -- for $0 \leq t \leq \pi$.

Therefore: $e(\tau) = \sin(\tau)$ for $0 \leq \tau \leq \pi$

$$h(t-\tau) = e^{-(t-\tau)} = e^{(\tau-t)}$$

Program Steps Code No.

7-c	↑	27
7-d	d	17
8-0	-	34
8-1	↓	25
8-2	e^x	74
8-3	↑	27
8-4	π	56
8-5	↑	27
8-6	e	12
8-7	IF x>y	53
8-8	CLX	37
8-9	↑	27
8-a	sin	70
8-b	R↑	22
8-c	X	36
8-d	GO TO	44
9-0	3	03
9-1	4	04
9-2	END	46

Set the forcing function to zero in the Y register if $t > \pi$.

EXAMPLES

(B) continued

Integrating analytically, the result is:

$$\int_0^t e(\tau) h(t-\tau) d\tau = \int_0^t e^{-(t-\tau)} \sin \tau d\tau$$

$$= 1/2 (\sin t - \cos t + e^{-t}) \text{ for } 0 \leq t \leq \pi$$

$$= \frac{e^{-t}}{2} (1 + e^{\pi}) \text{ for } t \geq \pi$$

Data: $\Delta t = \pi/4$, Panels/(unit time) = 100

Results:

t	$y(t)$
$\pi/4$	.22797
$\pi/2$	.60394
$(3\pi)/4$	.75450
π	.52161
$(5\pi)/4$	.23782
$(3\pi)/2$	.10843

NOTE: Simpson's one-third rule is used to perform the integration; therefore, accuracy depends on the number of panels per unit time that is selected. In both examples, accuracy to nine decimal places was obtained using 100 panels/(unit time).



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	01									
2	STOP	41	Δt	$\frac{\text{PANELS}}{\text{UNIT TIME}}$	0	ENTER DATA					
3	$y \rightarrow ()$	40									
4	b	14									
5	ROLL $\uparrow$	22									
6	$y \rightarrow ()$	40	STORE $\frac{\text{PANELS}}{\text{UNIT TIME}}, \Delta t,$ AND $\sum \Delta t$								
7	a	13									
8	+	33									
9	$y \rightarrow ()$	40									
	a	d	17								
	b	$\downarrow$	25								
	c	x	36								
	d	.	21								
1	0	5	05								
1	+	33									
2	$\downarrow$	25									
3	int x	64									
4	$\uparrow$	27									
5	$\uparrow$	27									
6	2	02	CALCULATE INCREMENTAL NUMBER OF PANELS AND MAKE THIS NUMBER AN EVEN NUMBER								
7	$\div$	35									
8	$\downarrow$	25									
9	$\uparrow$	27									
	a	int x	64								
	b	IF $x < y$	52								
	c	ROLL $\downarrow$	31								
	d	1	01								
2	0	+	33								
1	$\uparrow$	27									
2	RCL	61	CLEAR REGISTERS e & f								
3	ACC -	63									
4	d	17									
5	$x \rightleftharpoons y$	30									
6	CLEAR x	37									
7	ROLL $\downarrow$	31									
8	$x \rightleftharpoons y$	30									
9	$\div$	35	CALCULATE Δx OF SIMPSON'S RULE.								
	a	$y \rightarrow ()$	40								
	b	c	16								
	c	ROLL $\uparrow$	22								
	d	$x \rightarrow ()$	23								

FROM 7-b

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	E	12								
1	GOTO (X)	44									
2	7	07									
3	C	16									
4	E	12									
5	↑	27									
6	CLEAR x	37									
7	IF x=y	50									
8	6	06									
9	1	01									
a	d	17									
b	-	34									
c	y	55									
d	ENTER EXP	26									
4	0	9	11								
1	CHG SIGN	32									
2	IF x>y	53									
3	6	06									
4	7	07									
5	E	12									
6	x<y	30									
7	d	17									
8	IF x<y	52									
9	6	06									
a	7	07									
b	C	16									
c	ROLL↑	22									
d	↑	27									
5	0	IF FLAG	43								
1	5	05									
2	8	10									
3	SET FLAG	54									
4	4	04									
5	GOTO () ()	44									
6	5	05									
7	9	11									
8	2	02									
9	X	36									
a	↓	25									
b	ACC +	60									
c	GOTO () ()	44									
d	3	03									

BRANCH TO CALCULATE $f(x)$ RECALL a AND BRANCH
FOR INITIAL POINTCOMPARE $|a_1|$ TO 10^{-9} AND STOP INTEGRATION
IF $|a_1| < 10^{-9}$ COMPARE a_1 TO 0
AND STOP INTEGRATION
IF $a_1 > 0$ CALCULATE
 $4f(a + \Delta X) + 2f(a + 2X) + \dots$ BRANCH TO CALCULATE
ANOTHER PARTIAL AREA

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	00									
1	$\bar{C}$	16	RECALL Δx AND CALCULATE $a + \Delta x$. PLACE $a + \Delta x$ AND $f(a)$ IN THE ACCUMULATORS								
2	ROLL $\uparrow$	22									
3	ACC $+$	60									
4	GOTO (11)	44	BRANCH FOR OTHER PANEL CALCULATIONS								
5	3	03									
6	0	00									
7	CLEAR x	37	SUM $f(b)$ TO $f(a)$ $+ 4f(a + \Delta x) + 2f(a + 2\Delta x) + \dots$								
8	ROLL $\uparrow$	22									
9	ACC $+$	60									
a	RCL	61	MULTIPLY $\frac{\Delta x}{3}$ TIMES SUMMATION SERIES								
b	$\uparrow$	27									
c	$\bar{C}$	16									
d	$\times$	36									
7	0	03	RECALL CALCULATED END POINT AND POSITION DISPLAY								
1	$\div$	35									
2	CLEAR x	37									
3	ROLL $\uparrow$	22	0 t y (t) DISPLAY								
4	$x \leftrightarrow y$	30									
5	STOP	41									
6	b	14	BRANCH TO INCREMENT TIME AND CONTINUE SUMMATION PROCEDURE								
7	ROLL $\downarrow$	31									
8	$x \leftrightarrow y$	30									
9	IF FLAG	43	0 7 END								
a	0	00									
b	7	07									
c	END	46									
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

15. February 1969

PART NO.
09100-70019

4TH OR 5TH DEGREE POLYNOMIAL ROOTS

This program calculates the roots, real and/or imaginary, of a fifth or fourth degree equation of the form:

$$\text{5th degree} - x^5 + a_4x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

$$\text{4th degree} - x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

The fifth degree equation is reduced to a fourth degree by a normal iteration process, incrementing or decrementing an initial arbitrary value of x until $f(x) = 0$.

The fourth degree equation is then reduced to two quadratic equations by Brown's Method, after which the two quadratic equations of the form $ax^2 + bx + c$ are solved by means of the quadratic formula $x = -b/2 \pm \sqrt{b^2/4 - ac}$, or, in this case, $x = -b/2 \pm \sqrt{b^2/4 - c}$ since "a" is always normalized to one.

Brown's Method

Brown's Method states that given an equation of the form $x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$, a third degree of the form $Z^3 - a_2Z^2 + b_1Z + b_0 = 0$ may be reached

$$\text{where: } b_1 = a_3a_1 - 4a_0$$

$$b_0 = a_0(4a_2 - a_3^2) - a_1^2$$

Then solving for the largest real root (Z_1) of $f(z)$, the following constants are obtained:

$$A = \frac{a_3}{2}, B = \frac{Z_1}{2}, D = \sqrt{B^2 - a_0}, C = \frac{AB - A_{1/2}}{D}, \text{ if } D \neq 0; \text{ or } C = \sqrt{A^2 - a_2 + Z_1}, \text{ if } D = 0.$$

The resulting quadratic equations are:

$$x^2 + (A - C)x + (B - D) = 0$$

$$x^2 + (A + C)x + (B + D) = 0$$

Reference:

Numerical Methods in Engineering,
Mario G. Salvadori and Melvin L. Baron
Prentice-Hall, Inc., 1961

USER INSTRUCTIONS FOR 4TH DEGREE

Equation of the form:

$$x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

PRESS: GO TO (0) (0) [or END]

ENTER PROGRAM B: (Starting Address is 0 - 0)

PRESS: CLEAR

PRESS: GO TO (0) (0) [or END]

ENTER DATA:

$a_3 \longrightarrow Y$
 $a_2 \longrightarrow X$

PRESS: CONTINUE

DISPLAY

0 ——— Z
0 ——— Y
0 ——— X

ENTER DATA:

$a_1 \longrightarrow Y$
 $a_0 \longrightarrow X$

PRESS: CONTINUE

DISPLAY

——— Z
——— Y
1 ——— X

NOTE: Continue with 5th degree instructions beginning with entry of Card C. Card A is not used for 4th degree roots.

USER INSTRUCTIONS FOR 5TH DEGREE

Program includes 2 cards - 4 sides

Equation of the form:

$$x^5 + a_4x^4 + a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

ENTER PROGRAM A: (Starting Address is 0 - 0)

PRESS: CLEAR

PRESS: GO TO (0) (0) [or END]

Note: Do NOT press CONTINUE at this time.

ENTER DATA:

$a_4 \longrightarrow Z$
 $a_3 \longrightarrow Y$
 $a_2 \longrightarrow X$

PRESS: CONTINUE

DISPLAY

0 ——— Z
0 ——— Y
0 ——— X

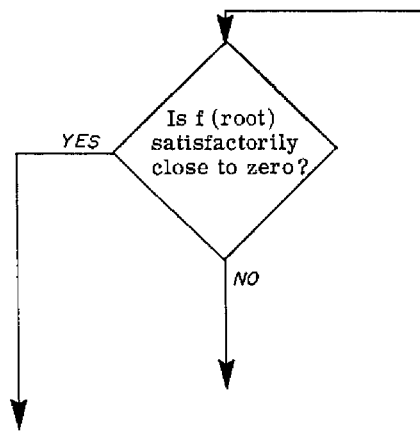
ENTER DATA:

$a_1 \longrightarrow Y$
 $a_0 \longrightarrow X$

PRESS: CONTINUE

DISPLAY

0 ——— Z
f (root) ——— Y
(root) ——— X



USER INSTRUCTIONS FOR 5TH DEGREE

YES NO

ENTER DATA:
Root approximation → X

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	_____	Z
f (root)	_____	Y
root	_____	X

→

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

← Indicates side B is to be entered.

ENTER PROGRAM B: (Starting Address is 0 - 0)

PRESS: CONTINUE

DISPLAY

_____	Z
_____	Y
1 _____	X

← Indicates side C is to be entered.

ENTER PROGRAM C: (Starting Address is 0 - 0)

PRESS: CONTINUE

DISPLAY

Intermediate	_____	Z
values	_____	Y
2 _____	X	

← Indicates side D is to be entered.

ENTER PROGRAM D: (Starting Address is 0 - 0)

PRESS: CONTINUE

USER INSTRUCTIONS FOR 5TH DEGREE

DISPLAY

root	_____	Z
root	_____	Y
0	_____	X

Note: 0 in X register indicates two real roots in Y and Z.

PRESS: CONTINUE

DISPLAY

Re. (root)
Im. (root)
(-) Im. (root)

Note: Z contains real part of complex root, Y and X contain + and -, imaginary part of complex root. The last two roots are therefore:

(Re + j Im.), (Re - j Im.)

EXAMPLES

1. Find the roots of the following equation:

$$x^5 - x^4 - 2x^3 - x^2 + x + 2$$

Solution: roots are -- -1, 1, 2, $(-.5 \pm .866j)$

2. Find the roots of the following equation:

$$x^4 - 6x^3 + 18x^2 - 24x + 16 = 0$$

Solution: roots are -- $(2 \pm j2)$, $(1 \pm j1)$

NOTES: A 4th or 5th degree polynomial must have the coefficient of the highest degree term normalized to 1; i.e., if the equation to be solved is:

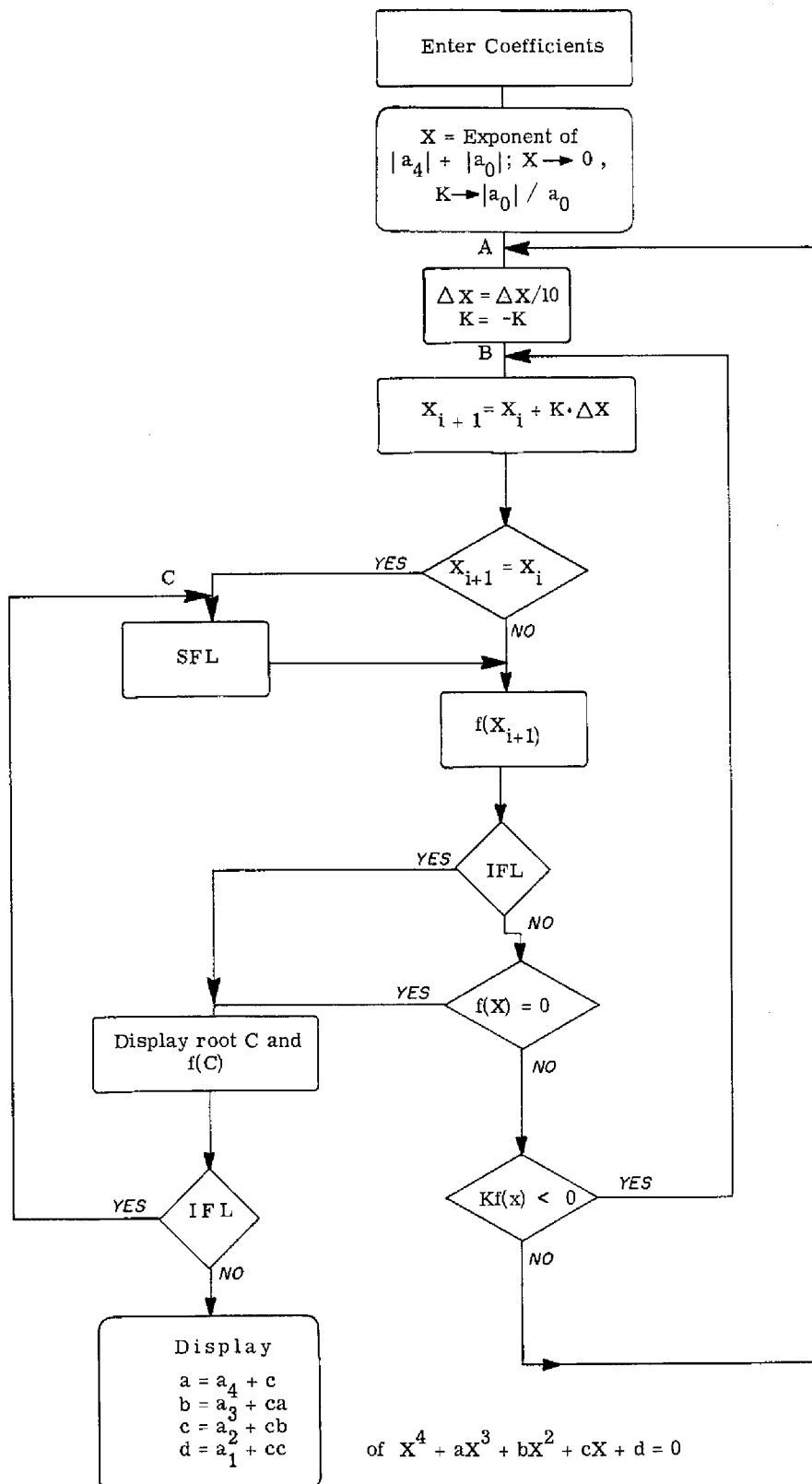
$$2x^5 + 4x^4 + 3x^3 + 6x^2 + 7x + 10, \text{ then the}$$

equation to be input on the calculator is:

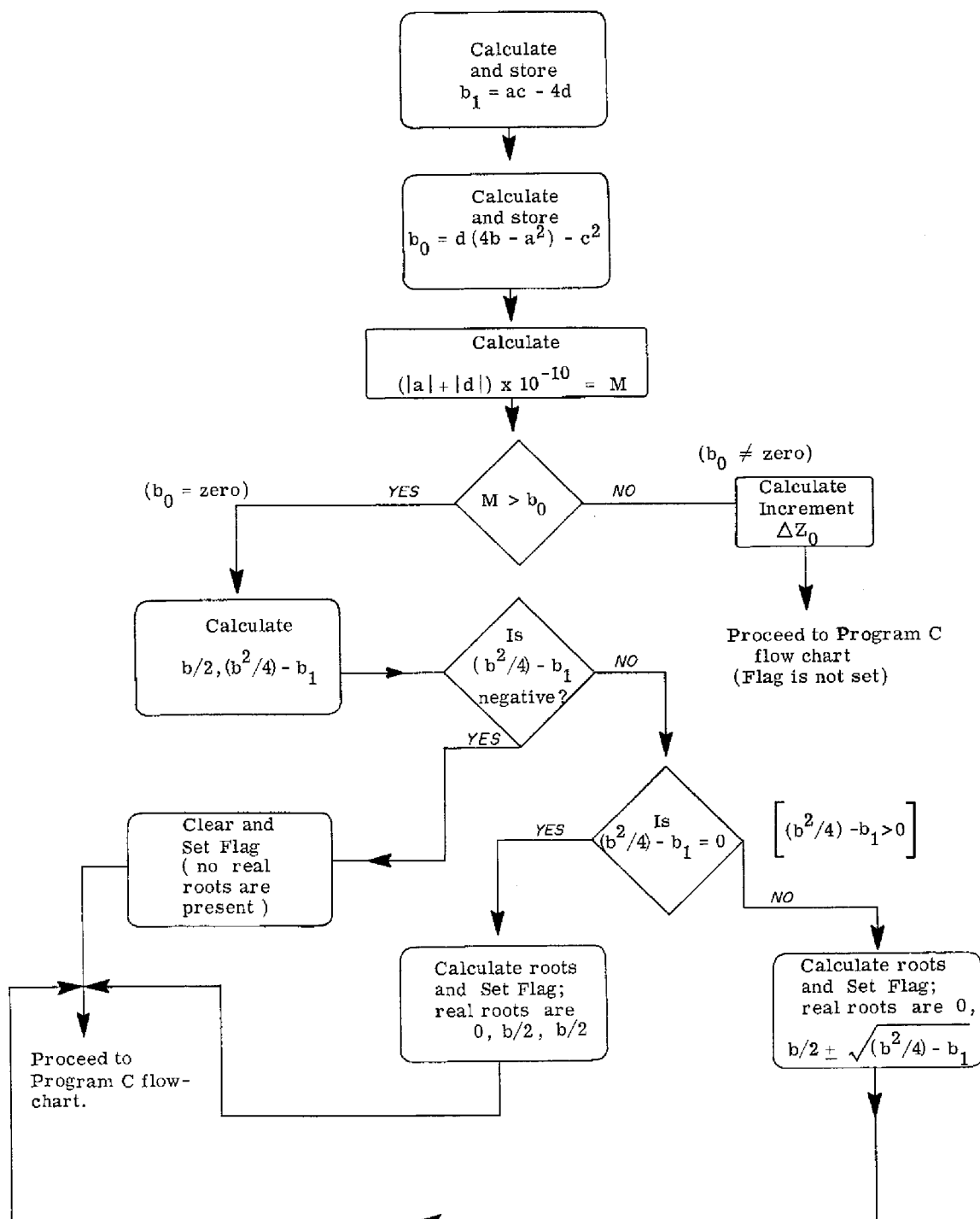
$$x^5 + 2x^4 + \frac{3}{2}x^3 + 3x^2 + \frac{7}{2}x + 5.$$

A 4th degree polynomial may be solved by using cards B, C, and D.

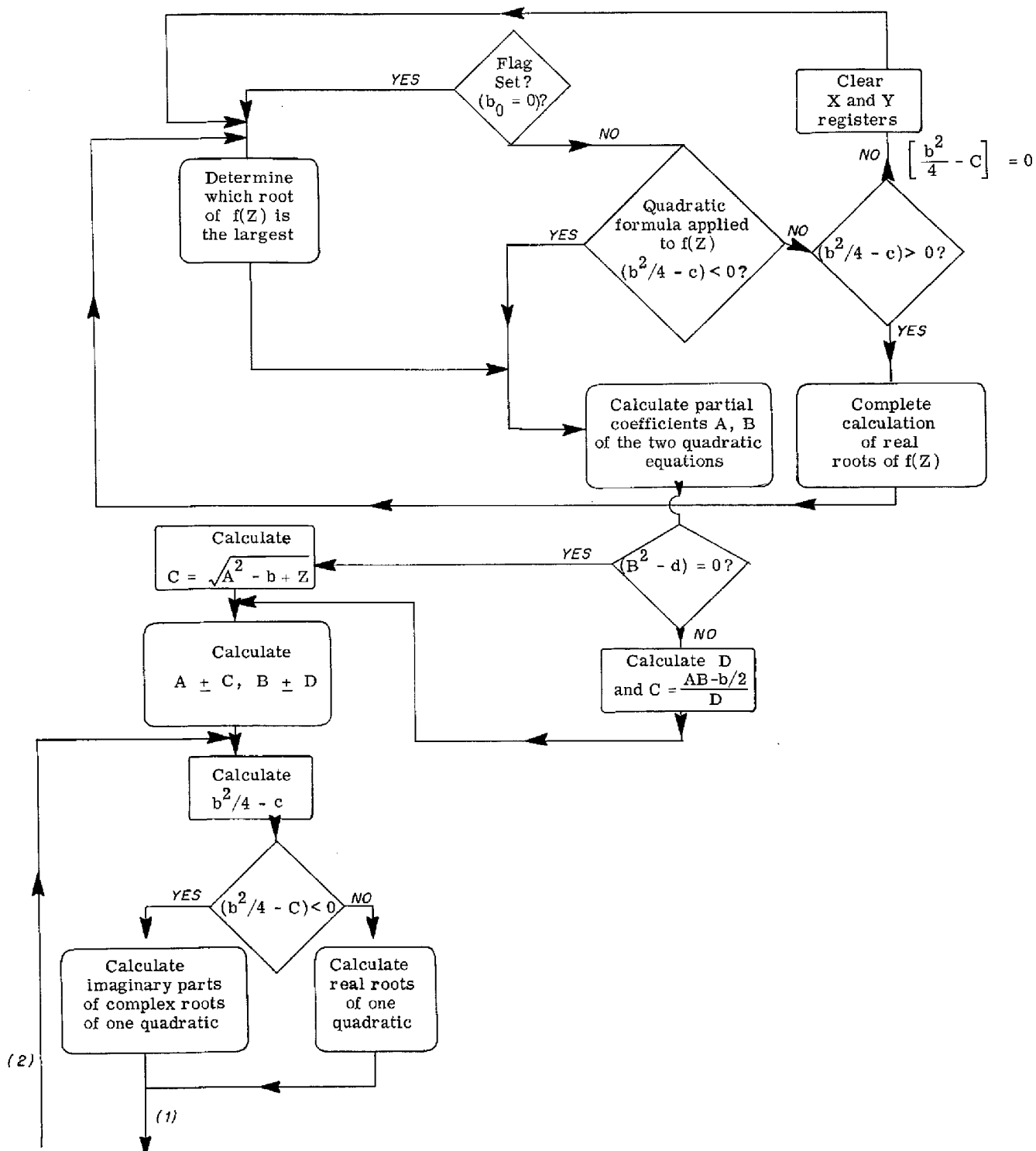
PROGRAM A



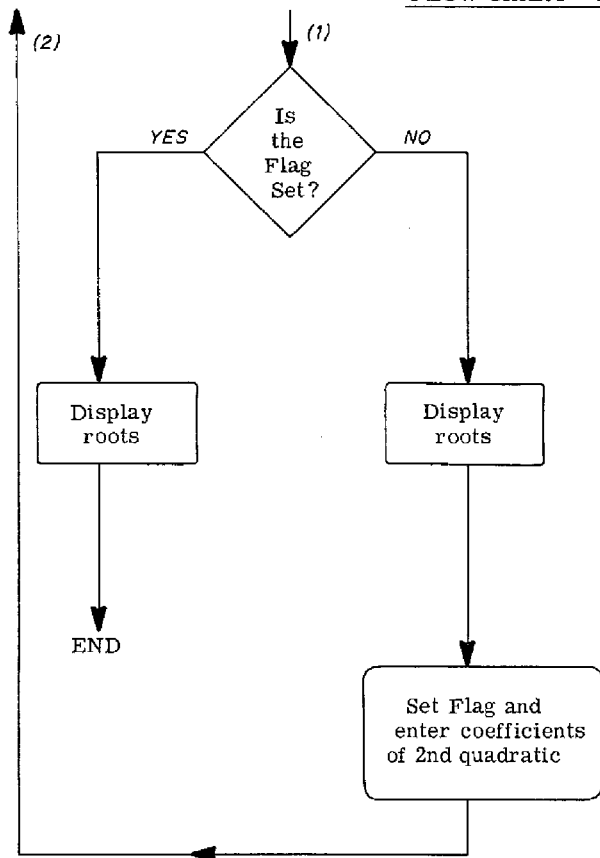
FLOW CHART - PROGRAM B



FLOW CHART - PROGRAM D



FLOW CHART - PROGRAM D (Con't)



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	CHG SIGN	32								
1	$x \rightarrow ()$	23									
2	$\bar{a}$	13									
3	$y \rightarrow ()$	24									
4	9	11									
5	$y \rightarrow ()$	40									
6	9	11									
7	$\bar{a}$	13									
8	x	36									
9	$\downarrow$	25									
$\bar{a}$	+	33									
b	$\downarrow$	25									
c	IF $x = v$	50									
d	SET FLAG	54									
4	0	SET FLAG	54								
1	ROLL $\downarrow$	31									
2	$\downarrow$	25									
3	b	14									
4	+	33									
5	$\downarrow$	25									
6	x	36									
7	c	16									
8	+	33									
9	$\downarrow$	25									
$\bar{a}$	x	36									
b	d	17									
c	+	33									
d	$\downarrow$	25									
5	0	x	36								
1	e	12									
2	+	33									
3	$\downarrow$	25									
4	x	36									
5	f	15									
6	+	33									
7	CLEAR x	37									
8	IF FLAG	43									
9	6	06									
$\bar{a}$	9	11									
b	IF $x = y$	50									
c	6	06									
d	9	11									

FORM -K AND STORE $\Delta X, -K$ INCREMENT x_i IF $x_{i+1} = x_i$ SET FLAG TO
BRANCH TO CALCULATION OF
COEFFICIENTS OF 4th DEGREE RESIDUECALCULATE $f(x)$ IF $f(x) = 0$ OR FLAG IS SET
BRANCH TO DISPLAY ROOT x
AND $f(x)$.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	$\bar{a}$	13								
	1	X	36								
	2	CLEAR X	37								
	3	IF $x > y$	53								
	4	3	03								
	5	3	03								
	6	GOTO () ()	44								
	7	2	02								
	8	6	06								
	9	ROLL $\downarrow$	31								
7	$\bar{a}$	$x \neq y$	30								
	b	PRINT	45								
	c	IF FLAG	43								
	d	4	04								
	0	0	00								
	1	ROLL $\downarrow$	31								
	2	$\downarrow$	25								
	3	b	14								
	4	+	33								
	5	$y \rightarrow ()$	40								
8	6	$\bar{a}$	13								
	7	$\downarrow$	25								
	8	X	36								
	9	c	16								
	$\bar{a}$	+	33								
	b	$y \rightarrow ()$	40								
	c	b	14								
	d	$\downarrow$	25								
	0	X	36								
	1	d	17								
	2	+	33								
	3	$y \rightarrow ()$	40								
	4	c	16								
	5	$\downarrow$	25								
	6	X	36								
	7	$\bar{a}$	12								
	8	+	33								
	9	$y \rightarrow ()$	40								
	$\bar{a}$	d	17								
	b	CLEAR	20								
	c	SET FLAG	54								
	d	END	46								

BRANCH TO INCREMENT x_i IF
 $K \cdot f(x)$ IS NEGATIVE

BRANCH TO DECREMENT Δx

DISPLAY ROOT X AND $f(x)$

BRANCH TO CALCULATE $f(x_{i+1})$

CALCULATE COEFFICIENTS OF
 4th DEGREE RESIDUE

FROM 5-a-5-d

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

Program			Display	Storage							
Step	Key	Code	x	y	z	f	e	d	c	b	a
0	0	IF FLAG	43	BRANCH TO CONTINUE CALCULATION OF 5th DEGREE EQUATION OTHERWISE BEGIN CALCULATION OF 4th DEGREE EQUATION							
	1	0	00								
	2	d	17								
	3	y→()	40								
	4	a	13								
	5	x→()	23								
	6	b	14								
	7	CLEAR	20	ENTER AND STORE COEFFICIENTS IF 4th DEGREE EQUATION IS TO BE FACTORED.							
	8	STOP	41								
	9	y→()	40								
	a	c	16								
		b	x→()	23							
	c	d	17								
	d	a	13								
1	0	↑	27								
	1	c	16								
	2	x	36								
	3	d	17								
	4	↑	27	CALCULATE AND STORE $b_1 = ac - 4d$ (COEFFICIENT OF CUBIC EQUATION IN Z)							
	5	4	04								
	6	x	36								
	7	↓	25								
	8	-	34								
	9	y→()	40								
	a	e	12								
	b	b	14								
c	↑	27									
d	4	04									
2	0	x	36								
	1	a	13								
	2	↑	27								
	3	x	36								
	4	↓	25	CALCULATE AND STORE $b_0 = d(4b - d^2) - c^2$ (COEFFICIENT OF CUBIC EQUATION IN Z)							
	5	-	34								
	6	d	17								
	7	x	36								
	8	c	16								
	9	↑	27								
	a	x	36								
	b	↓	25								
c	-	34									
d	y→()	40									

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	f	15								
	1	y	55								
	2	a	13								
	3	↑	27								
	4	y	55								
	5	d	17								
	6	xzy	30								
	7	y	55								
	8	+	33								
	9	ENTER EXP	26								
	a	CHG SIGN	32								
	b	1	01								
	c	0	00								
	d	x	36								
4	0	↓	25								
	1	IF x > y	53								
	2	5	05								
	3	b	14								
	4	b	14								
	5	xzy	30								
	6	y	55								
	7	+	33								
	8	ENTER EXP	26								
	9	CHG SIGN	32								
	a	2	02								
	b	↑	27								
	c	1	01								
	d	0	00								
5	0	x	36								
	1	↓	25								
	2	IF x < y	52								
	3	4	04								
	4	b	14								
	5	↑	27								
	6	CLEAR x	37								
	7	↑	27								
	8	GOTO (11)	44								
	9	8	10								
	a	9	11								
	b	b	14								
	c	↑	27								
	d	2	02								

CALCULATE $(|a| + |d|) \times 10^{-10}$ to
USE AS A BASE FOR COMPARISON

BRANCH IF $|b_0|$ IS $\cong$ ZERO
(THEREFORE ONE ROOT OF Z EQUATION
IS ZERO)

IF $|b_0| \neq$ ZERO CALCULATE AN INCREMENT
 ΔZ_0 AND PROCEED TO PROGRAM C TO FIND
THE REAL ROOT OF THE CUBIC EQUATION
IN Z BY ITERATION.

BRANCH TO END - BEGIN PROGRAM C

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	÷	35								
1	↓	25	CALCULATE $b/2$ AND $(b^2/4) - b_1$								
2	↑	27									
3	x	36									
4	ROLL ↓	31									
5	$x \leftrightarrow y$	30									
6	E	12									
7	-	34									
8	ENTER EXP	26									
9	CHG SIGN	32									
a	1	01									
b	0	00									
c	ROLL ↑	22									
d	x	36									
7	0	y	55								
1	ROLL ↓	31									
2	CHG SIGN	32									
3	IF $x > y$	53	BRANCH IF $(b^2/4) - b_1$ IS NEGATIVE AND CLEAR								
4	8	10	AND SET THE FLAG FOR PROGRAM C								
5	5	05	AT THIS POINT THE ROOTS OF Z EQUATION ARE 0 AND TWO								
6	CHG SIGN	32	COMPLEX ROOTS; THEREFORE NO REAL ROOTS ARE PRESENT								
7	IF $x > y$	53	BRANCH IF $(b^2/4) - b_1 \approx$ ZERO AND CALCULATE REMAINING ROOTS								
8	CLEAR x	37	ROOTS IN THIS CASE ARE 0, $b/2$, $b/2$								
9	x	36	IF $(b^2/4) - b_1 \neq$ ZERO CALCULATE THE								
a	↓	25	ROOTS $\rightarrow$ ZERO, $b/2 + \sqrt{\quad}$, $b/2 - \sqrt{\quad}$								
b	$\sqrt{x}$	76									
c	-	34									
d	ROLL ↑	22									
8	0	+	33								
1	CLEAR x	37									
2	GOTO ()	44									
3	8	10	BRANCH TO CLEAR F AND SET FLAG.								
4	6	06	CLEAR IF NO REAL ROOTS OF Z								
5	CLEAR	20	EQUATION ARE PRESENT.								
6	$x \rightarrow ()$	23									
7	f	15									
8	SET FLAG	54	SET THE FLAG FOR PROGRAM C;								
9	1	01	FLAG WILL NOT BE SET IF $ b_0 \neq$ ZERO								
a	END	46									
b											
c											
d											

FROM 5-10

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR x	37								
1	IF FLAG	43									
2	6	06	BRANCH TO SET THE FLAG IF $b_0 = 0$								
3	d	17									
4	ROLL $\uparrow$	22									
5	$x \rightarrow ()$	23	STORE ΔZ								
6	9	11									
7	F	15									
8	$\uparrow$	27									
9	$ y $	55	CALCULATE AND STORE K								
a	$\div$	35									
b	$y \rightarrow ()$	40									
c	8	10									
d	$y \rightarrow ()$	24									
1	0	9	11								
1	$y \rightarrow ()$	40									
2	9	11									
3	.	21									
4	1	01									
5	$\times$	36									
6	$y \rightarrow ()$	40									
7	9	11									
8	$y \rightarrow ()$	24									
9	8	10									
a	$\downarrow$	25									
b	CHG SIGN	32									
c	$x \rightarrow ()$	23	DECREMENT Z								
d	8	10									
2	0	$y \rightarrow ()$	24								
1	9	11									
2	$y \rightarrow ()$	40									
3	9	11									
4	$x \leftrightarrow y$	30									
5	$y \rightarrow ()$	24									
6	8	10									
7	$y \rightarrow ()$	40	INCREMENT Z								
8	8	10									
9	$\times$	36									
a	$\downarrow$	25									
b	$+$	33									
c	$\downarrow$	25									
d	IF $x = y$	50									

FROM 5-2

FROM 4-d

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Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
3	0	5	05									
	1	3	03	BRANCH TO FIND ONE ROOT OF			f(z)					
	2	↑	27									
	3	↑	27									
	4	b	14									
	5	-	34									
	6	↓	25									
	7	x	36	CALCULATE f(z) - 3rd DEGREE								
	8	E	12									
	9	+	33									
	a	↓	25									
	b	x	36									
	c	f	15									
	d	+	33									
4	0	CLEAR x	37									
	1	IF x=y	50									
	2	5	05	IF f(z)=0 BRANCH TO STORE								
	3	3	03	ROOT Z AND CALCULATE OTHER ROOTS								
	4	x↔y	30									
	5	y↔()	24									
	6	8	10									
	7	y↔()	40	CALCULATE K·f(z) IF f(z) ≠ 0								
	8	8	10									
	9	x	36									
	a	CLEAR x	37									
	b	IF x>y	53									
	c	2	02	BRANCH TO INCREMENT Z								
	d	0	00									
5	0	GO TO () ()	44									
	1	0	00	BRANCH TO DECREMENT Z								
	2	d	17									
	3	↓	25									
	4	y↔()	40									
	5	f	15									
	6	b	14									
	7	-	34									
	8	E	12									
	9	ROLL ↓	31									
	a	x	36									
	b	ROLL ↓	31	STORE Z AND BEGIN CALCULATION OF REMAINING								
	c	+	33	QUADRATIC IN Z								
	d	↓	25									

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	CHG SIGN	32								
1	ROLL ↓	31									
2	2	02									
3	CHG SIGN	32									
4	÷	35									
5	↓	25									
6	↑	27									
7	x	36									
8	ROLL ↓	31									
9	+	33									
a	GO TO () ()	44									
b	7	07									
c	0	00									
d	SET FLAG	54									
7	0	13									
1	x→()	23									
2	E	12									
3	2	02									
4	END	46									
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

BRANCH TO RESTORE a AND APPLY
QUADRATIC ROUTINE OF PROGRAM D
FOR OTHER ROOTS

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR X	37								
1		IF FLAG	43								
2	1	01									
3	8	10									
4		CHG SIGN	32								
5		ENTER EXP	26								
6		CHG SIGN	32								
7	1	01									
8	0	00									
9		IF $x > y$	53								
a	2	02									
b	5	05									
c		CHG SIGN	32								
d		IF $x > y$	53								
1	0	CLEAR X	37								
1	X	36									
2	↓	25									
3	$\sqrt{x}$	76									
4	—	34									
5	ROLL ↑	22									
6	+	33									
7	↓	25									
8		IF $x < y$	52								
9	$x \leftrightarrow y$	30									
a	CONTINUE	47									
b	↑	27									
c	F	15									
d		IF $x < y$	52								
2	0	$x \leftrightarrow y$	30								
1	CONTINUE	47									
2	GO TO () ()	44									
3	2	02									
4	6	06									
5	F	15									
6	↑	27									
7	2	02									
8	÷	35									
9	E	12									
a	↑	27									
b	2	02									
c	÷	35									
d	$y \rightarrow ()$	40									

BRANCH TO DETERMINE WHICH OF THE ROOTS OF EQUATION Z IS THE LARGEST.

BRANCH IF $\frac{b^2}{4} - C$ IS NEGATIVE, i.e.: ROOTS OF CUBIC EQUATION (Z) ARE COMPLEX.

CLEAR AND MULTIPLY IF $\frac{b^2}{4} - C = 0$

COMPLETE CALCULATION OF REAL ROOTS OF CUBIC EQUATION (Z)

EXCHANGE IF Z_1 IS $< Z_2$

EXCHANGE IF Z_0 IS $< Z_2$

USE LARGEST ROOT TO CALCULATE COEFFICIENTS OF THE TWO RESULTING QUADRATICS.

CALCULATE THE PARTIAL COEFFICIENTS A, B OF TWO REMAINING QUADRATIC EQUATIONS.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	E	12								
	1	↓	25								
	2	↓	25								
	3	X	36								
	4	d	17								
	5	-	34								
	6	ENTER EXP	26								
	7	CHG SIGN	32								
	8	1	01								
	9	0	00								
	a	IF x < y	52								
	b	5	05	BRANCH IF $(B^2 - d) \neq 0$ TO CALCULATE $D \text{ \& } C = \frac{AB - b/2}{D}$							
	c	7	07								
	d	↓	25								
4	0	CLEAR x	37								
	1	x → ()	23								
	2	d	17								
	3	y → ()	40								
	4	c	16								
	5	e	12								
	6	↑	27								
	7	X	36								
	8	b	14								
	9	-	34	FOR D = 0, CALCULATE $C = \sqrt{A^2 - b + Z}$							
	a	ROLL ↑	22								
	b	x ↔ y	30								
	c	2	02								
	d	X	36								
5	0	↓	25								
	1	+	33								
	2	↓	25								
	3	√x	76								
	4	GO TO () ()	44								
	5	6	06								
	6	a	13								
	7	↓	25								
	8	√x	76								
	9	x → ()	23								
	a	d	17								
	b	y ↔ ()	24								
	c	c	16								
	d	2	02								

Step	Key	Code	Display			Storage					
			x	y	z	F	E	d	c	b	a
0	$\bar{a}$	13									
1	$\downarrow$	25									
2	$\sqrt{x}$	76									
3	$-$	34									
4	ROLL $\uparrow$	22									
5	$+$	33									
6	CLEAR x	37									
7	GOTO () ()	44									
8	$\bar{a}$	13									
9	1	01									
$\bar{a}$	$\downarrow$	25									
b	CHG SIGN	32									
c	$\sqrt{x}$	76									
d	$\uparrow$	27									
$\bar{a}$	CHG SIGN	32									
1	IF FLAG	43									
2	$\bar{a}$	13									
3	c	16									
4	STOP	41									
5	SET FLAG	54									
6	b	14									
7	$\uparrow$	27									
8	E	12									
9	GOTO () ()	44									
$\bar{a}$	7	07									
b	d	17									
c	STOP	41									
d	END	46									
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
$\bar{a}$											
b											
c											
d											

IF $(b^2/4) - c$ IS POSITIVE, CALCULATE THE REAL ROOTS OF ONE OF THE QUADRATIC EQUATIONS USING THE QUADRATIC FORMULA.

BRANCH TO DISPLAY THE ROOTS OF THE QUADRATIC EQUATION

CALCULATE IMAGINARY PARTS OF COMPLEX ROOTS AND DISPLAY ROOTS OF ONE EQUATION

BRANCH TO END IF FLAG IS SET

SET THE FLAG AND ENTER THE COEFFICIENTS OF THE 2nd QUADRATIC IN THE DISPLAY REGISTERS.

BRANCH TO CALCULATE THE ROOTS OF THE 2nd QUADRATIC EQUATION.

[illegible]

15 February 1969

PART NO.
09100-70020

INTEGRAL OF THE FORM: $f(x) = \int_a^x f(u) du$

This program evaluates the integral of a function $f(u)$ between any lower limit a and a successively incremented upper limit.

A modification of Simpson's one third rule is used to perform the integration. The following equations are used:

$$\text{For } j = 0, \int_a^{x_j} f(u) du = h/6 \left[1/3 f(a) + 4/3 f(x_{j+1}) + 1/3 f(x_{j+2}) \right]$$

$$\text{For } j \geq 3, \int_{x_{j-1}}^{x_j} f(u) du = h/24 \left[f(x_{j-3}) + 5f(x_{j-2}) + 19f(x_{j-1}) + 9f(x_j) \right]$$

Notes:

Due to the manner in which the program is written, the function will initially be integrated over an area formed by twice the increment; thereafter, integration will proceed by one increment at a time.

To integrate with some constant (a) as a lower limit (other than zero), at the program steps starting at 7-8 add a to u to form u' and form $f(u')$. For a lower limit of zero simply form $f(u)$. In each case the upper limit will exceed the lower by some multiple of the increment depending on the number of times x is incremented by depression of the CONTINUE key.

To scale $f(x)$ include a scaling factor in the program steps beginning at 7-8, multiplying this factor times $f(u)$ or $f(u')$ after it has been formed.

To integrate from some lower limit to a specified upper limit without continually depressing the CONTINUE key, enter a Pause at step 4-d. Then just before the incremented upper limit (shown in a flashing display) reaches the desired upper limit, depress PAUSE--this will stop the program after the next integration.

If a plotter is available a plot of the function being integrated may be obtained by making the following changes:

Step 0 - 1	Insert FMT (Format)
Step 0 - 2	Insert ↓
Step 4 - d	Insert FMT
Step 5 - 0	Insert ↓

Reference:

Numerical Analysis
by
Kaiser S. Kunz
McGraw-Hill Book Company, Inc.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO(7) (8)

SET: PROGRAM

Starting at 7-8 enter the program steps to form the function $f(u)$ to be integrated; u is located in the Y register. After forming $f(u)$ place it in the Y register. The last four steps of the subroutine must be:

GO TO
0
9
End

SET: RUN

PRESS: GO TO (4) (8)

SET: PROGRAM

Enter scaling factor for x which may be necessary for a plot of $f(x)$ versus x . (3 spaces are available).

If scaling is unnecessary, set the scaling factor to 1.

Note: Registers 7-8 thru 7-d, 8 and 9 are available for programming and storage of $f(x)$.

SET: RUN

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: Increment (I) → X

PRESS: CONTINUE

DISPLAY

$\int_a^x f(u) du$	—	Z
$\int_a^x f(u) du$	—	Y
$x_1 = (2 \text{ times } I)$	—	X

PRESS: CONTINUE

USER INSTRUCTIONS (cont)

DISPLAY

$\int_a^{x+I} f(u) du$	—	Z
$\int_a^{x+I} f(u) du$	—	Y
$(x_1 + I)$	—	X

Each successive "CONTINUE" increments the upper limit and evaluates the integral using the incremented upper limit.

EXAMPLES

(A)

$\int_0^x u^2 du$ Increment = 1
Scale factor = 500

Program Steps

7-8 ↓
7-9 ↑
7-a X
7-b GO TO
7-c 0
7-d 9
8-0 End

PRESS: END
PRESS: CONTINUE
DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: Increment → X

PRESS: CONTINUE

DISPLAY

2.667	—	Z
2.667	—	Y
1,000	—	X

upper limit = 2
i.e.
[2x increment]

PRESS: CONTINUE

DISPLAY

9	—	Z
9	—	Y
1,500	—	X

upper limit = 3
i.e.
[2 + Increment]

Successive depressions of the CONTINUE key will give progressive values of x (scale factor x Increment + previous value of x), and the integral of the function evaluated using an upper limit which is equal to the upper limit of the previous evaluation plus the value of the given increment.

EXAMPLES (con't)

(B)

$$\int_2^x e^u du \quad \begin{array}{l} \text{Increment} = .1 \\ \text{Scale factor} = 1 \end{array}$$

SET: RADIANS

PROGRAM STEPS

```

7-8 2
7-9 +
7-a ↓
7-b ex      To integrate from 2 to n,
7-c ↑      add 2 to x to form x' = x + 2
7-d GO TO   and then form f(x'). In this
8-0 0       case f(x') = ex' = ex+2
8-1 9
8-2 End

```

PRESS: END

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: Increment → X

PRESS: CONTINUE

DISPLAY

1.6360	—	Z
1.6360	—	Y
.2	—	X

Upper limit = 2.2
i.e. (lower limit
+ 2 times the
increment)

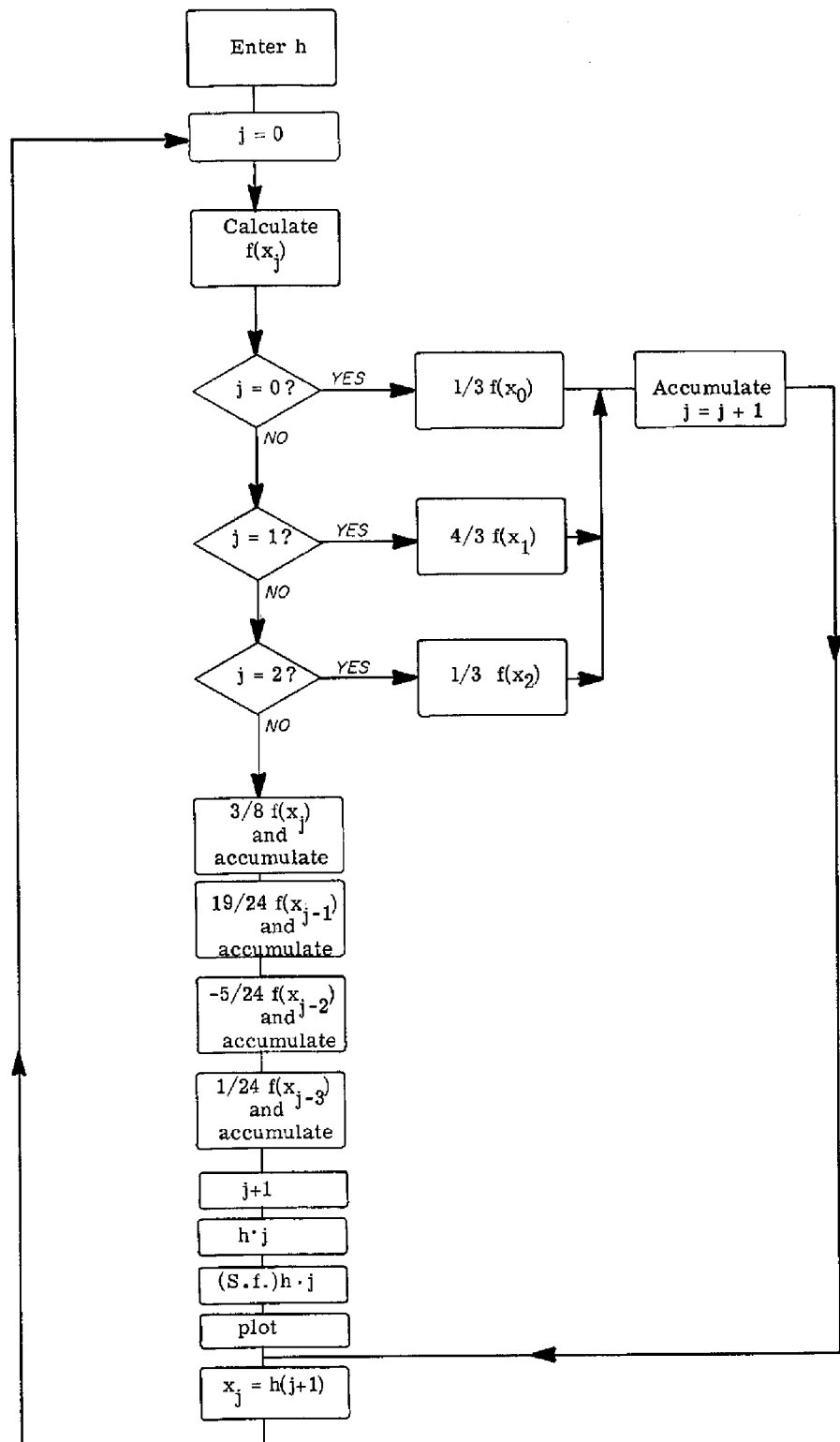
PRESS: CONTINUE

DISPLAY

2.5851	—	Z
2.5851	—	Y
.3	—	X

Upper limit = 2.3
i.e. (Increment +
previous upper
limit)

Successive depressions of the CONTINUE key will give the integral of the function evaluated between the lower limit and a successively incremented upper limit.



HEWLETT-PACKARD

PAGE 1			PART NO 65100 70020								
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	CONTINUE	47								
	2	CONTINUE	47								
	3	STOP	41	h	0	0	ENTER INCREMENT				
	4	x→()	23	STORE INCREMENT h							
	5	d	17								
	6	GO TO () ()	44								
	7	7	07	BRANCH TO CALCULATE f(x _j)							
	8	8	10								
	9	2	02								
	a	4	04	CALCULATE $\frac{1}{24} f(x_j)$							
	b	÷	35								
	c	B	12	RECALL j							
	d	↑	27								
1	0	0	00								
	1	IF x=y	50								
	2	5	05	BRANCH WHEN j=0							
	3	4	04								
	4	1	01								
	5	IF x=y	50								
	6	6	06	BRANCH WHEN j=1							
	7	1	01								
	8	2	02								
	9	IF x=y	50								
	a	6	06	BRANCH WHEN j=2							
	b	9	11								
	c	0	00								
	d	x≠y	30								
2	0	9	11								
	1	ROLL ↑	22	CALCULATE $\frac{9}{24} f(x_j)$							
	2	x	36								
	3	ROLL ↓	31								
	4	ACC +	60	ADD $\frac{9}{24} f(x_j)$							
	5	1	01	ENTER 19							
	6	9	11								
	7	ROLL ↓	31								
	8	y↔()	24	EXCHANGE $\frac{f(x_j)}{24}$ AND $\frac{f(x_{j-1})}{24}$							
	9	B	13								
	a	ROLL ↓	31								
	b	x	36	CALCULATE $\frac{19}{24} f(x_{j-1})$							
	c	ROLL ↓	31								
	d	ACC +	60	ADD $\frac{19}{24} f(x_{j-1})$							

FROM 9-c

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	05									
1	ROLL ↓	31									
2	y→()	24									
3	b	14									
4	ROLL ↓	31									
5	x	36									
6	ROLL ↓	31									
7	ACC -	63									
8	↓	25									
9	1	01									
a	y→()	24									
b	c	16									
c	x→y	30									
d	ACC +	60									
4	0	61									
1	↑	27									
2	d	17									
3	x	36									
4	ROLL ↑	22									
5	x	36									
6	d	17									
7	-	34									
8	CONTINUE	47									
9	↓										
a											
b	x	36									
c	↓	25									
d	STOP	41									
5	0	47									
1	GOTO () ()	44									
2	7	07									
3	4	04									
4	↓	25									
5	y→()	40									
6	c	16									
7	8	10									
8	x	36									
9	1	01									
a	x→y	30									
b	ACC +	60									
c	GOTO () ()	44									
d	7	07									

FROM 7-3

FROM 1-3

EXCHANGE $\frac{f(x_{j-1})}{24}$ AND $\frac{f(x_{j-2})}{24}$ CALCULATE $\frac{5}{24} f(x_{j-2})$ SUBTRACT $\frac{5}{24} f(x_{j-2})$ EXCHANGE $f(x_{j-2})$ AND $f(x_{j-3})$ WHEN $j \geq 3$ ADD $\frac{1}{24} f(x_{j-3})$ AND INCREMENT j RECALL ACCUMULATED SUM
MULTIPLY h TIMES $\sum w_s f_j$
TO GET AREA (w_s ARE WEIGHTING COEFFICIENTS)CALCULATE $h \cdot j$

ENTER APPROPRIATE SCALE FACTOR (s.f.) FOR PLOT

CALCULATE $x \cdot (s.f.)$

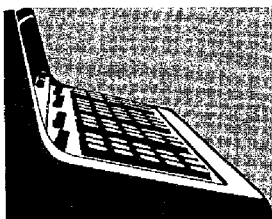
PLOT

STORE $\frac{1}{24} f(x_0)$

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
8	0	CONTINUE	47								
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
9	0	CONTINUE	47								
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a	GOTO () ()	44								
	b	0	00								
	c	9	11								
	d	END	46								
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

LEAVE $f(u)$ IN Y REGISTER
AND EXIT TO 0-9 FOLLOWED
BY END.
AVAILABLE REGISTERS ARE FROM 7-8 THROUGH 9-9

PART NO.
09100-70021POLYNOMIAL EVALUATION ($0 < n < 10$)

This program will evaluate a polynomial of the form:

$$f(x) = A_n x^n + A_{n-1} x^{n-1} + \dots + A_1 x + A_0$$

$$\text{for } 1 \leq n \leq 10$$

Input data is $A_n, A_{n-1}, \dots, A_0$, and the value of x for which the polynomial is to be evaluated. Any coefficient (A_i) may be zero. If any term(s) of the polynomial is absent, then the coefficient of that term(s) must be entered as zero.

The value of $f(x)$ for a new x may be obtained by entering the new x after the last $f(x)$ has been calculated.

To enter new coefficients for a different $f(x)$, the program card must be re-entered and the user instructions repeated. A_i 's and x 's must be real numbers.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) or [END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

ENTER DATA: $A_{10} \rightarrow Z$, $A_9 \rightarrow Y$, $A_8 \rightarrow X$

ENTER 0 if term does not exist.

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $A_7 \rightarrow Z$, $A_6 \rightarrow Y$, $A_5 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $A_4 \rightarrow Z$, $A_3 \rightarrow Y$, $A_2 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $A_1 \rightarrow Y$, $A_0 \rightarrow X$

PRESS: CONTINUE

0	_____	Z
0	_____	Y
2	_____	X

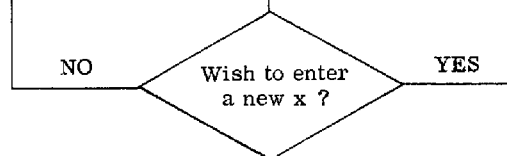
USER INSTRUCTIONS

ENTER DATA: $x \rightarrow X$

PRESS: CONTINUE

DISPLAY

x	_____	Z
f(x)	_____	Y
0	_____	X



EXAMPLES

(A) Polynomial: $x + 10$ ($A_1 = 1$, $A_0 = 10$)

x	f(x)
1	11
2	12
3	13

(B) Polynomial: $x^9 - 2x^8 + 4x^7 + x^2 + x + 100$
 ($A_9=1$, $A_8=-2$, $A_7=4$, $A_2=1$, $A_1=1$, $A_0=100$)

x	f(x)
1	105
2	618
.1	100.11000

General Form:

$$f(x) = A_n x^n + A_{n-1} x^{n-1} + \dots + A_1 x + A_0 \quad 1 \leq n \leq 10$$

[illegible]

Step	Key	Code	Display			Storage					
			<i>x</i>	<i>y</i>	<i>z</i>	<i>f</i>	<i>e</i>	<i>d</i>	<i>c</i>	<i>b</i>	<i>a</i>
3	0	$y \rightarrow ()$	40								
	1	8	10								
	2	+	33								
	3	↓	25								
	4	x	36								
	5	<i>a</i>	13								
	6	+	33								
	7	↓	25								
	8	x	36								
	9	<i>d</i>	17								
	<i>a</i>	+	33								
	<i>b</i>	↓	25								
	<i>c</i>	x	36								
	<i>d</i>	<i>c</i>	16								
4	0	+	33								
	1	↓	25								
	2	x	36								
	3	<i>b</i>	14								
	4	+	33								
	5	↓	25								
	6	x	36								
	7	↓	25								
	8	$y \rightarrow ()$	24								
	9	1	01								
	<i>a</i>	$y \rightarrow ()$	40								
	<i>b</i>	1	01								
	<i>c</i>	+	33								
	<i>d</i>	↓	25								
5	0	x	36								
	1	↓	25								
	2	$y \rightarrow ()$	24								
	3	7	07								
	4	$y \rightarrow ()$	40								
	5	7	07								
	6	+	33								
	7	↓	25								
	8	x	36								
	9	↓	25								
	<i>a</i>	$y \rightarrow ()$	24								
	<i>b</i>	0	00								
	<i>c</i>	$y \rightarrow ()$	40								
	<i>d</i>	0	00								

CALCULATE $f(x)$

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Step	Key	Code	Display			Storage					
			x	y	z	f	a	d	c	b	e
6	0	+	33								
	1	↓	25								
	2	x	36								
	3	e	12								
	4	+	33								
	5	↓	25								
	6	x	36								
	7	f	15								
	8	+	33								
	9	CLEAR x	37								
	B	GO TO () ()	44								
	b	2	02								
	c	5	05								
	d	END	46								
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

BRANCH TO DISPLAY
f(x) AND ENTER A
NEW x IF DESIRED

[illegible]

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$
$$A^{-1} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$
$$A \cdot A^{-1} = I$$
$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$
$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 = K_1$$

$$a_{21} x_1 + a_{22} x_2 + a_{23} x_3 = K_2$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 = K_3$$

for x_1 , x_2 , and x_3 .

Reference: Elementary Matrix Algebra
Franz E. Hohn
1958

USER INSTRUCTIONS

USER INSTRUCTIONS (con't)

This program is a destructive program

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA*:

$a_{11} \rightarrow Z$
 $a_{21} \rightarrow Y$
 $a_{31} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA:

$a_{12} \rightarrow Z$
 $a_{22} \rightarrow Y$
 $a_{32} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

*If the program for either mode should turn on the RED light in the RUN mode, interchange the second and third rows of the matrix or the second and third equations of the set and run the program again. If the RED light still comes on, the equations are dependent or the matrix is singular and a solution cannot be obtained. If the matrix or equation set is ill-conditioned, an answer will be obtained but the accuracy of the solution will suffer.

ENTER DATA:

$a_{13} \rightarrow Z$
 $a_{23} \rightarrow Y$
 $a_{33} \rightarrow X$

Wish to
invert the
input matrix

NO

YES

PRESS: CONTINUE

DISPLAY

b_{11}	—	Z
b_{21}	—	Y
b_{31}	—	X

PRESS: CONTINUE

DISPLAY

b_{12}	—	Z
b_{22}	—	Y
b_{32}	—	X

PRESS: CONTINUE

DISPLAY

b_{13}	—	Z
b_{23}	—	Y
b_{33}	—	X

Wish to
solve three
equations si-
multaneously?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

—	—	Z
—	—	Y
1	—	X

ENTER DATA:

(Do not disturb Y and Z registers when K_i 's ($i = 1, 2, 3$) are being entered) $K_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

—	—	Z
—	—	Y
0	—	X

ENTER DATA: $K_3 \rightarrow X$

PRESS: CONTINUE

DISPLAY

—	—	Z
—	—	Y
0	—	X

ENTER DATA: $K_2 \rightarrow X$

PRESS: CONTINUE

Desire
check?

NO

YES

ENTER DATA:

$b_{11} \rightarrow Z$
 $0 \rightarrow Y$
 $0 \rightarrow X$

PRESS: CONTINUE

DISPLAY

a_{11}	—	Z
a_{21}	—	Y
a_{31}	—	X

USER INSTRUCTIONS (con't)

PRESS: CONTINUE

DISPLAY

 a_{21} — Z a_{22} — Y a_{32} — X

PRESS: CONTINUE

DISPLAY

 a_{31} — Z a_{32} — Y a_{33} — X

TO RESET PROBLEM:
re-enter program
and repeat USER
INSTRUCTIONS.

DISPLAY

 x_1 — Z x_2 — Y x_3 — X

TO RESET PROBLEM:
re-enter program and
repeat USER INSTRUCTIONS.

EXAMPLES

- (A) Find the inverse of the following matrix (A).
General form:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$A^{-1} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

$$A = \begin{bmatrix} 8 & 4 & 2 \\ 2 & 8 & 4 \\ 1 & 2 & 8 \end{bmatrix}$$

Solution:

$$A^{-1} = \begin{bmatrix} .1429 & -.0714 & 0 \\ -.0306 & .1582 & -.0714 \\ -.0102 & -.0306 & .1429 \end{bmatrix}$$

- (B) Solve the following three equations
simultaneously.

General form:

$$\begin{bmatrix} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 = K_1 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 = K_2 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 = K_3 \end{bmatrix}$$

$$\begin{bmatrix} x_1 + x_2 + 2x_3 = 3 \\ 4x_1 + 3x_2 + x_3 = 1 \\ 2x_1 + x_2 + 6x_3 = 4 \end{bmatrix}$$

Solution:

$$\begin{bmatrix} x_1 = -3 \\ x_2 = 4 \\ x_3 = 1 \end{bmatrix}$$

STORAGE ALLOCATION OF THE $\{a_{ij}\}$ or $\{b_{ij}\}$
IS AS FOLLOWS:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \quad \text{OR} \quad \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

EXAMPLES (con't)

Stored in the following registers

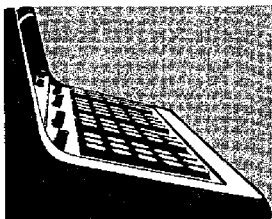
z	0	a
b	e	1
c	f	d

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	16									
1	$x \leftrightarrow y$	30	CALCULATE $a_{22} - \frac{a_{21} a_{12}}{a_{11}}$								
2	X	36									
3	ROLL ↓	31									
4	—	34									
5	f	15									
6	ROLL ↑	22									
7	X	36									
8	$x \leftrightarrow y$	30									
9	$y \rightarrow ()$	24	CALCULATE AND STORE $a_{23} - \frac{a_{21} a_{13}}{a_{11}}$								
a	0	00									
b	—	34									
c	$y \rightarrow ()$	24									
d	0	00									
7	0	17									
1	CHG SIGN	32									
2	X	36	CALCULATE $k_2 - \frac{a_{21} k_1}{a_{11}}$								
3	CLEAR X	37									
4	IF FLAG	43									
5	CLEAR X	37									
6	STOP	41	k_2	0	0	ENTER k_2					
7	+	33									
8	$y \rightarrow ()$	24									
9	B	13	INCREMENT COUNTER								
a	1	01									
b	+	33									
c	3	03									
d	IF $x > y$	53	BRANCH WHEN 3 IS GREATER THAN COUNTER AND REPEAT CALCULATION								
8	0	02									
1	2	02									
2	b	14									
3	$x \leftrightarrow y$	30	RECALL AND POSITION SOLUTION OR b_{11}, b_{21}, b_{31}								
4	16	16									
5	STOP	41	b_{31}	b_{21}	b_{11}	DISPLAY SOLUTION OR b_{11}, b_{21}, b_{31}					
6	$y \rightarrow ()$	24									
7	0	00									
8	$y \rightarrow ()$	40									
9	0	00	RECALL AND POSITION DISPLAY								
a	B	12									
b	↑	27									
c	f	15									
d	STOP	41	b_{32}	b_{22}	b_{12}	DISPLAY					

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	$y \rightarrow ()$	24								
	1	1	01								
	2	$y \rightarrow ()$	40								
	3	1	01								
	4	d	17								
	5	↑	27								
	6	B	13								
	7	ROLL ↓	31								
	8	STOP	41	b_{33}	b_{23}	b_{13}	DISPLAY				
	9	GO TO () ()	44								
	B	2	02								
	b	2	02								
	c	END	46								
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	B										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	B										
	b										
	c										
	d										

RECALL AND POSITION DISPLAY

BRANCH TO DISPLAY COEFFICIENTS OF
ORIGINAL MATRIX IF CHECK IS DESIRED



PART NO.
09100-70022

FOURIER SERIES when $f(t)$ is known

This program calculates the Fourier Series coefficients a_n and b_n that represent a periodic time function $f(t)$ with period T . The Fourier Series representation of $f(t)$ is:

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos \frac{2\pi nt}{T} + b_n \sin \frac{2\pi nt}{T}$$

where

$$a_n = \frac{2}{T} \int_{t_0}^{t_0+T} f(t) \cos \frac{2\pi nt}{T} dt \quad n = 0, 1, 2, \dots$$

$$b_n = \frac{2}{T} \int_{t_0}^{t_0+T} f(t) \sin \frac{2\pi nt}{T} dt \quad n = 1, 2, 3, \dots$$

The program evaluates the coefficients by numerically integrating using Simpson's Rule which is the same procedure used in program 09100-70015.

The specific $f(t)$ is programmed into the Calculator by the user and is then used by the general solution to evaluate the coefficients. Execution time is dependent on the number of panels.

Reference: Signals Systems and Communications
B. P. Lathi
Wiley (1965)

USER INSTRUCTIONS

SET: RADIANS

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO () ()

PRESS: 6

PRESS: 4

SET: PROGRAM

ENTER: Steps to take t from the X register (t is also stored in the e register) and form f(t). Leave f(t) in the Y register and exit to location 8-4. Steps 6-4 through 8-3 are available for forming f(t). The FLAG is not available.

SET: RUN

PRESS: GO TO () ()

PRESS: 9

PRESS: 9

SET: PROGRAM

PRESS: sin X or cos X depending on desired sine or cosine coefficients. If series involves both sine and cosine, then initialize program to cos X.

SET: RUN

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

(n is set to 0)

ENTER DATA:

Number of panels
must be an even number → Z

$t_0 + T$ → Y

t_0 → X

Note: n is contained in the a register.

PRESS: CONTINUE

DISPLAY

$t_0 + T$	_____	Z
a_n or b_n	_____	Y
n	_____	X

To change from cosine series to sine series--

USER INSTRUCTIONS (con't)

PRESS: GO TO () ()

PRESS: 9

PRESS: 9

SET: PROGRAM

PRESS: sin X

SET: RUN

PRESS: CLEAR

PRESS: X → ()

PRESS: a

(n is set to 1)

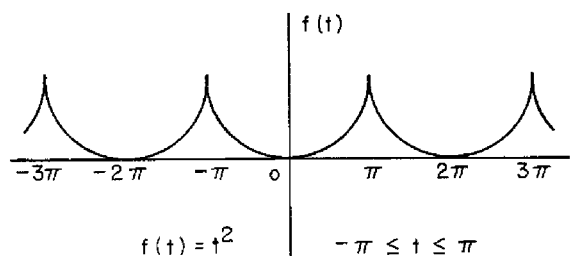
PRESS: GO TO () ()

PRESS: 5

PRESS: 7

EXAMPLES

Example #1



$$t^2 = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos nt + b_n \sin nt)$$

Data: Number of panels = 100

$$T = 2\pi$$

$$t_0 = -\pi$$

Solution:

$$t_0 + T = 3.14159$$

$$a_0 = 6.57974$$

$$a_1 = -4.00000$$

$$a_2 = 1.00000$$

$$a_3 = -.44444$$

$$a_4 = .24998$$

$$a_5 = -.15997$$

$$a_6 = .11107$$

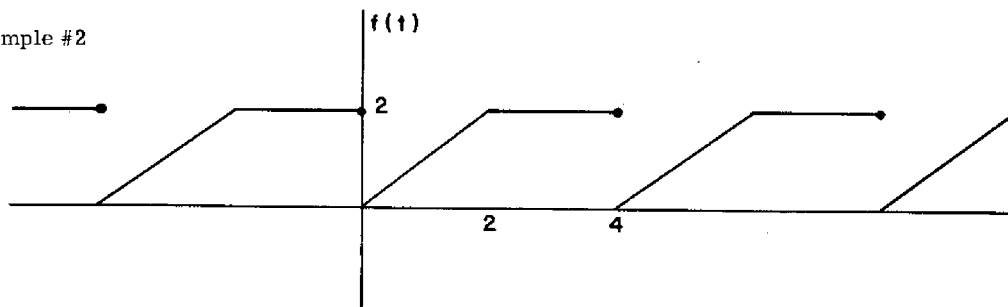
$$a_7 = -.08158$$

$$a_8 = .06243$$

$$b_n = 0; f(t) = f(-t)$$

EXAMPLES (con't)

Example #2



$$\begin{aligned} f(t) &= t & 0 < t \leq 2 \\ f(t) &= 2 & 2 \leq t \leq 4 \end{aligned}$$

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left(a_n \cos \frac{2n\pi t}{T} + b_n \sin \frac{2n\pi t}{T} \right)$$

Data:

$$T = 4$$

$$t_0 = 0$$

Number of panels = 50

Solution:

$$t_0 + T = 4.0$$

$$a_0 = 3.00053 \quad b_1 = -.63662$$

$$a_1 = -.40582 \quad b_2 = -.31832$$

$$a_2 = .00054 \quad b_3 = -.21223$$

$$a_3 = -.04557 \quad b_4 = -.15921$$

$$a_4 = .00057 \quad b_5 = -.12744$$

$$a_5 = -.01676 \quad b_6 = -.10631$$

$$a_6 = .00062 \quad b_7 = -.09128$$

$$a_7 = -.00883 \quad b_8 = -.08009$$

$$a_8 = .00069$$

Note: See step page 1 for steps needed to execute examples 1 and 2.



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0		EXAMPLE 1								
1											
2											
3			t								
4	↑	27	t	t							
5	X	36	$t^2 = f(t)$								
6	GO TO () ()	44									
7	8	10									
8	4	04									
9											
a											
b											
c											
d											
6	0		EXAMPLE 2								
1											
2											
3			t				t				
4	↑	27	t	t							
5	2	02	2								
6	IF x > y	53									
7	8	10									
8	4	04									
9	x > y	30	t	2							
a	GO TO () ()	44									
b	8	10									
c	4	04									
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20									
1	x→()	23	INITIALIZE n TO ZERO								
2	a	13									
3	1	01									
4	STOP	41	t ₀	t ₀ + T	PANELS	ENTER DATA: NUMBER OF PANELS (MUST BE EVEN), t ₀ + T, t ₀					
5	y→()	40									
6	d	17	STORE DATA								
7	x→()	23									
8	b	14									
9	—	34									
a	ROLL ↓	31									
b	x↔y	30	CALCULATE Δt								
c	÷	35									
d	y→()	40									
1	0	16									
1	ROLL ↑	22									
2	x→()	23	STORE t ₀								
3	e	12									
4	GO TO () ()	44									
5	6	06	BRANCH TO EVALUATE FUNCTION f(t)								
6	4	04									
7	e	12									
8	↑	27									
9	b	14	RECALL t ₀ AND BRANCH FOR INITIAL POINT								
a	IF x = y	50									
b	4	04									
c	4	04									
d	d	17									
2	0	34									
1	y	55	COMPARE t - (T + t ₀) TO 10 ⁻⁹ AND STOP INTEGRATION IF t - (T + t ₀) < 10 ⁻⁹								
2	ENTER EXP	26									
3	9	11									
4	CHG SIGN	32									
5	IF x > y	53									
6	4	04									
7	a	13	COMPARE t TO T + t ₀ AND STOP INTEGRATION IF t > T + t ₀								
8	e	12									
9	x↔y	30									
a	d	17									
b	IF x < y	52									
c	4	04									
d	a	13									

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	$\bar{C}$	16								
	1	ROLL $\uparrow$	22								
	2	$\uparrow$	27								
	3	IF FLAG	43								
	4	3	03								
	5	b	14								
	6	SET FLAG	54								
	7	4	04	CALCULATE $4g(t_0 + \Delta t) + 2g(t_0 + 2\Delta t)$							
	8	GO TO () ()	44								
	9	3	03								
	a	$\bar{C}$	16								
	b	2	02								
	c	X	36								
	d	$\downarrow$	25								
4	0	ACC +	60								
	1	GO TO () ()	44								
	2	1	01	BRANCH TO CALCULATE ANOTHER PARTIAL AREA							
	3	3	03								
	4	$\bar{C}$	16	RECALL Δt AND CALCULATE $t + \Delta t$.							
	5	ROLL $\uparrow$	22	PLACE $t + \Delta t$ AND $g(t)$ IN THE ACCUMULATORS							
	6	ACC +	60								
	7	GO TO () ()	44								
	8	1	01	BRANCH FOR OTHER PANEL CALCULATION							
	9	3	03								
	a	CLEAR X	37								
	b	ROLL $\uparrow$	22	SUM $g(t_0 + T)$ TO $g(t_0) + 4g(t_0 + \Delta t) + 2g(t_0 + 2\Delta t) + \dots$							
	c	ACC +	60								
	d	RCL	61								
5	0	$\uparrow$	27								
	1	$\bar{C}$	16	MULTIPLY $\Delta t / 3$ - TIMES SUMMATION SERIES							
	2	X	36								
	3	3	03								
	4	$\div$	35								
	5	a	13	RECALL n, THE HARMONIC NUMBER							
	6	STOP	41	n	a_n or b_n	$t_0 + T$	DISPLAY				
	7	CLEAR	20								
	8	a	13								
	9	$\uparrow$	27								
	a	1	01	INCREMENT n							
	b	+	33								
	c	$y \rightarrow ()$	40								
	d	a	13								

Step	Key	Code	Display				Storage						
			x	y	z	f	e	d	c	b	a		
6	0	b	14	RECALL t_0									
1	GOTO() ()	44											
2	1	01	BRANCH TO CALCULATE COEFFICIENT										
3	2	02											
4	CONTINUE	47	STEPS 6-4 THROUGH 8-3 ARE AVAILABLE FOR FORMING $f(t)$										
5													
6													
7													
8													
9													
a													
b													
c													
d													
7	0	CONTINUE	47										
1													
2													
3													
4													
5													
6													
7													
8													
9													
a													
b													
c													
d													
8	0	CONTINUE	47										
1													
2													
3													
4	2	02											
5	x	36											
6	d	17											
7	↑	27											
8	b	14	CALCULATE $\frac{2f(t)}{T}$										
9	-	34											
a	π	56											
b	ROLL ↓	31											
c	÷	35											
d	ROLL ↑	22											

Step	Key	Code	Display				Storage			
			x	y	z		f	e	d	c
9	0	$x \rightarrow y$	30							
1	.		35							
2	2		02							
3	X		36							
4	E		12							
5	X		36							
6	a		13							
7	X		36							
8	↓		25							
9	cos x		73							
a	X		36							
b	GO TO () ()		44							
c	1		01							
d	7		07							
a	0	END	46							
1										
2										
3										
4										
5										
6										
7										
8										
9										
a										
b										
c										
d										
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
a										
b										
c										
d										

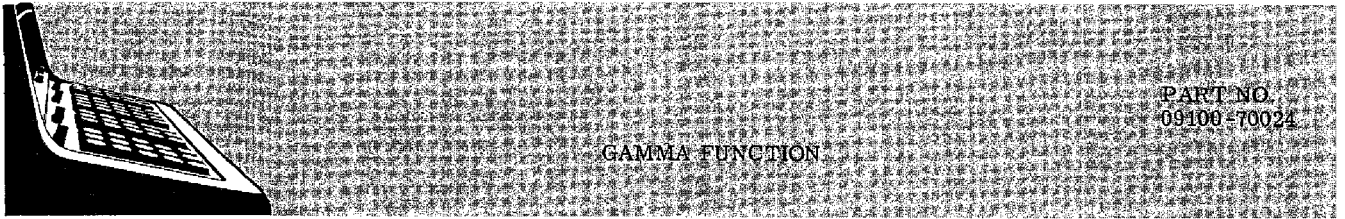
CALCULATE $\frac{2f(t)}{T} \cos \frac{2\pi nt}{T}$

OR $\frac{2f(t)}{T} \sin \frac{2\pi nt}{T} = g(t)$

AS ENTERED IN THIS STEP: COS CALCULATES a_n
SIN CALCULATES b_n

BRANCH TO INTEGRATE AND OBTAIN COEFFICIENTS

AFTER EXECUTION DATA IS STORED IN THIS REGISTER WHICH DESTROYS THE END STATEMENT, THEREFORE, RECORD PROGRAM ON A MAGNETIC CARD BEFORE EXECUTION.

PART NO.
09100-70024

GAMMA FUNCTION

These program evaluate the Gamma Function,
where

$$\Gamma(V) = \int_0^{\infty} e^{-t} t^{V-1} dt$$

Program 1 evaluates $\Gamma(V)$ over the range $0 < V \leq 69.98$

Program 2 evaluates $\Gamma(V)$ over the range $0 < V \leq 10^9$

Reference: Handbook of Mathematical Functions
National Bureau of Standards
Abramowitz & Stegun
Sixth Printing, 1967

USER INSTRUCTIONS

EXAMPLE

PROGRAM #1 $0 < \nu \leq 69.95$

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $\nu \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	_____	Z
$\Gamma(\nu)$	_____	Y
ν	_____	X

To enter new value for ν PROGRAM #2 $0 < \nu \leq 10^9$

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $\nu \rightarrow X$

PRESS: CONTINUE

DISPLAY

exponent of 10	_____	Z
decimal number	_____	Y
ν	_____	X

To enter a new value for ν

PROGRAM #1

$$\nu = 1.750$$

$$\Gamma(\nu) = 0.919062527$$

$$\nu = 51$$

$$\Gamma(\nu) = 3.041409320 \times 10^{64}$$

PROGRAM #2

$$\nu = 1.750$$

$$\Gamma(\nu) = 0.919062527$$

$$\nu = 97$$

$$\Gamma(\nu) = 9.916779322 \times 10^{149}$$

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	STOP	41	ν	0	0	ENTER	$\nu \rightarrow$	x			
	2	$\uparrow$	27									
	3	1	01									
	4	-	34									
	5	$y \rightarrow ()$	40									
	6	d	17									
	7	$\uparrow$	27									
	8	$\downarrow$	25									
	9	int x	64									
	a	-	34									
	b	CLEAR X	37									
	c	IF $x > y$	53									
	d	CLEAR X	37	REPLACE ν WITH ν WHEN $5 \leq \nu < 6$								
1	0	1	01									
	1	+	33									
	2	5	05									
	3	+	33									
	4	$\downarrow$	25									
	5	$\uparrow$	27									
	6	X	36									
	7	ACC +	60									
	8	2	02									
	9	$x \rightarrow y$	30									
	a	$\div$	35									
	b	3	03									
	c	-	34									
	d	E	12									
2	0	$\div$	35									
	1	2	02									
	2	$\div$	35									
	3	+	33									
	4	E	12									
	5	$\div$	35									
	6	7	07									
	7	$\div$	35	CALCULATE $P(\nu) = -\nu + \frac{1}{12\nu} - \frac{1}{360\nu^3} + \frac{1}{1260\nu^5} - \frac{1}{1680\nu^7} + \frac{1}{2520\nu^9}$								
	8	1	01	$= -\nu \frac{1}{60\nu} \left(5 + \frac{1}{6\nu^2} \left(-1 + \frac{1}{7\nu^2} \left(2 + \frac{1}{2\nu^2} \left(-3 + \frac{2}{\nu^2} \right) \right) \right) \right)$								
	9	-	34									
	a	E	12									
	b	$\div$	35									
	c	6	06									
	d	$\div$	35									

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	5	05								
	1	+	33								
	2	6	06								
	3	0	00								
	4	÷	35								
	5	f	15								
	6	÷	35								
	7	-	34								
	8	↑	27								
	9	.	21								
	a	5	05	CALCULATE $(v + \frac{1}{2}) \ln v$							
	b	+	33								
	c	f	15								
	d	ln x	65								
4	0	x	36								
	1	↓	25								
	2	+	33								
	3	π	56								
	4	↑	27								
	5	+	33	CALCULATE $\ln \sqrt{2\pi}$							
	6	↓	25								
	7	ln x	65								
	8	↑	27								
	9	2	02								
	a	÷	35								
	b	↓	25								
	c	+	33								
	d	↓	25								
5	0	e ^x	74								
	1	↑	27								
	2	f	15								
	3	↑	27								
	4	d	17								
	5	IF x > y	53								
	6	6	06								
	7	0	00								
	8	IF x < y	52								
	9	6	06								
	a	7	07								
	b	GO TO () ()	44								
	c	7	07	BRANCH TO DISPLAY							
	d	1	01								

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	STOP	41	ν	0	0	ENTER $\nu \rightarrow X$					
2	$\uparrow$	27									
3	1	01									
4	—	34									
5	$y \rightarrow ()$	40									
6	d	17									
7	1	01									
8	7	07									
9	IF $x < y$	52									
a	3	03	OMIT LAST TERMS OF $P(\nu)$ IF $\nu > 17$								
b	4	04									
c	d	17									
d	int x	64									
1	0	IF $x = y$	50								
1	SET FLAG	54	SET FLAG IF ν IS AN INTEGER								
2	SET FLAG	54									
3	—	34									
4	CLEAR X	37									
5	IF $x > y$	53									
6	CLEAR X	37	REPLACE ν WITH ν IF $\nu \leq 17$								
7	1	01									
8	+	33									
9	5	05									
a	+	33									
b	$\downarrow$	25									
c	$\uparrow$	27									
d	X	36									
2	0	ACC +	60								
1	2	02									
2	$x \rightarrow y$	30									
3	$\div$	35									
4	3	03	BEGIN CALCULATION OF $P(\nu)$								
5	—	34									
6	E	12									
7	$\div$	35									
8	2	02									
9	$\div$	35									
a	+	33									
b	E	12									
c	$\div$	35									
d	7	07									

			Display			Storage													
Step	Key	Code	x	y	z	f	e	d	c	b	a								
6	0	+	33	DON'T GO THRU. STEPS TO CONVERT $\bar{v}/$ TO $v/$ IF $v>17$															
1	3	03	AND DON'T TAKE e^x OF $\ln v$																
2	4	04	WITHOUT REMOVING CHARACTERISTIC FIRST																
3	IF $x<y$	52																	
4	$\bar{a}$	13																	
5	4	04																	
6	$\downarrow$	25																	
7	e^x	74																	
8	$\uparrow$	27																	
9	f	15																	
a	$\uparrow$	27																	
b	d	17																	
c	IF $x>y$	53																	
d	7	07																	
7	0	07																	
1	IF $x<y$	52																	
2	8	10																	
3	0	00																	
4	GOTO() ()	44																	
5	8	10	BRANCH TO REMOVE INSIGNIFICANT ZEROS																
6	8	10																	
7	1	01																	
8	+	33	CALCULATE $v/$ FROM $\bar{v}/$																
9	$\downarrow$	25																	
a	x	36																	
b	GOTO() ()	44																	
c	6	06																	
d	$\bar{a}$	13																	
8	0	$\downarrow$	25																
1	$\div$	35																	
2	$\uparrow$	27																	
3	1	01																	
4	-	34																	
5	GOTO() ()	44																	
6	6	06																	
7	b	14																	
8	CLEAR x	37																	
9	ROLL $\uparrow$	22																	
a	IF FLAG	43	REMOVE INSIGNIFICANT ZEROS																
b	int x	64																	
c	int x	64																	
d	$\uparrow$	27																	

FROM a-3

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	1	01								
	1	0	00								
	2	IF $x > y$	53								
	3	b	14								
	4	4	04								
	5	.	21								
	6	1	01								
	7	X	36								
	8	1	01								
	9	ROLL $\uparrow$	22								
	a	$x \div y$	30								
	b	+	33								
	c	$x \div y$	30								
	d	ROLL $\downarrow$	31								
	a	ROLL $\downarrow$	31								
	1	GO TO () ()	44								
	2	8	10								
	3	d	17								
	4	1	01								
	5	0	00								
	6	$\ln x$	65								
	7	$\div$	35								
	8	$x \div y$	30								
	9	$\uparrow$	27								
	a	$\ln x$	64								
	b	-	34								
	c	$x \div y$	30								
	d	ROLL $\uparrow$	22								
	b	0	X	36							
	1	$\downarrow$	25								
	2	e^x	74								
	3	$\uparrow$	27								
	4	$y \div ()$	24								
	5	d	17								
	6	1	01								
	7	+	33								
	8	$x \div y$	30								
	9	$y \div ()$	24								
	a	d	17								
	b	END	46								
	c										
	d										

CALCULATE P_{INT}

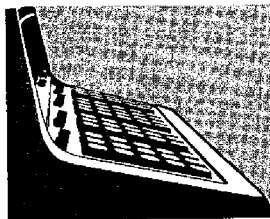
CONVERT $\ln v /$ TO $\log v /$,
REMOVE CHARACTERISTIC,
CONVERT DECIMAL NUMBER TO $\ln$
AND TAKE EXPONENT OF 10

RECALL AND POSITION DISPLAY

v DECIMAL NO. EXP. OF 10 DISPLAY

FROM 6-5

[illegible]



BESSEL FUNCTION

PART NO.
99100-70025

The differential equation:

$$x^2 \frac{d^2 y}{dx^2} + x \frac{dy}{dx} + (x^2 - n^2) y = 0$$

is called Bessel's equation of order n . When n is an integer the Bessel function of the first kind of order n , $J_n(x)$, is a solution where:

$$J_n(x) = \left(\frac{x}{2}\right)^n \sum_{k=0}^{\infty} \frac{\left(-\frac{x^2}{4}\right)^k}{k! (n+k)!} \quad x \geq 0$$

The computation is performed as follows:

$$J_n(x) = \frac{\left(\frac{x}{2}\right)^n}{n!} \left[1 - \frac{\left(\frac{x^2}{4}\right)}{1(n+1)} \cdot \left\{ 1 - \frac{\left(\frac{x^2}{4}\right)}{2(n+2)} \right\} \cdot \left\{ 1 - \frac{\left(\frac{x^2}{4}\right)}{3(n+3)} \right\} \cdot \left\{ 1 - \dots \right\} \right]$$

Reference:

Handbook of Mathematical Functions
M. Abramowitz & I. A. Stegun
National Bureau of Standards
Sixth Printing, 1967

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

→PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $n \rightarrow Y$, $x \rightarrow X$

PRESS: CONTINUE

DISPLAY

$J_n(x)$	_____	Z
n	_____	Y
x	_____	X

→To enter new value for n and x

(A)

$x = 5$

$n = 9$

$J_n(x) = 5.520283139 \times 10^{-3}$

(B)

$x = 24$

$n = 46$

$J_n(x) = 3.347208960 \times 10^{-10}$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	STOP	41	X	n	0	ENTER DATA					
2	$x \rightarrow I$	23									
3	9	11									
4	$x \rightarrow I$	23									
5	C	16									
6	$y \rightarrow I$	40									
7	d	17									
8	CLEAR	20									
9	3	03									
a	$\uparrow$	27									
b	C	16									
c	$\sqrt{x}$	76									
d	$\sqrt{x}$	76									
1	0	$\div$	35								
1	9	11									
2	+	33									
3	C	16									
4	$\ln x$	65									
5	$\uparrow$	27									
6	3	03									
7	$\div$	35									
8	$\downarrow$	25									
9	e^x	74									
a	+	33									
b	1	01									
c	+	33									
d	2	02									
2	0	$\uparrow$	27								
1	C	16									
2	$\div$	35									
3	$y \rightarrow I$	24									
4	C	16									
5	d	17									
6	IF $x < y$	52									
7	4	04									
8	3	03									
9	$\div$	35									
a	2	02									
b	$\div$	35									
c	$\downarrow$	25									
d	$\uparrow$	27									

STORE DATA

CALCULATE $\Delta = 1 + 9X^{\frac{1}{3}} + 3X^{\frac{1}{12}}$ TO BE
 ADDED TO LARGER OF n OR X TO FIND M

CALCULATE $2/X$ AND REPLACE X IN C

OMIT TEST IF $X \geq n$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	X	36								
	1	ln x	65								
	2	-	34								
	3	d	17								
	4	X	36								
	5	-	34								
	6	$\sqrt{x}$	76								
	7	ln x	65								
	8	+	33								
	9	2	02								
	a	2	02								
	b	7	07								
	c	IF x < y	52								
	d	7	07								
4	0	d	17								
	1	d	17								
	2	$x \leftrightarrow y$	30								
	3	CLEAR X	37								
	4	ROLL $\downarrow$	31								
	5	+	33								
	6	2	02								
	7	$\div$	35								
	8	$x \leftrightarrow y$	30								
	9	int x	64								
	a	X	36								
	b	ENTER EXP	26								
	c	CHG SIGN	32								
	d	9	11								
5	0	9	11								
	1	ROLL $\downarrow$	31								
	2	$y \rightarrow (1)$	40								
	3	b	14								
	4	ACC +	60								
	5	$x \leftrightarrow y$	30								
	6	d	17								
	7	IF x = y	50								
	8	$\downarrow$	25								
	9	$y \rightarrow (1)$	40								
	a	a	13								
	b	CLEAR X	37								
	c	$x \leftrightarrow y$	30								
	d	f	15								

CALCULATE $q = \frac{x^2}{4n} + (n + \frac{1}{2}) \cdot \ln(n) - n \cdot \ln(\frac{x}{2}) - n$
 EXPRESSED AS $q = n \left[\left(\frac{x}{2n}\right)^2 - \ln\left(\frac{x}{2n}\right) \right]$
 $- n + \ln(\sqrt{n})$ AND COMPARE WITH $99 \ln(10)$
 $- \ln(\sqrt{2\pi})$, EXIT AND DISPLAY ZERO FOR
 $J_n(X)$ IF LATTER IS LESS

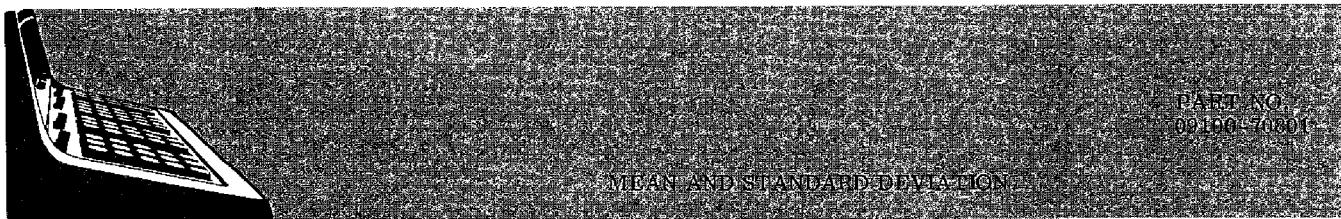
ADD GREATER OF n OR X TO Δ

FORCE m TO BE EVEN

FROM 7-C

HEWLETT-PACKARD [5] HEWLETT-PACKARD [79] HEWLETT-PACKARD [72]

Step	Key	Code	Display			Storage							
			x	y	z	f	e	d	c	b	a		
6	0	IF $x=y$	50										
	1	8	10	BRANCH WHEN $m=0$									
	2	1	01										
	3	ROLL $\downarrow$	31										
	4	IF FLAG	43										
	5	6	06	SKIP WHEN m IS ODD									
	6	9	11										
	7	ACC +	60										
	8	SET FLAG	54	ACCUMULATE EVEN TERMS									
	9	C	16										
	a	ROLL $\uparrow$	22										
	b	X	36										
	c	$\downarrow$	25										
	d	X	36	CALCULATE T_{k-1} FROM T_k AND T_{k+1}									
7	0	$\downarrow$	25										
	1	$y \rightarrow ()$	24										
	2	b	14										
	3	$x \rightarrow y$	30										
	4	-	34										
	5	CLEAR X	37										
	6	$\uparrow$	27	DECREMENT m (or k)									
	7	1	01										
	8	ACC -	63										
	9	f	15										
	a	GO TO () ()	44										
	b	5	05										
	c	5	05										
	d	CLEAR X	37										
8	0	$x \rightarrow ()$	23										
	1	a	13										
	2	ROLL $\downarrow$	31										
	3	e	12										
	4	+	33										
	5	+	33										
	6	$\downarrow$	25										
	7	$\div$	35										
	8	$\uparrow$	27	RECALL AND POSITION DISPLAY									
	9	$y \rightarrow ()$	24										
	a	9	11										
	b	d	17										
	c	$x \rightarrow y$	30										
	d	END	46	X	n	$J_n(X)$	DISPLAY						



PART NO.
00190-70801

MEAN AND STANDARD DEVIATION

This program calculates the mean, $\bar{X}$, and standard deviation, S , of a set of data points by the equations

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

and

$$S = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}}$$

Reference: Introduction to the Theory of Statistics
by Mood and Graybill

McGraw - Hill 1963

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) or END

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
i	—	X

(i indicates point to be entered)

ENTER DATA: $X_i \rightarrow X$

PRESS: CONTINUE

NO

Last Entry?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

S	—	Z
$\bar{X}$	—	Y
n	—	X

S = Standard deviation

 $\bar{X}$ = Mean

n = Number of data points

EXAMPLES

SAMPLE DATA

5.036

5.085

4.991

4.935

4.999

5.031

5.064

4.942

5.051

5.011

S = .0493

 $\bar{X}$ = 5.0145

n = 10

SAMPLE DATA

4

5

6

4

7

2

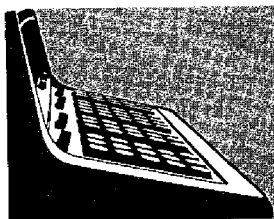
S = 1.7512

 $\bar{X}$ = 4.6667

n = 6

[illegible]

[illegible]

PART NO.
09100-70802

MEAN AND STANDARD DEVIATION OF GROUPED DATA

This program calculates the mean, $\bar{X}$, and standard deviation, S , of a set of data points $X_1, X_2, \dots, X_K$ with frequencies $f_1, f_2, \dots, f_K$ respectively. The equations used are

$$\bar{X} = \frac{\sum_{i=1}^K f_i X_i}{\sum_{i=1}^K f_i}$$
$$S = \sqrt{\frac{\sum_{i=1}^K f_i (X_i - \bar{X})^2}{\sum_{i=1}^K f_i - 1}}$$

Reference: Introduction to the Theory of Statistics
by Mood and Graybill

McGraw - Hill 1963

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
i	—	X

(i indicates pair of points to be entered)

ENTER DATA: $f_i \rightarrow Y$, $X_i \rightarrow X$

PRESS: CONTINUE

NO

Last Entry?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

S	—	Z
$\bar{X}$	—	Y
n	—	X

S = Standard Deviation

 $\bar{X}$ = Mean

n = Number of Data Points

SAMPLE DATA

X_i	f_i
1	3
2	3
3	1
4	2
5	1

$$S = 1.4337$$

$$\bar{X} = 2.5$$

$$n = 10$$

SAMPLE DATA

X_i	f_i
41	3
38	5
37	2
39	18
40	22

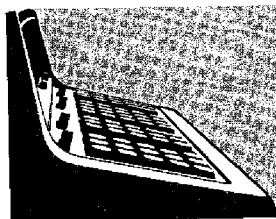
$$S = .9010$$

$$\bar{X} = 39.38$$

$$n = 50$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	$x \rightarrow ()$	23								
	2	$\square$	16								
	3	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY							
	4	$x \rightarrow ()$	23								
	5	d	17								
	6	STOP	41	x_i	f_i	0	ENTER x_i AND f_i				
	7	IF FLAG	43								
	8	2	02	BRANCH AFTER LAST ENTRY							
	9	5	05								
	a	ROLL $\uparrow$	22								
	b	$\square$	16								
	c	ROLL $\uparrow$	22								
	d	+	33	CALCULATE $\sum f_i$							
1	0	$y \rightarrow ()$	40								
	1	$\square$	16								
	2	ROLL $\uparrow$	22								
	3	X	36								
	4	$x \rightarrow y$	30	CALCULATE $\sum f_i x_i$ AND $\sum f_i x_i^2$							
	5	X	36								
	6	ACC +	60								
	7	0	00								
	8	$\uparrow$	27	CLEAR AND RECALL i							
	9	d	17								
	a	$\uparrow$	27								
	b	1	01	INCREMENT i							
	c	+	33								
	d	$y \rightarrow ()$	40								
2	0	d	17								
	1	$\downarrow$	25								
	2	GO TO () ()	44								
	3	0	00								
	4	6	06								
	5	$y \rightarrow ()$	24								
	6	f	15								
	7	$\uparrow$	27	CALCULATE $\bar{x}$							
	8	$\downarrow$	25								
	9	$\square$	16								
	a	$\div$	35								
	b	ROLL $\downarrow$	31								
	c	X	36								
	d	$x \rightarrow ()$	23								

[illegible]



PART NO.
09100-70803

LINEAR REGRESSION AND CORRELATION COEFFICIENT

This program calculates the equation of the straight line of best fit of a set of data points. The best fit is determined by minimizing the sum of the squares of the deviations of the data points from the line.

The program calculates m and b for the equation

$$Y = mX + b.$$

The program also calculates a correlation coefficient r , an indication of goodness of fit. Note $-1 < r < 1$ where the sign corresponds to the slope m . If $r = 0$ there is no correlation, and if $r = \pm 1$ there is perfect correlation or a perfect fit.

The defining equations are

$$m = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^n (X_i - \bar{X})^2}$$

$$b = \bar{Y} - m\bar{X}$$

$$\text{where } \bar{Y} = \frac{\sum_{i=1}^n Y_i}{n} \text{ and } \bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2 \sum_{i=1}^n (Y_i - \bar{Y})^2}}$$

Reference: Mathematical Statistics
by John E. Freund

Prentice - Hall 1962

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

→ DISPLAY

0	_____	Z
0	_____	Y
i	_____	X

(i indicates pair of points to be entered)

ENTER DATA: $Y_i \rightarrow Y, X_i \rightarrow X$

PRESS: CONTINUE

NO

Last Entry?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

r	_____	Z
b	_____	Y
m	_____	X

X	Y
26	92
30	85
44	78
50	81
62	54
68	51
74	40

$$r = -.96$$

$$b = 121.04$$

$$m = -1.03$$

$$Y = -1.03X + 121.04$$

X	Y
0	1
1	3
2	2
3	4
4	5

$$r = .9$$

$$b = 1.2$$

$$m = .9$$

$$Y = .9X + 1.2$$

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	00									
	1	ROLL ↓	31								
	2	xzy	30								
	3	↓	25								
	4	GOTO()()	44								
	5	0	00								
	6	B	13								
	7	B	13								
	8	↑	27								
	9	1	01								
	B	-	34								
	b	↓	25								
	C	x→()	23								
	d	B	13								
4	0	E	12								
	1	↑	27								
	2	B	13								
	3	÷	35								
	4	y→()	24								
	5	F	15								
	6	÷	35								
	7	y→()	40								
	8	E	12								
	9	X	36								
	B	E	12								
	b	X	36								
	C	d	17								
	d	xzy	30								
5	0	-	34								
	1	y→()	40								
	2	d	17								
	3	C	16								
	4	↑	27								
	5	F	15								
	6	↑	27								
	7	X	36								
	8	B	13								
	9	X	36								
	B	↓	25								
	b	-	34								
	C	y→()	40								
	d	C	16								

CLEAR DISPLAY REGISTERS
AND RECALL COUNTER

DECREMENT COUNT

CALCULATE $\bar{y}$

$\frac{\sum y_i}{n}$

$\sum y_i$
 $\sum y_i^2$
 $\frac{\sum y_i}{n}$
 $\frac{\sum y_i^2}{n}$

CALCULATE $\bar{x}$

$\frac{\sum x_i}{n}$

$\sum x_i$
 $\sum x_i^2$
 $\frac{\sum x_i}{n}$
 $\frac{\sum x_i^2}{n}$

CALCULATE $\sum (x_i - \bar{x})^2$

$\left[\sum x_i^2 - \frac{(\sum x_i)^2}{n} \right] \rightarrow d$

$\sum y_i^2$
 $\sum y_i$
 $\frac{\sum y_i^2}{n}$
 $\frac{(\sum y_i)^2}{n}$

CALCULATE $\sum (y_i - \bar{y})^2$

$\left[\sum y_i^2 - \frac{(\sum y_i)^2}{n} \right] \rightarrow c$

6

7

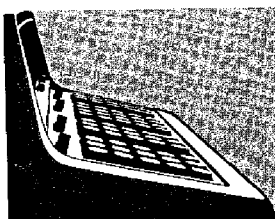
8

b	14	$\sum x_i y_i$
↑	27	$\sum x_i y_i$
f	15	$\bar{y}$
↑	27	CALCULATE $\sum (\bar{y} - \bar{x})(y_i - \bar{y})$
e	12	$\bar{x}$
x	36	$\bar{x} \bar{y}$
a	13	n
x	36	$n \bar{x} \bar{y}$
↓	25	$n \bar{x} \bar{y} \left(\sum x_i y_i - n \bar{x} \bar{y} \right)$
-	34	$\sum x_i^2 - \frac{(\sum x_i)^2}{n}$
d	17	$\sum x_i^2 - \frac{(\sum x_i)^2}{n}$
↑	27	
↓	25	$\sum x_i y_i - n \bar{x} \bar{y}$
$\sqrt{x}$	76	$\sqrt{\left(\sum x_i^2 - \frac{(\sum x_i)^2}{n} \right) \left(\sum y_i^2 - \frac{(\sum y_i)^2}{n} \right)}$
÷	35	CALCULATE r
c	16	
$\sqrt{x}$	76	$\left(\frac{\sum x_i y_i - n \bar{x} \bar{y}}{\sqrt{\left(\sum x_i^2 - \frac{(\sum x_i)^2}{n} \right) \left(\sum y_i^2 - \frac{(\sum y_i)^2}{n} \right)}} \right) \square = n$
÷	35	$\square = \sum x_i^2$
d	17	
ROLL ↑	22	CALCULATE $m = \frac{\sum x_i y_i - n \bar{x} \bar{y}}{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}$
$x \rightarrow y$	30	
÷	35	$\square = \sum x_i y_i$
$y \rightarrow 1$	24	
e	12	$\bar{x}$
e	12	n
x	36	CALCULATE $b = m \bar{x}$
f	15	$\bar{y}$
$x \rightarrow y$	30	$m \bar{x}$
-	34	$\bar{y} - m \bar{x}$
e	12	n
END	46	$\square = \sum y_i^2$

m	b	r
---	---	---

DISPLAY

[illegible]



PART NO.
09100-70804

NORMAL PROBABILITY INTEGRAL

This program computes the integral of the standardized normal distribution

$$P(X) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{1}{2}z^2} dz$$

mean

$$z = \frac{(x - \bar{x})}{s} \sqrt{n}$$

The following equations are used

$$P(X) = \frac{\text{erf}\left(\frac{x}{\sqrt{2}}\right)}{2} + \frac{1}{2}$$

where

$$\text{erf}(X) = \frac{2}{\sqrt{\pi}} e^{-X^2} \sum_{n=0}^{\infty} \frac{2^n}{1 \cdot 3 \cdots (2n+1)} X^{2n+1}$$

Reference: Handbook of Mathematical Functions
by Abramowitz and Stegun

National Bureau of Standards 1964

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) or END

PRESS: CONTINUE

DISPLAY

0 ——— Z

0 ——— Y

1 ——— X

ENTER DATA: X ———> X

PRESS: CONTINUE

DISPLAY

0 ——— Z

P(X) ——— Y

X ——— X

X = .3

P(X) = .618

X = -.3

P(X) = .382

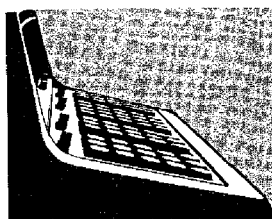
X = 0

P(X) = .5

X = 3

P(X) = .999

			Display		Storage						
Step	Key	Code	x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	01	DISPLAY 1 TO INDICATE FIRST DATA ENTRY								
2	STOP	41	X	0	0	ENTER X					
3	IF x=y	50									
4	0	00	TEST IF X=0								
5	9	11									
6	GOTO ()	44									
7	1	01									
8	1	01									
9	.	21									
a	5	05									
b	xzy	30	ENTER .5 AND BRANCH TO DISPLAY								
c	GOTO ()	44									
d	5	05									
1	d	17									
1	x→()	23	STORE X								
2	c	16									
3	IF x<y	52									
4	SET FLAG	54	IF X IS NEGATIVE, SET FLAG AND CHANGE SIGN								
5	CHG SIGN	32									
6	↑	27									
7	2	02									
8	$\sqrt{x}$	76	CALCULATE $\frac{x}{\sqrt{2}} = x'$								
9	÷	35									
a	↓	25									
b	↑	27									
c	x	36									
d	↑	27									
2	0	↓	25								
1	ROLL ↑	22									
2	e^x	74	CALCULATE $\frac{2x' e^{-x'^2}}{\sqrt{\pi}}$								
3	÷	35									
4	2	02									
5	x	36									
6	π	56									
7	$\sqrt{x}$	76									
8	÷	35									
9	1	01									
a	y→()	40									
b	a	13									
c	ROLL ↑	22	CALCULATE $\frac{1}{x'^2}$								
d	÷	35									



PART NO.
09100-70805

χ^2 - CHI SQUARE DISTRIBUTION

This program evaluates the Chi Square Distribution Integral for a given value of χ^2 and ν degrees of freedom; i.e., the program evaluates

$$P(\chi^2, \nu) = \frac{1}{2^{\nu/2} \Gamma(\frac{\nu}{2})} \int_0^{\chi^2} T^{\nu/2-1} e^{-T/2} dT \quad 0 \leq \chi^2$$

The series approximation used to evaluate the integral is

$$P(\chi^2, \nu) = (\frac{1}{2} \chi^2)^{\nu/2} \frac{e^{-\chi^2/2}}{\Gamma(\frac{\nu+2}{2})} \left\{ 1 + \sum_{r=1}^{\infty} \frac{\chi^{2r}}{(\nu+2)(\nu+4) \cdots (\nu+2r)} \right\}$$

Reference: Handbook of Mathematical Functions
by Abramowitz and Stegun

National Bureau of Standards 1964

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $X^2 \longrightarrow Y$, $\nu \longrightarrow X$

PRESS: CONTINUE

DISPLAY

$P(X^2, \nu)$	_____	Z
X^2	_____	Y
ν	_____	X

EXAMPLES

 $P(7.88, 1) = .995$ $P(10.6, 2) = .995$ $P(12.8, 17) = .251$

GENERAL FORM

 $P(X^2, \nu)$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20									
1	1 STOP	41	ν	X^2	0	ENTER	ν	AND	X^2		
2	2 $x \rightarrow ()$	23									
3	3 d	17									
4	4 $y \rightarrow ()$	40									
5	5 c	16									
6	6 2	02									
7	7 $\div$	35									
8	8 $y \rightarrow ()$	40									
9	9 f	15									
10	10 $\downarrow$	25									
11	11 $\ln x$	65									
12	12 $\uparrow$	27									
13	13 d	17									
1	1 0 $\uparrow$	27									
2	2 1	01									
3	3 +	33									
4	4 2	02									
5	5 $\div$	35									
6	6 $y \rightarrow ()$	40									
7	7 E	12									
8	8 $\downarrow$	25									
9	9 X	36									
10	10 $\downarrow$	25									
11	11 e^x	74									
12	12 $\uparrow$	27									
13	13 f	15									
1	1 CHG SIGN	32									
2	2 0 e^x	74									
3	3 X	36									
4	4 E	12									
5	5 $\uparrow$	27									
6	6 $\ln x$	64									
7	7 IF $x=y$	50									
8	8 4	04									
9	9 3	03									
10	10 2	02									
11	11 $\ln x$	65									
12	12 X	36									
13	13 $\downarrow$	25									
14	14 e^x	74									
15	15 X	36									

STORE DATA

CALCULATE $\left(\frac{X^2}{2}\right)^{\frac{\nu+1}{2}}$ CALCULATE $e^{\frac{-X^2}{2}} \left(\frac{X^2}{2}\right)^{\frac{\nu+1}{2}}$ TRUE IF ν IS ODDBRANCHES HERE IF ν IS EVEN

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	C	16								
	1	$\sqrt{x}$	76								
	2	$\div$	35								
	3	d	17								
	4	$\div$	35								
	5	$\uparrow$	27								
	6	2	02								
	7	-	34								
	8	0	00								
	9	IF x=y	50								
4	a	6	06								
	b	9	11								
	c	$\downarrow$	25								
	d	$\div$	35								
	0	GO TO () ()	44								
	1	3	03								
	2	5	05								
	3	4	04								
	4	ln x	65								
	5	x	36								
5	6	$\downarrow$	25								
	7	e^x	74								
	8	x	36								
	9	d	17								
	a	$\uparrow$	27								
	b	2	02								
	c	x	36								
	d	$\downarrow$	25								
	0	$\div$	35								
	1	$\uparrow$	27								
6	2	4	04								
	3	-	34								
	4	IF x < y	52								
	5	4	04								
	6	d	17								
	7	2	02								
	8	IF x > y	53								
	9	6	06								
	a	0	00								
	b	$\downarrow$	25								
7	c	$\div$	35								
	d	$\uparrow$	27								

CALCULATE COEFFICIENT $(\frac{1}{2}x^2)^{\frac{\nu}{2}} \frac{e^{-\frac{x^2}{2}}}{\Gamma(\frac{\nu+2}{2})}$

DECREMENT ν_1 BY 2

TEST IF ν_1 IS DECREMENTED TO ZERO

CONTINUE DECREMENTING ν_1 AND DIVIDING

BRANCHES HERE IF ν IS ODD

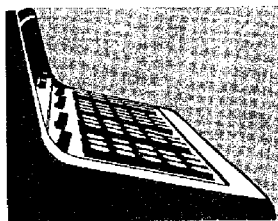
DIVIDE BY $(2\nu) \cdots 10 \cdot 6 \cdot 2 \cdot 1$

CALCULATE COEFFICIENT $(\frac{1}{2}x^2)^{\frac{\nu}{2}} \frac{e^{-\frac{x^2}{2}}}{\Gamma(\frac{\nu+2}{2})}$

FROM 2-7

[illegible]

[illegible]



PART NO.
09160-70806

χ^2 CHI SQUARE EVALUATION EXPECTED VALUES EQUAL ($E_1 = E$)

This program calculates the value of χ^2 by the equation

$$\chi^2 = \sum_{i=1}^n \frac{(O_i - E)^2}{E}$$

where

O_i — observed frequency

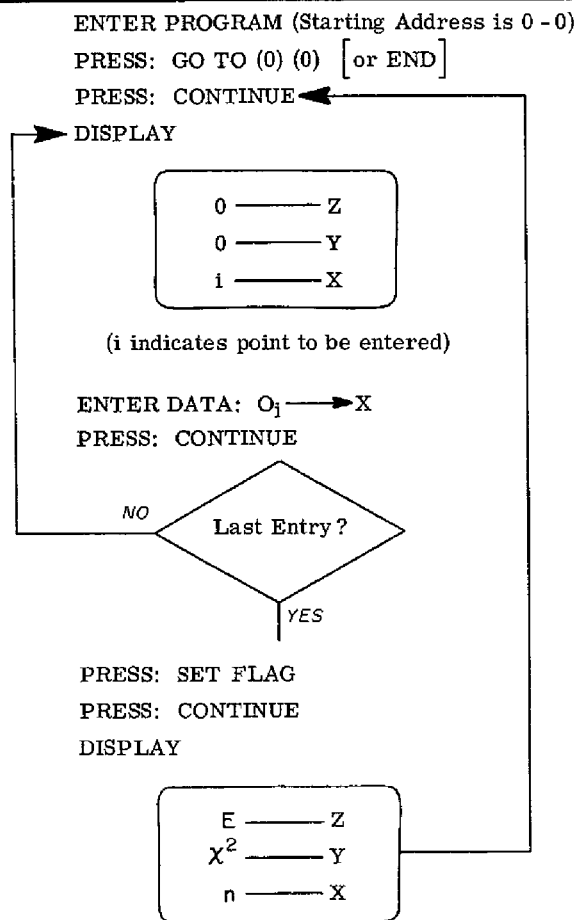
E — expected frequency of O_i is

$$E = \frac{\sum_{i=1}^n O_i}{n}$$

Reference: Mathematical Statistics
by John E. Freund

Prentice - Hall 1962

USER INSTRUCTIONS



EXAMPLES

The table shows the observed and expected frequencies in tossing a die 120 times. Calculate χ^2 for testing if the die is fair.

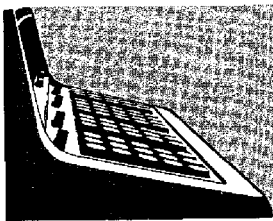
FACE	i	1	2	3	4	5	6
O_i Observed Frequency		25	17	15	23	24	16
E_i Expected Frequency		20	20	20	20	20	20

$$E = 20$$

$$\chi^2 = 5.0$$

$$n = 6$$

[illegible]



PART NO.
09100-70807

χ^2 2 x 2 CONTINGENCY TABLE

This program calculates χ^2 for a 2 x 2 contingency table containing observed frequencies. The table is shown below.

OBSERVED RESULTS

	I	II	TOTALS
GROUP A	a	b	a + b
GROUP B	c	d	c + d

(Note there is only one degree of freedom.) The equation used to evaluate χ^2 is

$$\chi^2 = \frac{(ad-bc)^2(a+b+c+d)}{(a+b)(c+d)(a+c)(b+d)}$$

Reference: Mathematical Statistics
by John E. Freund

Prentice - Hall 1962

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0 ——— Z

0 ——— Y

1 ——— X

ENTER DATA: a → Y, b → X

PRESS: CONTINUE

DISPLAY

0 ——— Z

0 ——— Y

2 ——— X

ENTER DATA: c → Y, d → X

PRESS: CONTINUE

DISPLAY

0 ——— Z

0 ——— Y

 χ^2 ——— X

FREQUENCIES OBSERVED

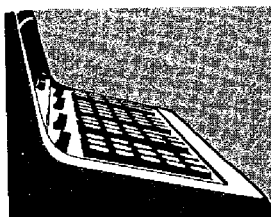
I II

GROUP A 75 (a) 25 (b)

GROUP B 65 (c) 35 (d)

$$\chi^2 = 2.381$$

[illegible]

PART NO.
09100-70808 χ^2 CHI SQUARE EVALUATION
EXPECTED VALUES UNEQUAL ($E_i \neq E_j$)

This program calculates the value of χ^2 by the equation

$$\chi^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i}$$

where O_i — observed frequency

E_i — expected frequency of O_i

Reference: Mathematical Statistics
by John E. Freund

Prentice - Hall 1962

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
i	_____	X

(i indicates points to be entered)

ENTER DATA: $O_i \rightarrow Y$, $E_i \rightarrow X$

PRESS: CONTINUE

NO

Last Entry?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	_____	Z
χ^2	_____	Y
n	_____	X

EXAMPLES

The table shows the observed and expected frequencies of some numbers. Calculate χ^2 .

i	1	2	3	4	5	6
O_i - Observed Frequency	8	50	47	56	5	14
E_i - Expected Frequency	9.6	46.75	51.85	54.4	8.25	9.15

$$\chi^2 = 4.844$$

$$n = 6$$

[illegible]

1. STATISTIC FOR MEANS OF TWO SAMPLES

PART NO
001003-00809

This program calculates the value of the t statistic from the equation

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{1}{n_x} + \frac{1}{n_y}} \sqrt{\frac{\sum (X_i - \bar{X})^2 + \sum (Y_i - \bar{Y})^2}{n_x + n_y - 2}}}$$

where $X_1, X_2, \dots, X_{n_x}$ and $Y_1, Y_2, \dots, Y_{n_y}$ are samples from normal populations with means μ_x , and μ_y ,

both with same variance σ^2 . The number of degrees of freedom $n = (n_x + n_y - 2)$. The sample means are calculated by the equations.

$$\bar{X} = \frac{\sum X_i}{n_x}$$

$$\bar{Y} = \frac{\sum Y_i}{n_y}$$

The sample estimates of the standard deviations are also displayed. These are calculated by the equations

$$S_x = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n_x - 1}}$$

$$S_y = \sqrt{\frac{\sum (Y_i - \bar{Y})^2}{n_y - 1}}$$

This program may be used to test the null hypothesis $\mu_x = \mu_y$ where we don't assume knowledge of σ^2 .

Reference: Statistical Theory and Methodology in Science and Engineering
by K. A. Brownlee
Second Edition

John Wiley and Sons, Inc. 1965

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
i	—	X

(i indicates point to be entered)

ENTER DATA: $X_i \rightarrow X$ (After last entry
SET FLAG be-
fore depressing
CONTINUE)

NO

Last X_i ?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
j	—	X

(j indicates point to be entered)

ENTER DATA: $Y_j \rightarrow X$ (After last entry
SET FLAG be-
fore depressing
CONTINUE)

NO

Last Y_j ?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	—	Z
$\bar{Y}$	—	Y
$\bar{X}$	—	X

PRESS: CONTINUE

USER INSTRUCTION (Cont'd)

DISPLAY

0	—	Z
S_Y	—	Y
S_X	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
t	—	Y
n	—	X

PRESS: CONTINUE To restart a new
problem

EXAMPLES

X	79, 84, 108, 114, 120, 103, 122, 120
Y	91, 103, 90, 113, 108, 87, 100, 80, 99, 54

$$\bar{Y} = 92.5$$

$$\bar{X} = 106.25$$

$$S_Y = 16.82$$

$$S_X = 16.64$$

$$t = 1.73$$

$$n = 16.$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	x→()	23									
3	d	17									
4	x→()	23									
5	a	13									
6	STOP	41	Z _i (X _i OR Y _i)	0	0	ENTER X _i OR Y _i (Z _i)					
7	↑	27				Z _i REPRESENTS X _i AND Y _i					
8	x	36	CALCULATE $\sum Z_i$ AND $\sum Z_i^2$			FOR NOTATION PURPOSES ONLY					
9	ACC +	60									
a	d	17									
b	↑	27									
c	1	01									
d	+	33	INCREMENT i								
1	0	y→()	40								
1	d	17									
2	0	00									
3	↑	27	CLEAR AND POSITION 1 IN THE X REGISTER								
4	ROLL ↑	22									
5	IF FLAG	43									
6	1	01	BRANCH AFTER LAST ENTRY								
7	b	14									
8	GOTO() ()	44									
9	0	00									
a	6	06									
b	↑	27									
c	1	01									
d	-	34	CHANGE n_{z+1} TO n_z								
2	0	y→()	40								
1	d	17									
2	↑	27									
3	RECALL	61									
4	ROLL ↑	22									
5	÷	35	CALCULATE $\bar{Z}$								
6	y→()	40									
7	E	12									
8	x	36									
9	E	12									
a	x	36									
b	↓	25	CALCULATE $\sum (Z_i - \bar{Z})^2$								
c	-	34									
d	y→()	40									

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	f	15								
	1	$\bar{a}$	13								
	2	$\uparrow$	27								
	3	1	01								
	4	IF $x < y$	52								
	5	4	04								
	6	8	10								
	7	RECALL	61								
	8	$x \rightarrow ()$	23								
	9	$\bar{c}$	16								
	$\bar{a}$	$y \rightarrow ()$	40								
	$\bar{b}$	$\bar{b}$	14								
	$\bar{c}$	$\bar{d}$	17								
	$\bar{d}$	$x \rightarrow ()$	23								
4	0	$\bar{a}$	13								
	1	CLEAR	20								
	2	1	01								
	3	$x \rightarrow ()$	23								
	4	$\bar{d}$	17								
	5	GO TO () ()	44								
	6	0	00								
	7	6	06								
	8	0	00								
	9	$\uparrow$	27								
	$\bar{a}$	$\bar{e}$	12								
	$\bar{b}$	$\uparrow$	27								
	$\bar{c}$	$\bar{b}$	14								
	$\bar{d}$	STOP	41	$\bar{x}$	$\bar{y}$	0					
5	0	$\bar{c}$	16								
	1	$\uparrow$	27								
	2	$\bar{a}$	13								
	3	$\uparrow$	27								
	4	1	01								
	5	-	34								
	6	$\downarrow$	25								
	7	$\div$	35								
	8	$\bar{d}$	17								
	9	$\uparrow$	27								
	$\bar{a}$	1	01								
	$\bar{b}$	-	34								
	$\bar{c}$	f	15								
	$\bar{d}$	$x \bar{z} y$	30								

BRANCH TO ENTER $\{y_i\}$
IF TEST FAILS

POSITION $\sum (x_i - \bar{x})^2$, $\bar{x}$, AND n_x
AND RETURN FOR y_i ENTRIES

RECALL $\bar{x}$ AND $\bar{y}$

DISPLAY

CALCULATE s_x^2

CALCULATE s_y^2

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	÷	35								
1	ROLL ↑	22									
2	$\sqrt{x}$	76									
3	ROLL ↑	22									
4	$\sqrt{x}$	76									
5	↑	27									
6	0	00									
7	ROLL ↓	31									
8	$x \leftrightarrow y$	30									
9	STOP	41	S_x	S_y	0	DISPLAY					
a	1	01									
b	↑	27									
c	a	13									
d	÷	35									
7	0	1	01								
1	↑	27									
2	d	17									
3	÷	35									
4	ROLL ↓	31									
5	+	33									
6	$y \leftrightarrow x$	24									
7	a	13									
8	2	02									
9	-	34									
a	↓	25									
b	+	33									
c	$y \leftrightarrow x$	40									
d	d	17									
8	0	c	16								
1	↑	27									
2	f	15									
3	+	33									
4	↓	25									
5	$x \leftrightarrow y$	30									
6	÷	35									
7	b	14									
8	↑	27									
9	e	12									
a	-	34									
b	a	13									
c	$\sqrt{x}$	76									
d	ROLL ↑	22									

CALCULATE S_x CALCULATE S_y CALCULATE $\frac{1}{n_x} + \frac{1}{n_y}$ CALCULATE $(n_x + n_y - 2)$ CALCULATE $\frac{\sum (x_i - \bar{x})^2 + \sum (y_i - \bar{y})^2}{n_x + n_y - 2}$ CALCULATE $\bar{x} - \bar{y}$

[illegible]

WEIBULL DISTRIBUTION PARAMETER CALCULATION FOR FAILURE DATA

PART NO.
09100-70810

The Weibull probability density function is given by

$$f(X) = \frac{bX^{(b-1)}}{\theta^b} e^{-\left(\frac{X}{\theta}\right)^b}$$

and the cumulative distribution function is given by

$$F(X) = 1 - e^{-\left(\frac{X}{\theta}\right)^b}$$

For a set of data, the Weibull parameters b and θ are to be calculated for these functions.

A common application is to use Weibull analysis for failure data where all samples are tested to failure. To use the program, list the items in order of increasing time to failure. The number of items and times to failure are entered. The parameters b , θ , and r are displayed. r is a correlation coefficient indicating goodness of fit. The time required for 10% (B_{10}) to fail is displayed and times to other failure percentages ($B\%$) may be requested.

The Median Rank (M. R.) is calculated by the equation

$$M.R. = \frac{j - .3}{N + 4}$$

where j = failure order number

N = number of samples tested

This is an approximation of $F(X)$.

The cumulative distribution function is linearized into the form

$$b \ln X - b \ln \theta = \ln \ln \left(\frac{1}{1 - F(X)} \right)$$

A least squares fit is performed which calculates the slope, intercept, and correlation coefficient. The solution is similar to the linear regression program 09100-70803. Thus estimates of b and θ are obtained.

USER INSTRUCTIONS

ENTER PROGRAM 1 (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

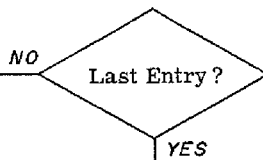
ENTER DATA: N → X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
j	—	X

(j indicates point to be entered)

ENTER DATA: t_j → X (Data must be ordered)

PRESS: CONTINUE

ENTER PROGRAM 2 (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

r	—	Z
θ	—	Y
b	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
B%	—	Y
%	—	X

(first time will be 10%)

ENTER DATA: % → X

TO RESTART A NEW PROBLEM GO TO
BEGINNING OF USER INSTRUCTIONS

EXAMPLES

TEST DATA

Hours to failure (must be ordered)

34

60

75

95

119

158

N = 6 (number of samples)

$$r = .999$$

$$\theta = 104.091$$

$$b = 1.953$$

$$B_{10} = 32.887$$

$$B_{90} = 159.539$$

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	$x \rightarrow ()$	23									
	2	d	17									
	3	$x \rightarrow ()$	23									
	4	c	16	CLEAR STORAGE REGISTERS								
	5	$x \rightarrow ()$	23									
	6	b	14									
	7	STOP	41	N	0	0	ENTER N					
	8	$x \rightarrow ()$	23									
	9	8	10	STORE N								
	a	↑	27									
	b	·	21									
	c	4	04									
	d	+	33	CALCULATE N+.4								
1	0	↓	25									
	1	$x \rightarrow ()$	23									
	2	9	11									
	3	1	01	DISPLAY 1 TO INDICATE FIRST DATA ENTRY								
	4	$x \rightarrow ()$	23									
	5	a	13									
	6	STOP	41	T _j	0	0	ENTER T _j					
	7	ln x	65	CALCULATE Ln T _j								
	8	↑	27									
	9	a	13									
	a	↑	27									
	b	·	21	CALCULATE j-.3								
	c	3	03									
	d	-	34									
2	0	xzy	30									
	1	yz()	24									
	2	9	11									
	3	y→()	40	CALCULATE M.R. j								
	4	9	11									
	5	xzy	30									
	6	÷	35									
	7	1	01									
	8	xzy	30									
	9	-	34									
	a	1	01									
	b	xzy	30	CALCULATE $\text{LnLn} \left(\frac{1}{1-\text{M.R.}_j} \right)$								
	c	÷	35									
	d	↓	25									

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FROM 6-2

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	E	12								
1	↑	27									
2	B	13									
3	÷	35									
4	y→()	24									
5	F	15									
6	÷	35									
7	y→()	40									
8	E	12									
9	X	36									
a	E	12									
b	X	36									
c	d	17									
d	x↔y	30									
1	0	—	34								
1	y→()	40									
2	d	17									
3	c	16									
4	↑	27									
5	F	15									
6	↑	27									
7	X	36									
8	a	13									
9	X	36									
a	↓	25									
b	—	34									
c	y→()	40									
d	c	16									
2	0	b	14								
1	↑	27									
2	F	15									
3	↑	27									
4	E	12									
5	X	36									
6	a	13									
7	X	36									
8	↓	25									
9	—	34									
a	d	17									
b	↑	27									
c	↓	25									
d	√x	76									

CALCULATE $\bar{Y}$ CALCULATE $\bar{X}$ CALCULATE $\sum (X_i - \bar{X})^2$ CALCULATE $\sum (Y_i - \bar{Y})^2$ CALCULATE $\sum (X_i - \bar{X})(Y_i - \bar{Y})$

CALCULATE r

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	÷	35								
	1	C	16								
	2	$\sqrt{x}$	76								
	3	÷	35								
	4	d	17								
	5	ROLL ↑	22								
	6	x↔y	30								
	7	÷	35								
	8	y↔()	24								
	9	E	12								
	a	E	12								
	b	x	36								
	c	F	15								
	d	x↔y	30								
4	0	—	34								
	1	E	12								
	2	CHG SIGN	32								
	3	÷	35								
	4	x↔y	30								
	5	e ^x	74								
	6	x↔y	30								
	7	CHG SIGN	32								
	8	STOP	41	b	θ	r					
	9	↑	27								
	a	1	01								
	b	x↔y	30								
	c	÷	35								
	d	y↔()	40								
5	0	F	15								
	1	ROLL ↑	22								
	2	ln x	65								
	3	x↔()	23								
	4	E	12								
	5	1	01								
	6	0	00								
	7	x↔()	23								
	8	d	17								
	9	↑	27								
	a	ENTER EXP	26								
	b	2	02								
	c	÷	35								
	d	1	01								

CALCULATE b

CALCULATE $-b \ln \theta$ CALCULATE θ CALCULATE $\frac{1}{b}$ CALCULATE $\ln \theta$

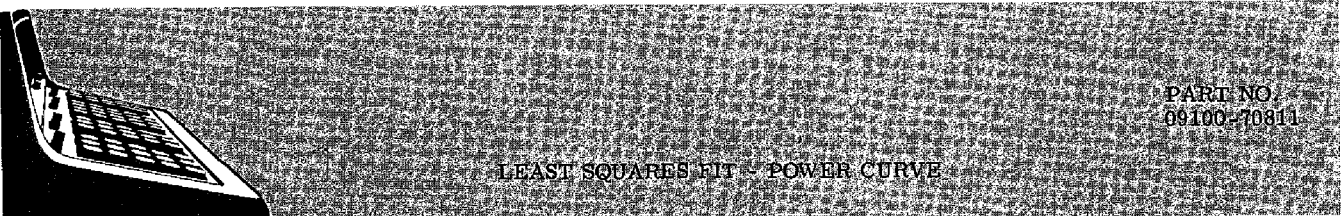
ENTER 10%

STORE %

DIVIDE % BY 100

PROGRAM 2			PAGE 3			PART NO.							
Step	Key	Code	Display			Storage							
			x	y	z	f	e	d	c	b	a		
6	0	34	CALCULATE $\frac{1}{1-F(X)}$										
	1	$x \leftrightarrow y$				30							
	2	CHG SIGN				32							
	3	$\div$				35							
	4	$\downarrow$	25	CALCULATE $\text{LnLn} \left[\frac{1}{1-F(X)} \right]$									
	5	$\ln x$	65										
	6	$\ln x$	65										
	7	$\uparrow$	27										
	8	f	15	CALCULATE $X = e^{\frac{1}{b} \text{LnLn} \left(\frac{1}{1-F(X)} \right) + \text{Ln}\theta}$									
	9	$\times$	36										
a	e	12											
b	$+$	33											
	c	00											
d	ROLL $\downarrow$	31											
7	0	74	% B% 0			DISPLAY % AND TIME %							
	1	$x \leftrightarrow y$				30							
	2	d				17							
	3	STOP				41							
	4	GO TO (X)	44	BRANCH FOR % CALCULATIONS									
	5	5	05										
	6	7	07										
	7	END	46										
		8											
		9											
	a												
	b												
	c												
	d												
	0												
	1												
	2												
	3												
	4												
	5												
	6												
	7												
	8												
	9												
	a												
	b												
	c												
	d												

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PART NO.
09100-70811

LEAST SQUARES FIT - POWER CURVE

This program computes the least squares fit and correlation coefficient of N pairs of data points for a power curve of the form:

$$Y = aX^b$$

The equation is linearized into $\ln Y = b \ln X + \ln a$

where

$$b = \frac{N \sum (\ln X \ln Y) - \sum \ln X \sum \ln Y}{N \sum (\ln X)^2 - (\sum \ln X)^2}$$

and

$$r = \frac{N \sum \ln X \ln Y - (\sum \ln X)(\sum \ln Y)}{\sqrt{[N \sum (\ln X)^2 - (\sum \ln X)^2][N \sum (\ln Y)^2 - (\sum \ln Y)^2]}}$$

$$\ln a = \frac{\sum \ln Y}{N} - \frac{\sum \ln X}{N} b$$

Note: $X_i > 0$ and $Y_i > 0$, $i=1, \dots, N$

Reference: Statistical Theory and Methodology in Science and Engineering
by K. A. Brownlee

John Wiley and Sons 1965

November 15, 1968
09100-70811

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

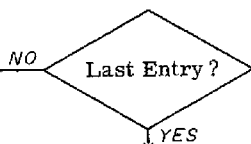
DISPLAY

0	—	Z
0	—	Y
i	—	X

(i indicates pair of points to be entered)

ENTER DATA: $Y_i \rightarrow Y$, $X_i \rightarrow X$

PRESS: CONTINUE



PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

r	—	Z
b	—	Y
a	—	X

$$Y = aX^b$$

X	Y
1.0001	25.58
3.16	14.55
10	9.26
31.6	5.63
100	3.48
316	2.12
1000	1.7

$$r = -0.9964$$

$$b = -0.4022$$

$$a = 23.5871$$

$$Y = 23.5871X^{-.4022}$$

X	Y
1	3
2	4.2574
3	5.2248
4	6.0417
5	6.7624

$$r = 1.000$$

$$b = .505$$

$$a = 3.000$$

$$Y = 3X^{.505}$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	$x \rightarrow ()$	23									
2	d	17									
3	$x \rightarrow ()$	23									
4	c	16									
5	$x \rightarrow ()$	23	CLEAR STORAGE AND DISPLAY 1 TO INDICATE FIRST ENTRY								
6	b	14									
7	1	01									
8	$x \rightarrow ()$	23									
9	a	13									
a	STOP	41	X_i	Y_i	0	ENTER X_i AND Y_i					
b	IF FLAG	43									
c	3	03	BRANCH AFTER ALL DATA HAS BEEN ENTERED								
d	b	14									
1	0	In x	65								
1	$x \rightarrow y$	30									
2	In x	65									
3	$x \rightarrow y$	30									
4	ACC +	60	CALCULATE $\sum \ln X_i, \sum \ln Y_i$								
5	$\uparrow$	27									
6	x	36									
7	$x \rightarrow y$	30	CALCULATE $\sum (\ln X_i)^2$								
8	$y \rightarrow ()$	24									
9	d	17									
a	+	33									
b	$y \rightarrow ()$	24									
c	d	17									
d	$\downarrow$	25									
2	0	x	36	CALCULATE $\sum (\ln X_i)(\ln Y_i)$							
1	b	14									
2	+	33									
3	$y \rightarrow ()$	40									
4	b	14									
5	ROLL $\uparrow$	22									
6	$\uparrow$	27									
7	x	36									
8	c	16	CALCULATE $\sum (\ln Y_i)^2$								
9	+	33									
a	$y \rightarrow ()$	40									
b	c	16									
c	a	13									
d	$\uparrow$	27									

FROM 3-a

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	1	01								
	1	+	33	INCREMENT COUNTER							
	2	y→()	40								
	3	a	13								
	4	CLEAR x	37								
	5	ROLL ↓	31								
	6	x↔y	30								
	7	↓	25	CLEAR DISPLAY AND RECALL COUNTER							
	8	GO TO () ()	44								
	9	0	00								
	a	a	13								
	b	a	13								
4	c	↑	27								
	d	1	01	DECREMENT COUNTER							
	0	-	34								
	1	y→()	40								
	2	a	13								
	3	e	12								
	4	↑	27	CALCULATE $\sum \frac{\ln Y_i}{N}$							
	5	a	13								
	6	÷	35								
	7	y→()	24								
	8	f	15	CALCULATE $\sum \frac{\ln X_i}{N}$							
	9	÷	35								
5	a	y→()	40								
	b	e	12								
	c	x	36								
	d	e	12	CALCULATE $\sum (\ln X_i - \frac{\sum \ln X_i}{N})^2$							
	0	x	36								
	1	d	17								
	2	x↔y	30								
	3	-	34								
	4	y→()	40								
	5	d	17								
	6	c	16								
	7	↑	27								
	8	f	15								
	9	↑	27	CALCULATE $\sum (\ln Y_i - \frac{\sum \ln Y_i}{N})^2$							
	a	x	36								
	b	a	13								
	c	x	36								
	d	↓	25								

FROM 0-d

Step

Key

Code

x

y

z

6	0	—	34
	1	y→()	40
	2	C	16
	3	b	14
	4	↑	27
	5	f	15
	6	↑	27
	7	E	12
	8	X	36
	9	a	13
	a	X	36
	b	↓	25
	c	—	34
	d	d	17
7	0	↑	27
	1	↓	25
	2	√x	76
	3	÷	35
	4	C	16
	5	√x	76
	6	÷	35
	7	d	17
	8	ROLL ↑	22
	9	x↔y	30
	a	÷	35
	b	y↔()	24
	c	E	12
	d	E	12
8	0	X	36
	1	f	15
	2	x↔y	30
	3	—	34
	4	E	12
	5	x↔y	30
	6	e ^x	74
	7	END	46
	8		
	9		
	a		
	b		

CALCULATE $\sum (\ln X_i - \frac{\sum \ln X_i}{N})(\ln Y_i - \frac{\sum \ln Y_i}{N})$

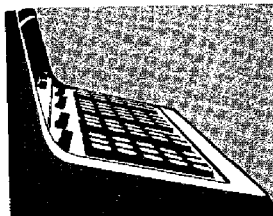
CALCULATE r

CALCULATE b

CALCULATE ln a

a b r DISPLAY

[illegible]



PART NO.
09100-70812

LEAST SQUARES FIT - EXPONENTIAL

This program computes the least squares fit and a correlation coefficient of n pairs of data points for an exponential function of the form:

$$y = ae^{bx}$$

The equation is linearized into

$$\ln y = \ln a + bx$$

or

$$Y = A + bx$$

Using a linear regression method,

$$b = \frac{n \sum xY - \sum x \sum Y}{n \sum x^2 - (\sum x)^2}$$

$$A = \frac{\sum Y - b \sum x}{n}$$

$$a = e^A$$

the correlation coefficient is given by

$$r = \frac{n \sum xY - \sum x \sum Y}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum Y^2 - (\sum Y)^2]}}$$

Note: $Y_i > 0 \quad i = 1, \dots, n$

Reference: Statistical Theory and Methodology in Science and Engineering
by K.A. Brownlee

John Wiley and Sons 1965

November 15, 1968
09100-70812

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

(i indicates pair of points to be entered)

ENTER DATA: $Y_i \rightarrow Y$, $X_i \rightarrow X$

PRESS: CONTINUE

NO

Last Entry?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

r	—	Z
b	—	Y
a	—	X

EXAMPLES

GENERAL FORM: $Y = ae^{bX}$

X	Y
.5	7.12
1.2	11.67
3.1	44.75
7.4	935.64

$r = 1.000$

$b = .707$

$a = 4.998$

$Y = 4.998e^{.707X}$

X	Y
.72	2.16
1.31	1.61
1.95	1.16
2.58	.85

$r = -1.000$

$b = -.503$

$a = 3.103$

$Y = 3.103e^{-.503X}$

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HEWLETT-PACKARD
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HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	$x \rightarrow ()$	23									
2	a	13									
3	$x \rightarrow ()$	23									
4	b	14	CLEAR STORAGE AND DISPLAY 1 TO INDICATE FIRST ENTRY								
5	$x \rightarrow ()$	23									
6	c	16									
7	1	01									
8	$x \rightarrow ()$	23									
9	d	17									
a	STOP	41	x_i	y_i	0	ENTER x_i AND y_i					
b	IF FLAG	43									
c	3	03	TEST FOR LAST ENTRY								
d	6	06									
1	0	$x \rightarrow y$	30								
1	$\ln x$	65	CALCULATE $\ln y_i$								
2	ACC +	60									
3	$\uparrow$	27									
4	$\times$	36									
5	$x \rightarrow y$	30									
6	$y \rightarrow ()$	24									
7	b	14									
8	+	33									
9	$y \rightarrow ()$	24	CALCULATE, ACCUMULATE AND STORE $\sum x, \sum \ln y, \sum \ln^2 y, \sum x \ln y$								
a	b	14									
b	$\downarrow$	25									
c	$\times$	36									
d	c	16									
2	0	+	33								
1	$y \rightarrow ()$	40									
2	c	16									
3	ROLL $\uparrow$	22									
4	$\uparrow$	27									
5	$\times$	36									
6	a	13	CALCULATE, ACCUMULATE AND STORE $\sum x^2$								
7	+	33									
8	$y \rightarrow ()$	40									
9	a	13									
a	CLEAR x	37									
b	$\uparrow$	27									
c	d	17	INCREMENT COUNTER								
d	$\uparrow$	27									

FROM 3-5

15 NOV. 68

PAGE 2

PART NO. 09100-70812

FROM U-d

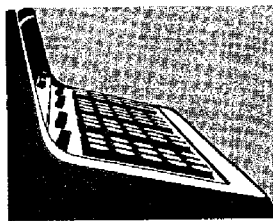
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	1	01								
	1	+	33								
	2	↓	25								
	3	GO TO () ()	44								
	4	0	00								
	5	8	10								
	6	d	17								
	7	↑	27								
	8	1	01								
	9	-	34								
	a	y→()	40								
	b	d	17								
4	c	c	16								
	d	x	36								
	0	↑	27								
	1	RCL	61								
	2	x	36								
	3	↓	25								
	4	-	34								
	5	y→()	40								
	6	c	16								
	7	d	17								
	8	↑	27								
5	9	a	13								
	a	x	36								
	b	e	12								
	c	↑	27								
	d	x	36								
	0	↓	25								
	1	-	34								
	2	y→()	40								
	3	a	13								
	4	d	17								
	5	↑	27								
	6	b	14								
	7	x	36								
	8	f	15								
	9	↑	27								
	a	x	36								
	b	↓	25								
	c	-	34								
	d	a	13								

DECREMENT COUNTER

CALCULATE $n \sum x \ln y$ CALCULATE $\sum x \sum \ln y$ CALCULATE AND STORE $n \sum x \ln y - \sum x \sum \ln y$ CALCULATE AND STORE $n \sum x^2 - (\sum x)^2$ CALCULATE AND STORE $n \sum \ln y - (\sum \ln y)^2$

				Display			Storage					
	Step	Key	Code	x	y	z	f	e	d	c	b	a
6	0	X	36									
	1	↓	25	CALCULATE $\sqrt{[n\sum x^2 - (\sum x)^2][n\sum \ln^2 y - (\sum \ln y)^2]}$								
	2	$\sqrt{x}$	76									
	3	↑	27									
	4	C	16									
	5	$x \leftrightarrow y$	30									
	6	÷	35	CALCULATE AND STORE r								
	7	$y \rightarrow ()$	40									
	8	b	14									
	9	C	16									
7	a	↑	27									
	b	a	13	CALCULATE b								
	c	÷	35									
	d	E	12									
	0	↑	27									
	1	↓	25									
8	2	X	36									
	3	F	15	CALCULATE A								
	4	$x \leftrightarrow y$	30									
	5	-	34									
	6	d	17									
	7	÷	35									
	8	b	14									
	9	ROLL ↓	31	RECALL , POSITION, AND CALCULATE a								
	a	e^x	74									
	b	END	46	a	b	r	DISPLAY					

[illegible]



PART NO.
09100-70813

POISSON DENSITY

The Poisson density function is defined by $f(n; \lambda) = \frac{\lambda^n e^{-\lambda}}{n!}$ where λ may be estimated by

$\hat{\lambda}$ = the expected value of X_1 ($n = 0, 1, 2, \dots$)

$$\sum_{n=0}^{\infty} \frac{\lambda^n e^{-\lambda}}{n!} = e^{-\lambda} \sum_{n=0}^{\infty} \frac{\lambda^n}{n!} = e^{-\lambda} e^{\lambda} = 1$$

The Poisson density function is a discrete density which is used to evaluate such things as component failure probabilities. It is also used to approximate the Binomial Distribution when the number of events (N) is large and the probability that an event will happen (p) is small i.e., a general rule of thumb is for $p \leq .1$ and

$$\hat{\lambda} = Np \leq 5.$$

Reference: Mathematical Statistics
by John E. Freund

1962 Prentice-Hall

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

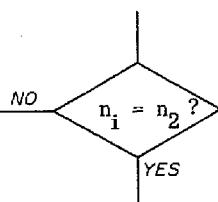
PRESS: CONTINUE

ENTER DATA: $n_2 \rightarrow Z, n_1 \rightarrow Y, \hat{\lambda} \rightarrow X$

PRESS: CONTINUE

DISPLAY

Z	—	n_1
Y	—	$\sum_{n=n_1}^{n_2} f(n; \hat{\lambda})$
X	—	$f(n_1; \hat{\lambda})$



PRESS: CONTINUE

A Poisson distribution is given by

$$f(n; .72) = \frac{(.72)^n e^{-.72}}{n!}$$

Find: a) $f(0; .72)$

$$\hat{\lambda} = .72, n_1 = 0, n_2 = 0$$

$$f(0; .72) = .48675226$$

b) $f(3; .72)$

$$\hat{\lambda} = .72, n_1 = 3, n_2 = 3$$

$$f(3; .72) = .03027988$$

If 3% of the electric bulbs manufactured by a company are defective find the probability that in a sample of 100 bulbs

a) Between 1 and 3 bulbs will be defective.

$$\left. \begin{array}{l} \text{Expected no.} \\ \text{of bulbs that} \\ \text{are defective} \end{array} \right\} = \hat{\lambda} = (.03)(100) = 3$$

$$\sum_{n=1}^3 f(n; 3) = .59744482$$

$$\text{where } \hat{\lambda} = 3, n_1 = 1, n_2 = 3$$

b) Less than or equal to 2 bulbs are defective

$$\sum_{n=0}^2 f(n; 3) = .42319008$$

$$\text{where } \hat{\lambda} = 3, n_1 = 0, n_2 = 2$$

Step	Key	Code	Display			Storage							
			x	y	z	f	e	d	c	b	a		
0	0	CLEAR	20										
1	1	STOP	41	λ	n_1	n_2	ENTER DATA; n_2, n_1, λ						
2	2	$x \rightarrow ()$	23										
3	3	C	16										
4	4	$y \rightarrow ()$	40										
5	5	b	14	STORE DATA									
6	6	ROLL $\uparrow$	22										
7	7	$x \rightarrow ()$	23										
8	8	d	17										
9	9	$x \hat{=} y$	30										
0	0	CHG SIGN	32										
1	1	e^x	74										
2	2	$\uparrow$	27										
3	3	C	16										
1	0	$\ln x$	65										
1	1	$\uparrow$	27										
2	2	b	14	CALCULATE $e^{-\lambda} \lambda^{n_i}$									
3	3	X	36										
4	4	$x \hat{=} y$	30										
5	5	e^x	74										
6	6	ROLL $\uparrow$	22										
7	7	X	36										
8	8	$y \rightarrow ()$	40										
9	9	a	13										
0	0	b	14										
1	1	$\uparrow$	27										
2	2	$\uparrow$	27	DECREMENT n_i									
3	3	d	01										
2	0	-	34										
1	1	IF $x > y$	53										
2	2	2	02										
3	3	a	13										
4	4	ROLL $\downarrow$	31										
5	5	X	36										
6	6	ROLL $\uparrow$	22	CONTINUE CALCULATING $n_i \cdot (n_i - 1) \cdots 1$									
7	7	GOTO () ()	44										
8	8	2	02										
9	9	0	00										
0	0	a	13										
1	1	ROLL $\uparrow$	22										
2	2	$\uparrow$	27										
3	3	0	00										

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	$x \neq y$	30								
1	IF $x=y$	50									
2	CONTINUE	47									
3	1	01									
4	$x \neq y$	30									
5	↓	25									
6	÷	35									
7	$x \neq y$	30									
8	↑	27									
9	ACC +	60									
a	b	14									
b	ROLL ↓	31									
c	RCL	61									
d	STOP	41									
4	0	CLEAR x	37								
1	$x \rightarrow ()$	23									
2	f	15									
3	d	17									
4	ROLL ↑	22									
5	IF $x=y$	50									
6	0	00									
7	0	00									
8	↑	27									
9	1	01									
a	+	33									
b	$y \rightarrow ()$	40									
c	b	14									
d	c	16									
5	0	GO TO () ()	44								
1	0	00									
2	a	13									
3	END	46									
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

IF $n_i! = 0$, ENTER 1CALCULATE $\frac{e^{-\hat{\lambda}} \hat{\lambda}^{n_i}}{n_i!}$ AND $\sum_{n=n_i}^{n_i} f(n, \hat{\lambda})$

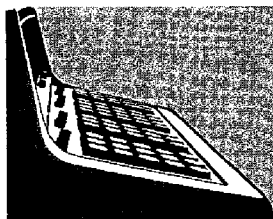
POSITION DISPLAY

$$\frac{e^{-\hat{\lambda}} \hat{\lambda}^{n_i}}{n_i!} \quad \sum_{n=n_i}^{n_i} f(n, \hat{\lambda}) \quad 0$$

ZERO STORAGE REGISTER f

BRANCH TO INITIAL ENTRY WHEN THROUGH

INCREMENT n_i RECALL $\hat{\lambda}$ AND CONTINUE SUMMATION



PART NO.
09100-70814

MULTIPLE LINEAR REGRESSION

This program fits any number of data points (X_i, Y_i, Z_i) to a linear, two variable equation of the form:

$$Z = a_0 + a_1 X + a_2 Y$$

where X and Y are the independent variables.

Development:

The constants a_0 , a_1 , and a_2 of the equation may be found by solving simultaneously the following normal equations which represent the least square plane (approximating plane) formed by the data points.

$$\sum Z = a_0 n + a_1 \sum X + a_2 \sum Y$$

$$\sum XZ = a_0 \sum X + a_1 \sum X^2 + a_2 \sum XY$$

$$\sum YZ = a_0 \sum Y + a_1 \sum XY + a_2 \sum Y^2$$

In the program the constant a_2 is found from solving the equations by matrix algebra. Therefore,

$$a_2 = \frac{n(\sum X^2 \sum YZ - \sum XZ \sum XY) - \sum X(\sum X \sum YZ - \sum Y \sum XZ) + \sum Z(\sum X \sum XY - \sum Y \sum X^2)}{D}$$

Where D (the determinant) =

$$\begin{vmatrix} n & \sum X & \sum Y \\ \sum X & \sum X^2 & \sum XY \\ \sum Y & \sum XY & \sum Y^2 \end{vmatrix}$$

After finding a_2 , the solution is reduced to two equations in two unknowns which are:

$$M = a_0 n + a_1 \sum X$$

$$N = a_0 \sum X + a_1 \sum X^2$$

$$\text{where } M = (\sum Z - a_2 \sum Y)$$

$$N = (\sum XZ - a_2 \sum XY)$$

These two equations are then solved for a_0 and a_1 .

Reference:

Introduction to the Theory of Statistics
Mood and Graybill
McGraw-Hill, 1963

USER INSTRUCTIONS

ENTER PROGRAM 1 (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

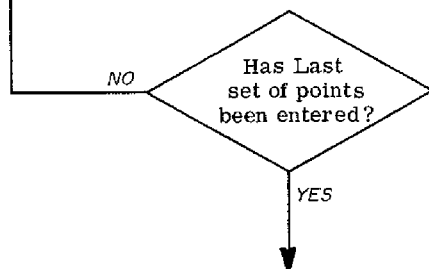
PRESS: CONTINUE

DISPLAY

i	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $Z_i \rightarrow Z$, $Y_i \rightarrow Y$, $X_i \rightarrow X$

PRESS: CONTINUE



PRESS: SET FLAG

PRESS: CONTINUE

(Intermediate results displayed)

ENTER PROGRAM 2 (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

(Intermediate results displayed)

ENTER PROGRAM 3 (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

a_2	_____	Z
a_1	_____	Y
a_0	_____	X

To reset problem, repeat USER INSTRUCTIONS

EXAMPLES

(A) Equation of the form:

$$Z = a_0 + a_1 X + a_2 Y$$

Input data:

X	Y	Z
1	0	3
0	1	4
1	1	6
3	4	19
2	2	11

Solution:

$$Z = 1 + 2X + 3Y$$

(B) Equation of the form:

$$Z = a_0 + a_1 (\log X) + a_2 (\log Y)$$

Note to enter data;

ENTER: $Z_i \rightarrow Z$

PRESS: $\uparrow$

ENTER: $Y_i \rightarrow X$

PRESS: $\log X$

PRESS: $\uparrow$

ENTER: $X_i \rightarrow X$

PRESS: $\log X$

Input data:

X	Y	Z
1	2	4.6505
1	1	4.5
4	3.63	5.9841
10	5	6.8495
8	16	6.9082
13	7	7.1504
3	10	5.9542

Solution:

$$Z = 4.5 + 2 (\log X) + .4999 (\log Y)$$

PROGRAM 1			Display			Storage						
Step	Key	Code	x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	x→()	23									
	2	a	13									
	3	x→()	23									
	4	b	14									
	5	x→()	23									
	6	c	16									
	7	x→()	23									
	8	9	11									
	9	x→()	23									
	a	8	10									
	b	x→()	23									
	c	7	07									
	d	1	01									
1	0	x→()	23									
	1	d	17									
	2	ROLL↓	31									
	3	STOP	41	x _i	y _i	z _i	ENTER z _i , y _i , x _i					
	4	IF FLAG	43									
	5	5	05									
	6	a	13									
	7	y→()	40									
	8	6	06									
	9	x	36									
	a	x↔y	30									
	b	y↔()	24									
	c	a	13									
	d	+	33									
2	0	y↔()	24									
	1	a	13									
	2	ROLL↓	31									
	3	ACC +	60									
	4	↑	27									
	5	x	36									
	6	x↔y	30									
	7	y↔()	24									
	8	7	07									
	9	+	33									
	a	y↔()	24									
	b	7	07									
	c	↓	25									
	d	x	36									

NEWLEI-FACARD [760]
NEWLEI-FACARD [760]
NEWLEI-FACARD [760]
NEWLEI-FACARD [760]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	d	17								
1	↑	27									
2	1	01									
3	—	34									
4	y→()	40									
5	d	17									
6	↓	25									
7	f	15									
8	x	36									
9	CHG SIGN	32									
a	x	36									
b	ROLL ↑	22									
c	y→()	24									
d	7	07									
1	0	y→()	40								
1	7	07									
2	x	36									
3	d	17									
4	x	36									
5	ROLL ↓	31									
6	+	33									
7	a	13									
8	↑	27									
9	x	36									
a	d	17									
b	x	36									
c	↓	25									
d	—	34									
2	0	↑	27								
1	y→()	24									
2	7	07									
3	y→()	40									
4	7	07									
5	b	14									
6	x	36									
7	x	36									
8	↓	25									
9	—	34									
a	b	14									
b	↑	27									
c	f	15									
d	x	36									

CALCULATE D

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	$\bar{a}$	13								
	1	X	36								
	2	2	02								
	3	X	36								
	4	$\downarrow$	25								
	5	+	33								
	6	$y \rightarrow ()$	40								
	7	8	10								
	8	$y \rightarrow ()$	24								
	9	9	11								
	$\bar{a}$	$\uparrow$	27								
	$\bar{b}$	$\downarrow$	25								
	$\bar{c}$	F	15								
	$\bar{d}$	X	36								
4	0	CHG SIGN	32								
	1	X	36								
	2	ROLL $\uparrow$	22								
	3	$x \rightarrow y$	30								
	4	$\bar{d}$	17								
	5	X	36								
	6	$x \rightarrow y$	30								
	7	$y \rightarrow ()$	24								
	8	7	07								
	9	$y \rightarrow ()$	40								
	$\bar{a}$	7	07								
	$\bar{b}$	$x \rightarrow y$	30								
	$\bar{c}$	X	36								
	$\bar{d}$	ROLL $\downarrow$	31								
5	0	+	33								
	1	ROLL $\uparrow$	22								
	2	$x \rightarrow y$	30								
	3	$\bar{b}$	14								
	4	X	36								
	5	e	12								
	6	X	36								
	7	ROLL $\downarrow$	31								
	8	-	34								
	9	F	15								
	$\bar{a}$	ROLL $\uparrow$	22								
	$\bar{b}$	X	36								
	$\bar{c}$	$\bar{a}$	13								
	$\bar{d}$	X	36								

STORE D

CALCULATE NUMERATOR OF a_2

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	b	14								
1	X	36									
2	↓	25									
3	+	33									
4	$x \leftrightarrow y$	30									
5	$y \rightarrow ()$	24									
6	8	10									
7	$x \leftrightarrow y$	30									
8	÷	35									
9	$y \rightarrow ()$	40									
	a	9									
	b	↑									
	c	↓									
	d	b									
1	0	X	36								
1	E	12									
2	$x \leftrightarrow y$	30									
3	-	34									
4	a	13									
5	$y \rightarrow ()$	40									
6	a	13									
7	ROLL ↑	22									
8	X	36									
9	c	16									
	a	$x \leftrightarrow y$									
	b	-									
	c	$y \rightarrow ()$									
	d	c									
2	0	f	15								
1	↑	27									
2	d	17									
3	$y \rightarrow ()$	40									
4	d	17									
5	$y \rightarrow ()$	24									
6	7	07									
7	$y \rightarrow ()$	40									
8	8	10									
9	$x \rightarrow ()$	23									
	a	b									
	b	CLEAR									
	c	$y \rightarrow ()$									
	d	8									

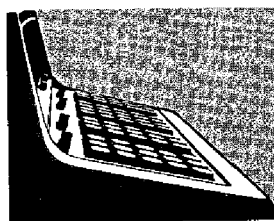
COMPLETE CALCULATION OF THE
NUMERATOR OF a_2

RECALL D, CALCULATE AND STORE a_2

CALCULATE AND STORE M

CALCULATE AND STORE N

STORE ΣX , ΣX^2 AND n
IN THE APPROPRIATE REGISTERS



NON-LINEAR REGRESSION THE LEAST SQUARES PARABOLA

PART NO.
09100-70815

The least square parabola approximating the set of points $(X_1, Y_1) \dots (X_i, Y_i)$ has the equation:

$$Y = a_0 + a_1 X + a_2 X^2$$

where the constants a_0 , a_1 , and a_2 are determined by solving simultaneously the following normal equations.

$$\sum Y = a_0 n + a_1 \sum X + a_2 \sum X^2$$

$$\sum XY = a_0 \sum X + a_1 \sum X^2 + a_2 \sum X^3$$

$$\sum X^2 Y = a_0 \sum X^2 + a_1 \sum X^3 + a_2 \sum X^4$$

In the program the constant a_2 is found by matrix algebra; the determinate (D) involved in the solution is:

$$D = \begin{vmatrix} n & \sum X & \sum X^2 \\ \sum X & \sum X^2 & \sum X^3 \\ \sum X^2 & \sum X^3 & \sum X^4 \end{vmatrix}$$

The equation for a_2 is therefore:

$$a_2 = \frac{(n(\sum X^2 \sum X^2 Y - \sum X^3 \sum XY) - \sum X(\sum X \sum X^2 Y - \sum X^2 \sum XY) + \sum Y [\sum X \sum X^3 - (\sum X^2)^2])}{D}$$

After finding a_2 the solution is reduced to two equations in two unknowns which are:

$$N = a_0 n + a_1 \sum X$$

$$M = a_0 \sum X + a_1 \sum X^2$$

$$\text{where } M = \sum XY - a_2 \sum X^3 \quad N = \sum Y - a_2 \sum X^2$$

These equations are then solved for a_0 and a_1 .

Note: Curves with the following equations may also be fitted with this program.

$$Y = a_0 + a_1 X \quad (1)$$

$$\log Y = a_0 + a_1 X \quad (2)$$

$$\log Y = a_0 + a_1 X + a_2 X^2 \quad (3)$$

$$Y = a_0 + a_1 \log X \quad (4)$$

$$\log Y = a_0 + a_1 \log X \quad (5)$$

$$\log Y = a_0 + a_1 (\log X) + a_2 (1 \log X)^2 \quad (6)$$

An equation of the form of (6) is solved in the examples.

The general form, representing all of these equations which can be fitted is:

$$f(Y) = a_0 + a_1 f(X) + a_2 f^2(X)$$

Reference: Introduction into the Theory of Statistics

by
Alexander M. Mood & Franklin A. Graybill

McGraw-Hill
(1961)

2nd Edition

USER INSTRUCTIONS

ENTER PROGRAM 1 (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

→ DISPLAY

i	_____	Z
0	_____	Y
0	_____	X

(i indicates pair of points to be entered)

ENTER DATA: $Y_i \rightarrow Y$, $X_i \rightarrow X$

PRESS: CONTINUE

NO

LAST ENTRY?

YES

PRESS: SET FLAG

PRESS: CONTINUE

ENTER PROGRAM 2 (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

a_2	_____	Z
a_1	_____	Y
a_0	_____	X

To calculate coefficients for new data repeat
User Instructions.

EXAMPLES

(A) Equation of the form: $Y = a_0 + a_1 X + a_2 X^2$

Data: X	Y
3	29
0	2
5	67
2	16
1.5	11
4	46
1	7

Solution: $Y = 2X^2 + 3X + 2$

(B) Equation of the form:

$$\log Y = a_0 + a_1 \log X + a_2 (\log X)^2$$

Note: Data to be entered is $\log Y_i$, $\log X_i$;
therefore, to enter sets of data:

ENTER: $Y_i \rightarrow X$

PRESS: $\log X$

PRESS: ↑

ENTER: $X_i \rightarrow Y$

PRESS: $\log X$

Data: X	Y
1	2.7183
2	35.1595
3	245.3746
4	1188.7946
5	4530.5750

Solution: $\ln Y = (\ln X)^2 + 3 (\ln X) + 1$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	$x \rightarrow ()$	23								
	2	$\bar{c}$	16								
	3	$x \rightarrow ()$	23								
	4	b	14								
	5	$x \rightarrow ()$	23								
	6	$\bar{a}$	13								
	7	$x \rightarrow ()$	23								
	8	9	11								
	9	$x \rightarrow ()$	23								
	$\bar{a}$	8	10								
	b	1	01								
	$\bar{c}$	$x \rightarrow ()$	23								
	$\bar{d}$	$\bar{d}$	17								
1	0	ROLL $\downarrow$	31								
	1	STOP	41	X	Y	0	ENTER Y AND X				
	2	IF FLAG	43								
	3	4	04								
	4	$\bar{d}$	17								
	5	ACC +	60	STORE $\sum X$ AND $\sum Y$							
	6	X	36								
	7	$x \rightarrow y$	30								
	8	$y \rightarrow ()$	24								
	9	$\bar{c}$	16								
	$\bar{a}$	+	33								
	b	$y \rightarrow ()$	24								
	$\bar{c}$	$\bar{c}$	16								
	$\bar{d}$	$\uparrow$	27								
2	0	$\downarrow$	25								
	1	X	36								
	2	$\downarrow$	25								
	3	$y \rightarrow ()$	24								
	4	9	11								
	5	+	33								
	6	$y \rightarrow ()$	24								
	7	9	11								
	8	$\downarrow$	25								
	9	X	36								
	$\bar{a}$	$x \rightarrow y$	30								
	b	$y \rightarrow ()$	24								
	$\bar{c}$	b	14								
	$\bar{d}$	+	33								

CLEAR THE NECESSARY STORAGE REGISTERS
AND INITIALIZE THE COUNTER (n)

STORE $\sum X$ AND $\sum Y$

FORM $\sum XY$ AND STORE

FORM $\sum X^2 Y$ AND STORE

FORM $\sum X^2$ AND STORE

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	y ² (1)									
1	d	17									
2	d	17									
3	ROLL ↑	22									
4	x	36									
5	v	25									
6	+	33									
7	B	13									
8	↑	27									
9	x	36									
a	d	17									
b	x	36									
c	v	25									
d	-	34									
7	0	b									
1	↑	27									
2	x	36									
3	x	36									
4	ROLL ↓	31									
5	-	34									
6	f	15									
7	ROLL ↑	22									
8	x	36									
9	2	02									
a	x	36									
b	B	13									
c	x	36									
d	END	46									
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

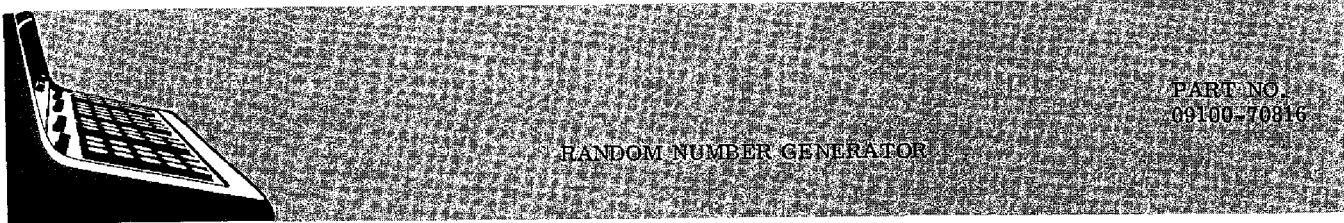
CALCULATE D

HEWLETT-PACKARD HEWLETT-PACKARD HEWLETT-PACKARD HEWLETT-PACKARD HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	↓	25								
	1	+	33								
	2	$y \rightarrow (1)$	24								
	3	9	11								
	4	↑	27								
	5	↓	25								
	6	b	14								
	7	x	36								
	8	d	17								
	9	x	36								
	a	f	15								
	b	ROLL ↑	22								
	c	$x \rightarrow y$	30								
1	d	x	36								
	0	x	36								
	1	ROLL ↓	31								
	2	-	34								
	3	e	12								
	4	ROLL ↑	22								
	5	x	36								
	6	a	13								
	7	x	36								
	8	ROLL ↓	31								
	9	+	33								
	a	d	17								
	b	ROLL ↑	22								
2	c	x	36								
	d	c	16								
	0	x	36								
	1	ROLL ↓	31								
	2	-	34								
	3	f	15								
	4	$x \rightarrow (1)$	23								
	5	8	10								
	6	ROLL ↑	22								
	7	x	36								
	8	b	14								
	9	x	36								
	a	ROLL ↓	31								
	b	+	33								
	c	↓	25								
	d	ROLL ↓	31								

CALCULATE NUMERATOR OF a_2

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	ACC +	60	STORE $\frac{\sum X}{n}$	AND $\frac{N}{n}$						
	1	b	14								
	2	$y^2()$	24								
	3	8	10	POSITION COEFFICIENTS FOR CALCULATION							
	4	↑	27	OF $\frac{M}{\sum X}$ AND $\frac{\sum X^2}{\sum X}$							
	5	a	13								
	6	ROLL ↑	22								
	7	SET FLAG	54								
	8	GOTO ()	44	SET FLAG AND BRANCH TO							
	9	5	05	CALCULATE $\frac{M}{\sum X}$ AND $\frac{\sum X^2}{\sum X}$							
	a	6	06	CALCULATE $(\frac{N}{n} - \frac{M}{\sum X})$ AND $(\frac{\sum X}{n} - \frac{\sum X^2}{\sum X})$							
	b	ACC -	63								
	c	xzy	30								
	d	$y^2()$	24								
7	0	e	12	CALCULATE a_1							
	1	f	15								
	2	÷	35								
	3	e	12								
	4	xzy	30								
	5	x	36	CALCULATE a_0							
	6	ROLL ↓	31								
	7	-	34								
	8	ROLL ↑	22								
	9	$y^2()$	24								
	a	9	11								
	b	ROLL ↑	22								
	c	END	46	a_0	a_1	a_2	DISPLAY COEFFICIENTS				
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										



PART NO.
09100-70816

RANDOM NUMBER GENERATOR

This program calculates random numbers (RN) in the range $0 \leq RN_i \leq 1$ using the formula given below:

$$RN_i = \left[\pi + RN_{(i-1)} \right]^8 - \text{Int.} \left\{ \left[\pi + RN_{(i-1)} \right]^8 \right\}$$

RN_i is the current random number and $RN_{(i-1)}$ is the last calculated random number. More than 10,000 random numbers may be generated before values are repeated.

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM: (Starting Address is 0 - 0)

→ PRESS: GO TO (0) (0) [or END]

→ PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
RN ₁	—	X

→ TO RESET PROBLEM:

RN₁ = .5310

RN₂ = .6918

RN₃ = .3712

RN₄ = .6890

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
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f											
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b											
c											
d											
e											
f											
0											
1											
2											
3											
4											

HEWLETT-PACKARD
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HEWLETT-PACKARD
HEWLETT-PACKARD
HEWLETT-PACKARD
HEWLETT-PACKARD

PART NO.
89100-70317

MEAN, DEVIATION AND PROBABLE ERROR

This program calculates the mean, $\bar{X}$; standard deviation, σ_x ; probable error, pe_x ; the standard deviation from the mean, $\sigma_{\bar{X}}$; and the probable error of the mean, $pe_{\bar{X}}$.

The mean is continually displayed after the second entry. The other terms can be manually called as required:

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}} = \sqrt{\frac{\sum (X_i)^2 - n(\bar{X})^2}{n-1}}$$

$$\sigma_{\bar{X}} = \frac{\sigma_x}{\sqrt{n}}$$

$$pe_x = .6745 \sigma_x$$

$$pe_{\bar{X}} = .6745 \sigma_{\bar{X}}$$

- References: 1. Reference Data for Radio Engineers, International Telephone and Telegraph Corporation, 1956.
2. Treatment of Experimental Data, Worthing and Geffner, John Wiley and Sons, 1943.

* This program was written by J. Carlos Chavez of Jet Propulsion Laboratories, Pasadena, California.

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
1	_____	Y
0	_____	X

Data	Display $\bar{X}$	N	Key a σ_x	b $\sigma_{\bar{X}}$	c pe_x	d $pe_{\bar{X}}$
1		1				
2	1.5	2	.707	.5	.477	.337
3	2.0	3	1.0	.577	.675	.389
4	2.5	4	1.29	.645	.871	.435
5	3.0	5	1.581	.707	1.066	.477

SAMPLE DATA

90
80
70
60
50
40

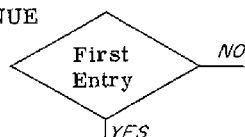
Final result after last data entry:

 $\bar{X} = 65$

N = 6

 $\sigma_x = 18.708287$ in a $\sigma_{\bar{X}} = 7.637626$ in b $pe_x = 12.618740$ in c $pe_{\bar{X}} = 5.151579$ in dENTER DATA: $X_i \rightarrow X$

PRESS: CONTINUE



DISPLAY

1	_____	Z
1	_____	Y
1	_____	X

(N indicates entries thus far)

DISPLAY

$\bar{X}$	_____	Z
N	_____	Y
0	_____	X

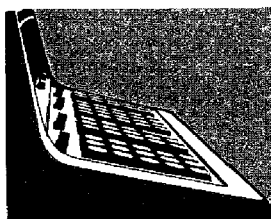
PRESS KEY	TO GET
a	σ_x
b	$\sigma_{\bar{X}}$
c	pe_x
d	$pe_{\bar{X}}$

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	16									
1	RCL	61									
2	↑	27									
3	CLEAR X	37									
4	GOTO () ()	44									
5	0	00									
6	7	07									
7	END	46									
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
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a											
b											
c											
d											
0											
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6											
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9											
a											
b											
c											
d											

RECALL CURRENT $\bar{X}$ AND n
AND POSITION FOR DISPLAY

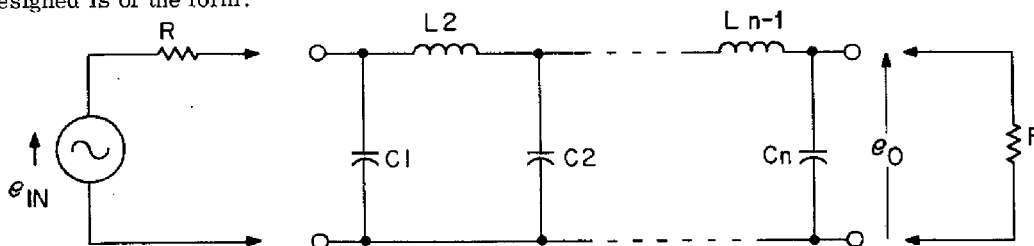
BRANCH TO DISPLAY CURRENT
 $\bar{X}$ AND n AND ENTER NEXT
DATA POINT IF APPLICABLE.



PART NO.
09100-71001

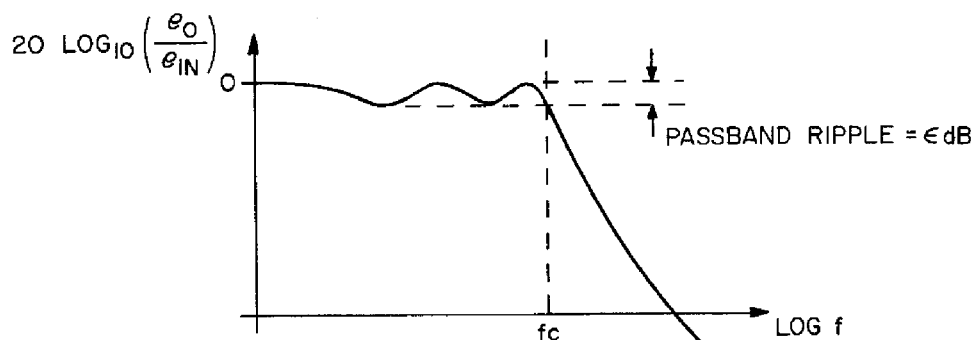
TCHEBYSHEFF FILTER DESIGN

This program computes component values for Tchebysheff low pass filters between equal terminations. The network designed is of the form:



The first element of the filter is a shunt C. The order (no. of poles) must be odd. (Even order requires unequal terminations for realizability.)

Frequency response of filter is:



User specifies: Filter Order n (must be odd)
Pass Band Ripple ϵ_{dB} (in dB)

Termination Resistance R (in ohms)
Corner ($-\epsilon_{dB}$) Frequency f_c (in Hz)

The equations used are:

$$G_1 = \frac{2a_1}{\gamma}$$

$$G_K = \frac{4a_{K-1} a_K}{b_{K-1} G_{K-1}} \quad K = 2, 3, 4, \dots, n$$

where $\gamma = \sinh \left[\frac{\ln(\coth 40 \log_{10} e)}{2n} \right]$

$$a_K = \sin \left[\frac{(2K-1)\pi}{2n} \right] \quad K = 1, 2, 3, \dots, n \text{ and } b_K = \gamma^2 + \sin^2 \left(\frac{K\pi}{n} \right) \quad K = 1, 2, 3, \dots, n$$

$$C_K = \frac{G_K}{2\pi f_c R} \quad K = 1, 3, 5, \dots, n \text{ and } L_K = \frac{R G_K}{2\pi f_c} \quad K = 2, 4, 6, \dots, (n-1)$$

Reference: A Handbook on Electrical Filters

White Electromagnetics, Inc. 1963

USER INSTRUCTIONS

SET ☐ RADIANS ☐ FLOATING ☐
 ENTER PROGRAM (Starting address is 0-0)

This program is self-destructive ie.,
 each solution requires reloading the
 calculator.

PRESS: END

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $n \rightarrow Y$, $\epsilon_{dB} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $R \rightarrow Y$, $f_c \rightarrow X$

PRESS: CONTINUE

DISPLAY

(K odd)

0	—	Z
C_K	—	Y
K	—	X

(C_K is in
farads)

(K even)

0	—	Z
L_K	—	Y
K	—	X

(L_K is in
henries)

Displays component values until $K = N$.
 Next CONTINUE clears DISPLAY. The
 program steps must be reentered to en-
 ter another problem.

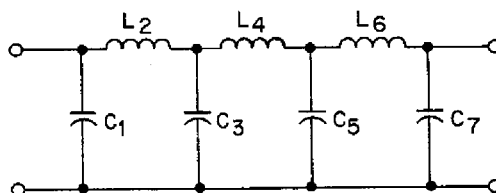
EXAMPLE

7th Order (n)

0.1 dB Ripple (ϵ_{dB})

50 Ω Impedance Level (R)

3.2 MHz Corner Frequency (f_c)



$$C_1 = 1175 \text{ pF}$$

$$L_2 = 3.538 \text{ } \mu\text{H}$$

$$C_3 = 2086 \text{ pF}$$

$$L_4 = 3.913 \text{ } \mu\text{H}$$

$$C_5 = 2086 \text{ pF}$$

$$L_6 = 3.538 \text{ } \mu\text{H}$$

$$C_7 = 1175 \text{ pF}$$

HEWLETT-PACKARD FROM c-5

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	GO TO ()	44									
	1	$\bar{a}$	13									
	2	0	00									
	3	CLEAR	20									
	4	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	5	STOP	41	fc	R	0	ENTER R, fc					
	6	$y \rightarrow ()$	40	STORE R								
	7	F	15									
	8	$x \leftrightarrow y$	30									
	9	2	02									
	a	X	36									
	b	π	56	CALCULATE $\omega_c = 2\pi fc$								
	c	X	36									
	d	$y \rightarrow ()$	40									
1	0	E	12									
	1	$\uparrow$	27									
	2	2	02									
	3	$\div$	35									
	4	d	17									
	5	$\div$	35									
	6	$\downarrow$	25									
	7	$\sin x$	70	CALCULATE G_1 - FIRST NORMALIZED COMPONENT VALUE								
	8	$\uparrow$	27									
	9	2	02									
	a	X	36									
	b	$\bar{a}$	13									
	c	$\div$	35									
	d	$y \rightarrow ()$	40									
2	0	b	14									
	1	$\uparrow$	27									
	2	X	36	REPLACE γ WITH γ^2								
	3	$y \rightarrow ()$	40									
	4	$\bar{a}$	13									
	5	CLEAR X	37									
	6	ROLL $\uparrow$	22									
	7	$\uparrow$	27									
	8	E	12	CALCULATE C_1								
	9	$\div$	35									
	a	F	15									
	b	$\div$	35									
	c	1	01	DISPLAY 1 TO INDICATE FIRST COMPONENT								
	d	STOP	41	1	C_1	0	DISPLAY					

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	d	17								
	1	÷	35								
	2	↓	25								
	3	sin x	70								
	4	↑	27								
	5	x	36								
	6	a	13								
	7	+	33								
	8	↓	25								
	9	÷	35								
	a	b	14								
	b	÷	35								
	c	y→()	40								
	d	b	14								
7	0	E	12								
	1	÷	35								
	2	f	15								
	3	IF FLAG	43								
	4	8	10								
	5	2	02								
	6	÷	35								
	7	0	00								
	8	x↔y	30								
	9	↑	27								
	a	c	16								
	b	STOP	41								
	c	SET FLAG	54								
	d	GO TO () ()	44								
8	0	8	10								
	1	8	10								
	2	x	36								
	3	0	00								
	4	x↔y	30								
	5	↑	27								
	6	c	16								
	7	STOP	41								
	8	↑	27								
	9	1	01								
	a	+	33								
	b	y→()	40								
	c	c	16								
	d	d	17								

CALCULATE G_K/ω_c

RECALL R

ALTERNATING BRANCH

COMPLETES C_K CALCULATION

POSITION DISPLAY AND RECALL K

K C_K 0 DISPLAYBRANCH TO ISOLATE L_K CALCULATIONCOMPLETES L_K CALCULATION

POSITION DISPLAY AND RECALL K

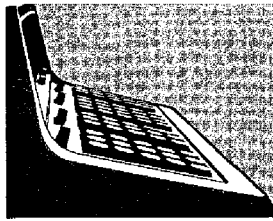
K L_K 0 DISPLAY

INCREMENT K BY 1

RECALL n

[illegible]

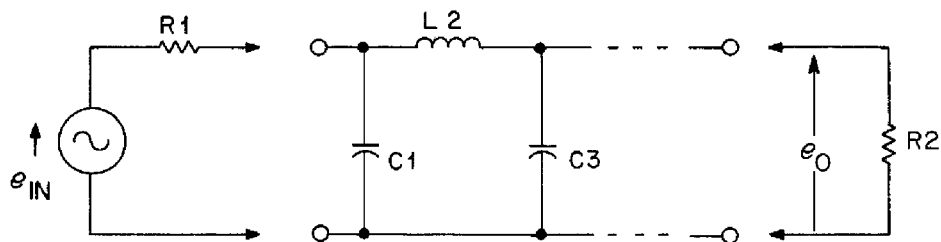
[illegible]



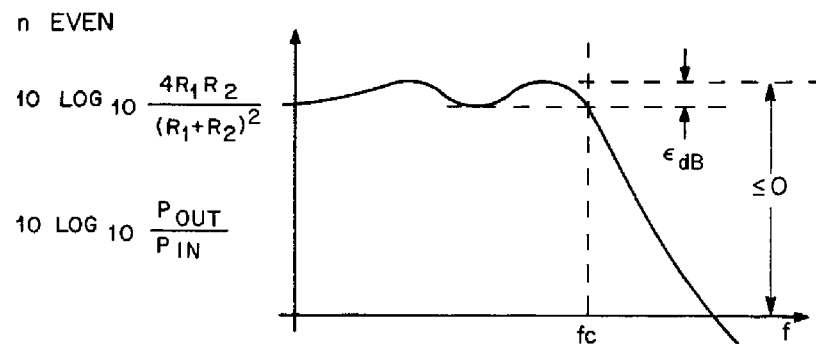
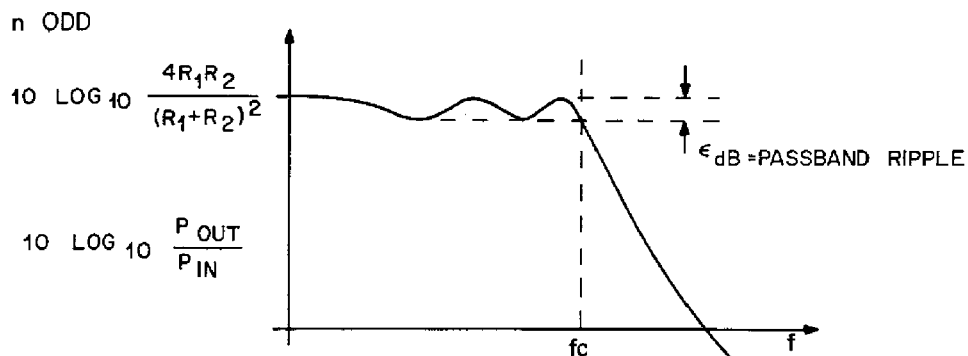
PART NO.
09100-71002

Tchebysheff FILTER DESIGN - FINITE TERMINATIONS

This program computes component values for Tchebysheff lowpass filters between equal or unequal finite terminations. The network designed is of the form:



The first element of the filter is a shunt C. The order (no. of poles) may be even or odd but if the order is even the mismatch loss between the terminating impedances must be equal to or greater than the ripple.



User specifies:

- Pass Band Ripple - ϵ_{dB} (dB)
- Corner ($-\epsilon_{dB}$) Frequency - f_c (Hz)
- Filter Order - n
- Load Resistance - R_2 (Ω)
- Generator Resistance - R_1 (Ω)

09100-71002

The equations used are:

$$C_1 = \frac{4 \sin \frac{\pi}{2n}}{(\xi - \eta) \omega_c R_1}$$

$$L_{K+1} = \frac{16 \left(\sin \frac{\pi(2K-1)}{2n} \right) \left(\sin \frac{\pi(2K+1)}{2n} \right)}{(\xi^2 + \eta^2 + 4 \sin^2 \frac{\pi K}{n} - 2 \xi \eta \cos \frac{\pi K}{n}) C_K \omega_c^2}$$

$$C_{K+1} = \frac{16 \left(\sin \frac{\pi(2K-1)}{2n} \right) \left(\sin \frac{\pi(2K+1)}{2n} \right)}{(\xi^2 + \eta^2 + 4 \sin^2 \frac{\pi K}{n} - 2 \xi \eta \cos \frac{\pi K}{n}) L_K \omega_c^2}$$

$$K = 1, 2, \dots, n$$

where $\xi = 2 \sinh \left\{ \frac{1}{n} \sinh^{-1} \frac{1}{\epsilon} \right\}$

$$\eta = 2 \sinh \left\{ \frac{1}{n} \ln \left(\frac{\sqrt{\epsilon^2 + 1 - A} + \sqrt{1 - A}}{\epsilon} \right) \right\}$$

$$\eta = \sqrt{10 \cdot 1\epsilon \text{ dB} - 1}$$

$$A = \frac{4R_1 R_2}{(R_1 + R_2)^2} \text{ (n odd)}$$

or

$$A = \frac{4R_1 R_2}{(R_1 + R_2)^2} \times 10 \cdot 1\epsilon \text{ dB (n even)}$$

NOTE: $A \leq 1$

In general, Tchebysheff filter designs with unequal terminations the solution will be non-unique. Filters designed by other methods may differ considerably from those formed by use of this program. This does not imply that either method is incorrect.

Reference: Network Analysis and Synthesis
by Louis Weinberg

McGraw-Hill 1962

EXAMPLES

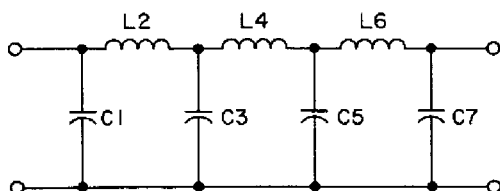
$$\epsilon_{dB} = .1 \text{ dB ripple}$$

$$f_c = 620 \text{ kHz}$$

$$n = 6 \text{ (Filter Order)}$$

$$R_2 = 600 \Omega \text{ (Load Impedance)}$$

$$R_1 = 135 \Omega \text{ (Generator Impedance)}$$



$$C_1 = .0117 \mu F$$

$$L_2 = 13.71 \mu H$$

$$C_3 = .0143 \mu F$$

$$L_4 = 12.94 \mu H$$

$$C_5 = .0113 \mu F$$

$$L_6 = 5.030 \mu H$$

USER INSTRUCTIONS

SET:

RADIANS

FLOATING

ENTER PROGRAM 1 (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0 — Z

0 — Y

1 — X

ENTER DATA: $\epsilon_{dB} \rightarrow Z$, $f_c \rightarrow Y$,
 $n \rightarrow X$

PRESS: CONTINUE

DISPLAY

0 — Z

0 — Y

2 — X

ENTER DATA: $R_2 \rightarrow Y$, $R_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

n — Z

1 — Y

 C_1 — X

ENTER PROGRAM 2 (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

n — Z

K — Y

 L_K — X

K EVEN

n — Z

K — Y

 C_K — X

K ODD

After $K = n$ the display clears. To solve another problem repeat user instructions.



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	IF $x < y$	52								
	1	3	03								
	2	b	14								
	3	↓	25	BRANCH HERE IF n IS EVEN							
	4	d	17	CALCULATE ATTEMPTED MAXIMUM POWER GAIN							
	5	x	36								
	6	1	01								
	7	IF $x > y$	53	STOP IF ATTEMPTED MAXIMUM POWER GAIN IS GREATER THAN 1							
	8	3	03								
	9	c	16								
	a	STOP	41	ATTEMPTED MAXIMUM POWER GAIN		POWER GAIN AT D.C.		ERROR STOP-ATTEMPTED MAXIMUM POWER GAIN CANNOT BE GREATER THAN 1 FOR PASSIVE FILTERS I.E., TOO LITTLE MISMATCH.			
	b	↓	25	BRANCH HERE IF n IS ODD							
	c	$y \rightarrow ()$	40	STORE MAXIMUM POWER GAIN							
	d	e	12								
4	0	d	17								
	1	↑	27								
	2	1	01								
	3	-	34								
	4	↓	25								
	5	$\sqrt{x}$	76								
	6	$x \rightarrow ()$	23								
	7	d	17								
	8	↑	27								
	9	x	36								
	a	1	01								
	b	↑	27								
	c	e	12	CALCULATE η							
	d	-	34								
5	0	↓	25								
	1	↑	27								
	2	$\sqrt{x}$	76								
	3	ROLL ↓	31								
	4	+	33								
	5	↓	25								
	6	$\sqrt{x}$	76								
	7	+	33								
	8	d	17								
	9	÷	35								
	a	↓	25								
	b	$\ln x$	65								
	c	↑	27								
	d	b	14								

Step	Key	Code	Display			Storage					
			<i>x</i>	<i>y</i>	<i>z</i>	<i>f</i>	<i>e</i>	<i>d</i>	<i>c</i>	<i>b</i>	<i>a</i>
6	0	÷	35								
	1	↓	25								
	2	hyper ▾	67								
	3	sin <i>x</i>	70								
	4	↑	27								
	5	2	02								
	6	×	36								
	7	<i>y</i> →()	40								
	8	<i>E</i>	12								
	9	1	01								
	0	↑	27								
	1	<i>d</i>	17								
	2	÷	35								
	3	↓	25								
7	0	arc ▾	72								
	1	hyper ▾	67								
	2	sin <i>x</i>	70								
	3	↑	27								
	4	<i>b</i>	14								
	5	÷	35								
	6	↓	25								
	7	hyper ▾	67								
	8	sin <i>x</i>	70								
	9	↑	27								
	0	2	02								
	1	×	36								
	2	<i>y</i> →()	40								
	3	<i>d</i>	17								
8	0	<i>c</i>	16								
	1	↑	27								
	2	2	02								
	3	×	36								
	4	π	56								
	5	×	36								
	6	<i>y</i> →()	40								
	7	<i>c</i>	16								
	8	↑	27								
	9	2	02								
	0	÷	35								
	1	<i>b</i>	14								
	2	÷	35								
	3	↓	25								

CALCULATE ξ CALCULATE ω_c

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	sin x	70								
1	↑	27									
2	d	17									
3	↑	27									
4	E	12									
5	—	34									
6	↓	25									
7	÷	35									
8	C	16									
9	÷	35									
a	F	15									
b	÷	35									
c	4	04									
d	X	36									
a	b	14									
1	↑	27									
2	1	01									
3	ROLL ↑	22									
4	X→()	23									
5	F	15									
6	CONTINUE	47									
7	END	46	C ₁	1	n	DISPLAY					
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

CALCULATE C₁

X 36 IN THIS STEP GIVES FILTER WITH L INPUT

RECALL n, DISPLAY 1, AND POSITION C₁

DISPLAY

HEWLETT-PACKARD

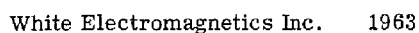
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	C	16								
1	↑	27									
2	X	36	CALCULATE ω_c^2								
3	y→()	40									
4	C	16									
5	1	01									
6	x→()	23									
7	B	13									
8	↑	27									
9	π	56									
	X	36									
	b	14									
	÷	35									
	↓	25									
1	0	↑	27								
	1	sin x	70								
	2	↑	27								
	3	X	36								
	4	4	04								
	5	X	36								
	6	ROLL ↑	22								
	7	cos x	73								
	8	x↔y	30								
	9	B	12								
	X	36									
	d	17	CALCULATE DENOMINATOR OF C_K (K ODD) OR L_K (K EVEN)								
	X	36									
	2	02									
2	0	X	36								
	1	↓	25								
	2	-	34								
	3	B	12								
	4	↑	27								
	5	X	36								
	6	↓	25								
	7	+	33								
	8	d	17								
	9	↑	27								
	X	36									
	b	↓	25								
	+	33									
	C	16									

FROM 7-7

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	X	36								
	1	F	15								
	2	X	36								
	3	1	01								
	4	6	06								
	5	÷	35								
	6	y→()	40								
	7	F	15								
	8	a	13								
	9	↑	27								
	a	b	14								
	b	÷	35								
	c	↑	27								
4	d	÷	35								
	0	÷	35								
	1	2	02								
	2	÷	35								
	3	↓	25								
	4	—	34								
	5	π	56								
	6	X	36								
	7	↓	25								
	8	sin x	70								
	9	↑	27								
	a	F	15								
	b	÷	35								
5	c	y→()	40								
	d	F	15								
	0	↓	25								
	1	1	01								
	2	↑	27								
	3	b	14								
	4	÷	35								
	5	2	02								
	6	÷	35								
	7	↓	25								
	8	+	33								
	9	π	56								
	a	X	36								
	b	↓	25								
	c	sin x	70								
	d	↑	27								

→ CALCULATE C_K OR L_K

[illegible]



USER INSTRUCTIONS

SET: ☐ RADIANS ☐ FLOATING ☐

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $n \rightarrow Z$, $R(\text{in ohms}) \rightarrow Y$,
 $f_c(\text{in hertz}) \rightarrow X$

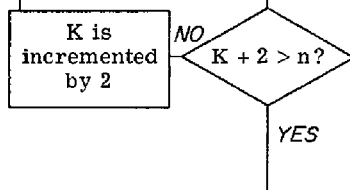
(K is initialized to 1)

PRESS: CONTINUE

DISPLAY

0	—	Z
C_K	—	Y
K	—	X

(C_K is in farads)



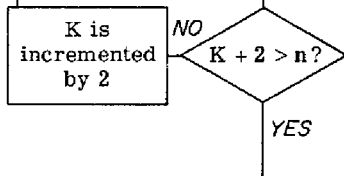
(K is initialized to 2)

PRESS: CONTINUE

DISPLAY

0	—	Z
L_K	—	Y
K	—	X

(L_K is in henries)

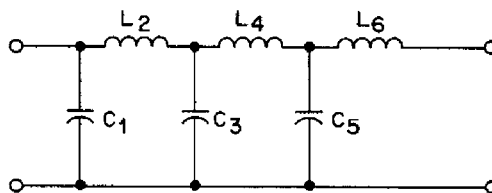


EXAMPLES

$$n = 6$$

$$R = 50 \, \Omega$$

$$f_c = 10 \, \text{mHz}$$



$$C_1 = 164.8 \, \text{pF}$$

$$C_3 = 614.9 \, \text{pF}$$

$$C_5 = 450.2 \, \text{pF}$$

$$L_2 = 1.125 \, \mu\text{H}$$

$$L_4 = 1.537 \, \mu\text{H}$$

$$L_6 = .412 \, \mu\text{H}$$

Step	Key	Code	Display			Storage					
			x	y	z	F	E	D	C	B	A
0	CLEAR	20									
1	STOP	41	f_c	R	n	ENTER n, R, f_c					
2	$x \rightarrow ()$	23									
3	C	16									
4	$y \rightarrow ()$	40									
5	b	14	STORE INPUT								
6	ROLL $\uparrow$	22									
7	$x \rightarrow ()$	23									
8	B	13									
9	CLEAR	20									
	1	01									
	$x \rightarrow ()$	23	INITIALIZE COUNTER FOR C'S								
	d	17									
	$\uparrow$	27									
1	0	02									
	X	36									
	1	01									
	-	34									
	π	56									
	X	36									
	2	02									
	$\div$	35									
	B	13	CALCULATE $\frac{\sin}{\pi f_c R} \left(\frac{(2K+1)\pi}{2n} \right)$								
	$\div$	35									
	$\downarrow$	25									
	sin x	70									
	$x \leftrightarrow y$	30									
	π	56									
2	$\div$	35									
	C	16									
	$\div$	35									
	b	14									
	$\div$	35									
	d	17	RECALL K								
	STOP	41	K	C_K	0	DISPLAY					
	$\uparrow$	27									
	2	02	INCREMENT K								
	+	33									
	B	13	RECALL n								
	IF $x < y$	52									
	3	03	BRANCH IF ALL C'S ARE CALCULATED								
	6	06									

HEWLETT-PACKARD
FROM 5-a

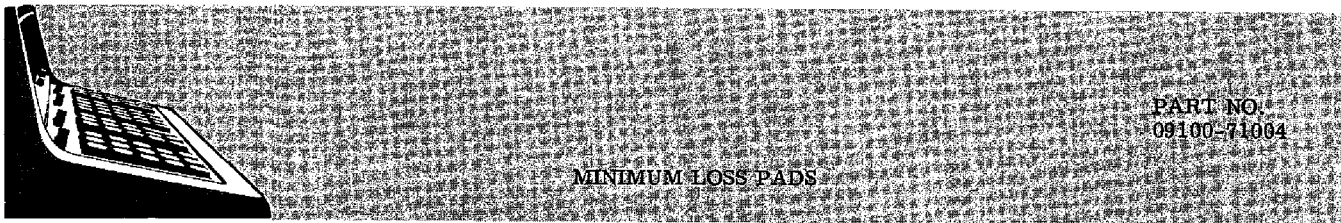
HEWLETT-PACKARD
FROM 3-5

HEWLETT-PACKARD

HEWLETT-PACKARD

[illegible]

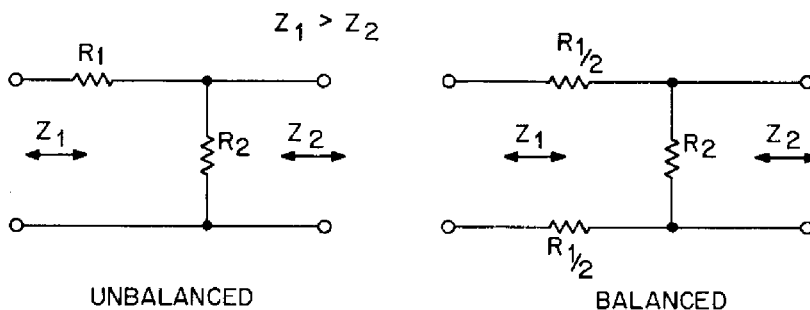
[illegible]



PART NO.
09100-71004

MINIMUM LOSS PADS

Given 2 impedances to be matched, program calculates resistive minimum loss pad and displays resistor values and loss in dB.



The equations used are:

$$R_1 = Z_1 \sqrt{1 - \frac{Z_2}{Z_1}}$$

$$R_2 = \frac{Z_2}{\sqrt{1 - \frac{Z_2}{Z_1}}}$$

$$A(\text{dB}) = \frac{20}{\ln 10} \operatorname{arccosh} \sqrt{\frac{Z_1}{Z_2}}$$

Reference: Reference Data for Radio Engineers, ITT
Fourth Edition 1963

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $Z_2 \rightarrow Y$, $Z_1 \rightarrow X$

$$\underline{\underline{Z_1 > Z_2}}$$

PRESS: CONTINUE

DISPLAY

A(dB) — Z

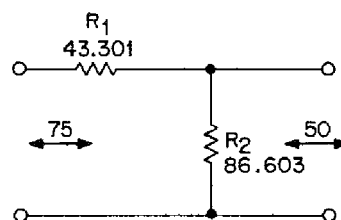
 R_2 — Y R_1 — X

EXAMPLES

$$Z_1 = 75 \Omega$$

$$Z_2 = 50 \Omega$$

UNBALANCED

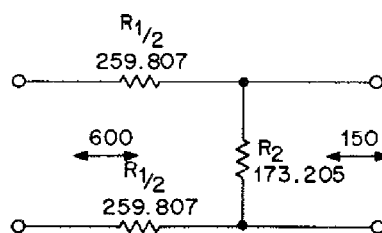


$$\text{Loss} = 5.719 \text{ dB}$$

$$Z_1 = 600$$

$$Z_2 = 150$$

BALANCED



$$\text{Loss} = 11.439 \text{ dB}$$

$$R_1 = 519.615$$

$$R_2 = 173.205$$

[illegible]

[illegible]

PART NO.
09100-71005

TCHEBYSHEFF EVALUATION

This program evaluates the response of a Tchebysheff filter. The programmed input-output routine is designed to facilitate the use of the program in determining the optimum filter for a given application.

User specifies:

Pass Band Ripple - ϵ_{dB} (dB)
 Corner ($-\epsilon_{dB}$) Frequency - f_c
 Frequency at which response is to be found - f_i } in any consistent units
 Filter Order - n

The equations are:

$$G(\Omega)_{dB} = \log_{10} \frac{1}{1 + \epsilon^2 T_n^2(\Omega)}$$

where $\Omega = \frac{f_i}{f_c}$

$G(\Omega)_{dB}$ = the attenuation in dB below the minimum attenuation

$$\epsilon^2 = 10^{\epsilon_{dB}/10} - 1$$

T_n is the Tchebysheff polynomial

$$T_n(\Omega) = \cos(n \cos^{-1}(\Omega)) \quad \Omega \leq 1$$

$$T_n(\Omega) = \cosh(n \cosh^{-1}(\Omega)) \quad \Omega \geq 1$$

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $f_c \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $f_i \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER DATA: $n \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
4	—	X

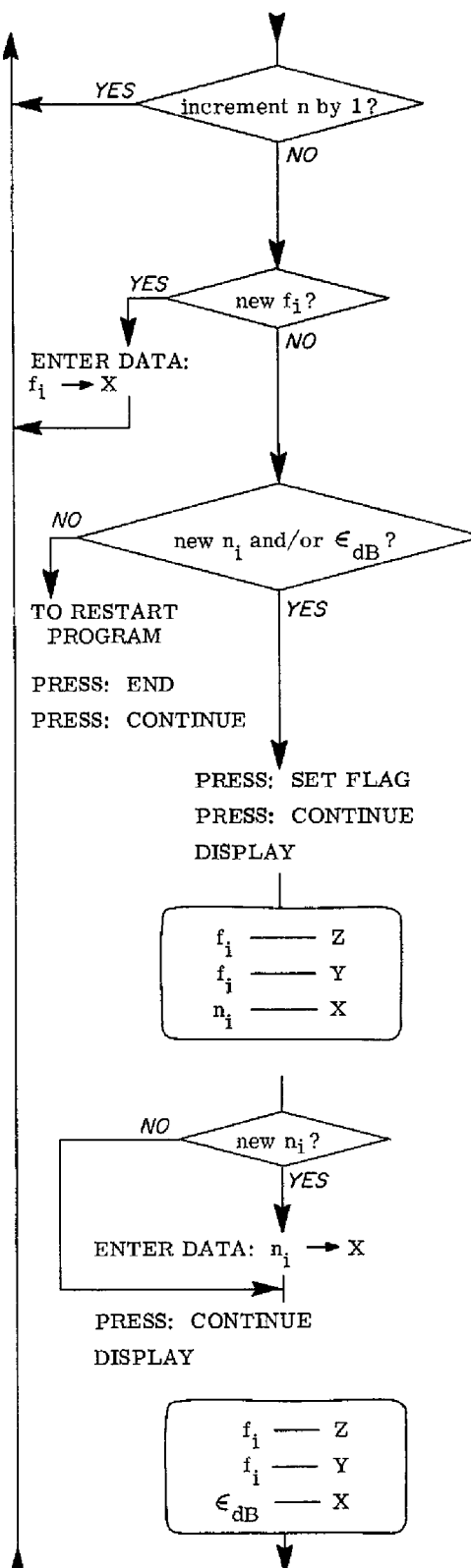
ENTER DATA: $\epsilon_{dB} \rightarrow X$

PRESS: CONTINUE

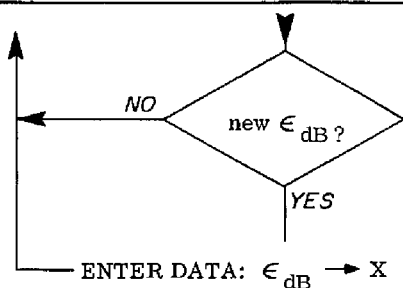
DISPLAY

f_i	—	Z
n_i	—	Y
A_{dB}	—	X

USER INSTRUCTIONS (Cont'd)



USER INSTRUCTIONS (Cont'd)



EXAMPLES

The following general filter requirements are known:

1. Filter cutoff frequency is 10 MHz
2. Minimum ripple is desired ($0 < \max \leq .1$ dB)
3. At 14 MHz amplitude attenuation of 15 dB is required
4. At 20 MHz 35 dB attenuation is required
5. Minimize components
6. Prefer matched terminations i.e., n odd

Initial design parameters are:

$$\begin{aligned} f_c &= 10 \text{ MHz} \\ f_i &= 20 \text{ MHz} \\ n &= 2 \\ \epsilon_{dB} &= .025 \text{ dB} \end{aligned}$$

Results are

$$A_{dB} = 1.1 \text{ dB}$$

thus increase n (increment n)

$$\begin{aligned} n &= 3 \\ A_{dB} &= 6.9 \text{ dB} \end{aligned}$$

increase n (increment n)

$$\begin{aligned} n &= 4 \\ A_{dB} &= 17.4 \text{ dB} \end{aligned}$$

increase n

$$\begin{aligned} n &= 5 \\ A_{dB} &= 28.8 \text{ dB} \end{aligned}$$

increase n

$$\begin{aligned} n &= 6 \\ A_{dB} &= 40.2 \text{ dB} \end{aligned}$$

EXAMPLES (Cont'd)

Because of matching preference, increase ϵ_{dB} and decrement n to 5.

$$\begin{aligned} n &= 5 \\ \epsilon_{dB} &= .05 \\ A_{dB} &= 31.8 \end{aligned}$$

further increase ϵ_{dB}

$$\begin{aligned} \epsilon_{dB} &= .08 \text{ dB} \\ A_{dB} &= 33.9 \text{ dB} \end{aligned}$$

further increase ϵ_{dB}

$$\begin{aligned} \epsilon_{dB} &= .1 \\ A_{dB} &= 34.8 \end{aligned}$$

try increasing n to 7 since want odd and decreasing ϵ_{dB}

$$\begin{aligned} n_1 &= 7 \\ \epsilon_{dB} &= .01 \\ A_{dB} &= 47.7 \text{ dB} \end{aligned}$$

$\epsilon_{dB} = .01$ is about the minimum ripple achievable so we check attenuation at 14 MHz.

$$\begin{aligned} f_i &= 14 \text{ MHz} \\ A_{dB} &= 20.4 \text{ dB} \end{aligned}$$

Thus the requirements are met. The element values may be found from program #09100-71001 Tchebysheff for Equal Terminations.



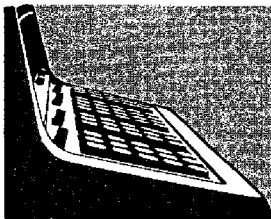
Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	3	03									
	2	$x \rightarrow ()$	23									
	3	f	15	STORE DISPLAY CONSTANTS								
	4	4	04									
	5	$x \rightarrow ()$	23									
	6	E	12									
	7	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
	8	STOP	41	f_c	0	0	ENTER f_c					
	9	$x \rightarrow ()$	23	STORE f_c								
a	d	17										
b	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY									
c	STOP	41	f_i	0	0	ENTER f_i						
d	$x \rightarrow ()$	23	STORE f_i									
1	0	C	16									
	1	↑	27									
	2	d	17	CALCULATE $\frac{f_i}{f_c}$								
	3	÷	35									
	4	$y \rightarrow ()$	40									
	5	b	14									
	6	↓	25	RECALL AND DISPLAY 3 TO INDICATE THIRD ENTRY								
	7	f	15	n	0	0	ENTER n					
	8	STOP	41	n	f_i	f_i	DISPLAY					
	9	$x \rightarrow ()$	23	STORE n								
a	f	15										
b	E	12	RECALL AND DISPLAY 4 TO INDICATE FOURTH ENTRY									
c	STOP	41	ϵ_{dB}	0	0	ENTER ϵ_{dB}						
d	$x \rightarrow ()$	23	ϵ_{dB}	f_i	f_i	DISPLAY						
			STORE ϵ_{dB}									
2	0	E	12									
	1	1	01									
	2	0	00									
	3	↑	27									
	4	$\ln x$	65									
	5	$x \rightarrow y$	30									
	6	÷	35									
	7	E	12	CALCULATE ϵ^2								
	8	x	36									
	9	↓	25									
a	e^x	74										
b	↑	27										
c	1	01										
d	-	34										

FROM 6-8

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	y→()	40								
	1	a	13								
	2	b	14								
	3	↑	27								
	4	1	01								
	5	IF x>y	53								
	6	4	04	BRANCH DEPENDING ON Ω							
	7	7	07								
	8	b	14								
	9	arc ▽	72								
	a	hyper ▽	67								
	b	cos x	73								
	c	↑	27								
	d	f	15								
4	0	x	36	CALCULATE $T_n(\Omega)$ $\Omega \geq 1$							
	1	↓	25								
	2	hyper ▽	67								
	3	cos x	73								
	4	GO TO () ()	44								
	5	5	05								
	6	1	01								
	7	↓	25								
	8	arc ▽	72								
	9	cos x	73								
	a	↑	27	CALCULATE $T_n(\Omega)$ $\Omega < 1$							
	b	f	15								
	c	x	36								
	d	↓	25								
5	0	cos x	73								
	1	↑	27								
	2	x	36								
	3	a	13								
	4	x	36								
	5	1	01								
	6	+	33								
	7	↓	25								
	8	log x	75	CALCULATE A_{dB}							
	9	↑	27								
	a	1	01								
	b	0	00								
	c	x	36								
	d	y→()	40								

FROM 7-9 & 8-4

[illegible]

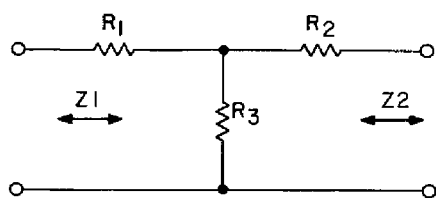


PART NO.
09100-71006

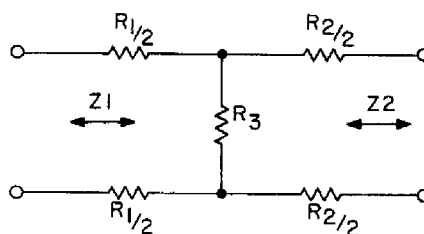
ATTENUATOR PADS T OR Π

Given input and output impedances and attenuation desired, program calculates resistor values for either T or Π pads.

'T' OR 'H' PAD



UNBALANCED



BALANCED

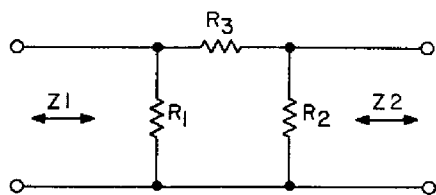
$$\theta = \frac{A(\text{dB})}{20} \ln 10$$

$$R_3 = \frac{\sqrt{Z_1 Z_2}}{\sinh \theta}$$

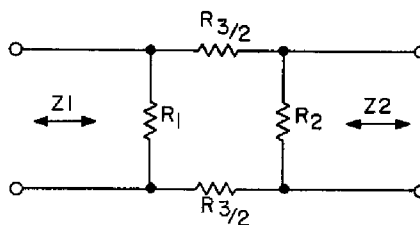
$$R_2 = \frac{Z_2}{\tanh \theta} - R_3$$

$$R_1 = \frac{Z_1}{\tanh \theta} - R_3$$

'Π' OR 'O' PAD



UNBALANCED



BALANCED

$$R_3 = \sqrt{Z_1 Z_2} \sinh \theta$$

$$R_2 = \frac{R_3 Z_2 \tanh \theta}{R_3 - Z_2 \tanh \theta}$$

$$R_1 = \frac{R_3 Z_1 \tanh \theta}{R_3 - Z_1 \tanh \theta}$$

Reference: Reference Data for Radio Engineer, ITT

4th Edition 1963

USER INSTRUCTIONS

SET: ☐ FIXED

ENTER PROGRAM (Starting address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $Z_1 \rightarrow Z$, $Z_2 \rightarrow Y$, $A_{dB} \rightarrow X$ YES Π PAD?

PRESS: SET FLAG

NO

PRESS: CONTINUE

DISPLAY

R_3	—	Z
R_2	—	Y
R_1	—	X

PRESS: CONTINUE

DISPLAY

Z_1	—	Z
Z_2	—	Y
A_{dB}	—	X

ENTER NEW VALUES OF A_{dB} , Z_1 and/or Z_2 AS BEFORE

PRESS: CONTINUE

DISPLAY NEW VALUES OF R_1 , R_2 and R_3

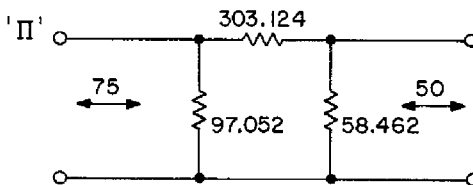
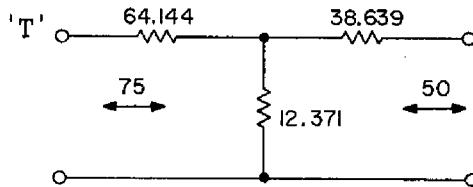
NOTE: If SET FLAG is pressed, program continues Π calculation. To change from Π program back to T program, press IF FLAG after entering new data, then press CONTINUE. Thus the selection of Π or T pads needs to be made only once at entry point.

EXAMPLES

Input impedance 75 Ω Output impedance 50 Ω

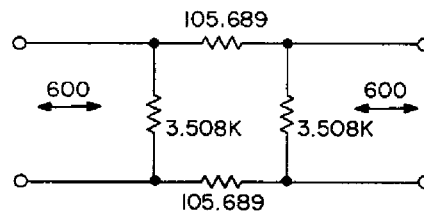
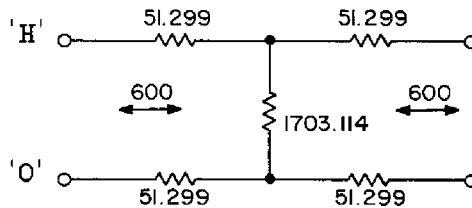
Attenuation 20 dB

UNBALANCED

Input and output impedance 600 Ω

Attenuation 3 dB

BALANCED



$R_1 = 102.598$	$R_1 = 3508.826$
$R_2 = 102.598$	$R_2 = 3508.826$
$R_3 = 1703.114$	$R_3 = 211.378$

All units are in ohms

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	$x \leftrightarrow y$	30								
1	$\div$	35	CALCULATE R_2								
2	$\downarrow$	25									
3	$x \leftrightarrow y$	30									
4	$-$	34									
5	d	17									
6	STOP	41	R_1	R_2	R_3	DISPLAY					
7	a	13									
8	$\uparrow$	27									
9	b	14	RECALL AND POSITION INPUT								
a	$\uparrow$	27									
b	c	16									
c	GOTO() ()	44									
d	0	00	RETURN TO INITIAL ENTRY								
4	0	1	01								
1	$\times$	36	BRANCH TO THIS POSITION FOR II PAD, CALCULATE R_3								
2	a	13									
3	ROLL $\uparrow$	22									
4	hyper $\downarrow$	67									
5	$\tan x$	71									
6	$\times$	36									
7	ROLL $\uparrow$	22									
8	ACC $+$	60									
9	$\downarrow$	25	CALCULATE R_1								
a	f	15									
b	$\times$	36									
c	ROLL $\uparrow$	22									
d	$-$	34									
5	0	$\downarrow$	25								
1	$\div$	35									
2	$y \rightarrow ()$	40									
3	d	17									
4	b	14									
5	$\uparrow$	27									
6	e	12									
7	$\times$	36									
8	$\uparrow$	27									
9	$\downarrow$	25	CALCULATE R_2								
a	f	15									
b	$\times$	36									
c	ROLL $\uparrow$	22									
d	$-$	34									

[02] HEWLETT-PACKARD

[02] HEWLETT-PACKARD

[02] HEWLETT-PACKARD

[02] HEWLETT-PACKARD

[02] HEWLETT-PACKARD

FROM 6-b

FROM 1-c

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	↓	25								
	1	÷	35								
	2	d	17								
	3	↑	27								
	4	f	15								
	5	ROLL ↓	31								
	6	STOP	41	R ₁	R ₂	R ₃	DISPLAY				
	7	CLEAR	20								
	8	SET FLAG	54								
	9	GO TO () ()	44								
	a	3	03								
	b	7	07								
	c	END	46								
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

POSITION DISPLAY

SET FLAG AND BRANCH FOR ANOTHER II PAD

[illegible]

$$0 < \frac{X_a}{4X_b} \quad (40 \log_{10} e) \left(\sinh^{-1} \sqrt{\frac{X_a}{4X_b}} \right)$$

(Attenuation in dB)

$$-1 < \frac{X_a}{4X_b} < 0$$

0

$$\frac{X_a}{4X_b} < -1 \quad (40 \log_{10} e) \left(\cosh^{-1} \sqrt{-\frac{X_a}{4X_b}} \right)$$

USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

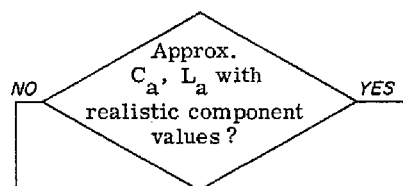
0	—	Z
0	—	Y
0	—	X

ENTER DATA: $R \rightarrow Z$, $f_2 \rightarrow Y$, $f_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

C_a	—	Z
L_a	—	Y
1	—	X



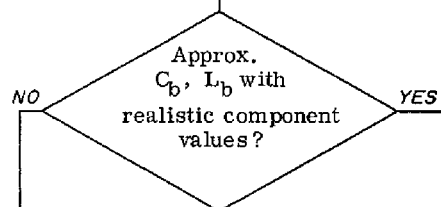
PRESS: CONTINUE



USER INSTRUCTIONS (con't)

DISPLAY

C_b	—	Z
L_b	—	Y
2	—	X



Enter approxima-
tions: $C_{b0} \rightarrow Z$,
 $L_{b0} \rightarrow Y$, $0 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

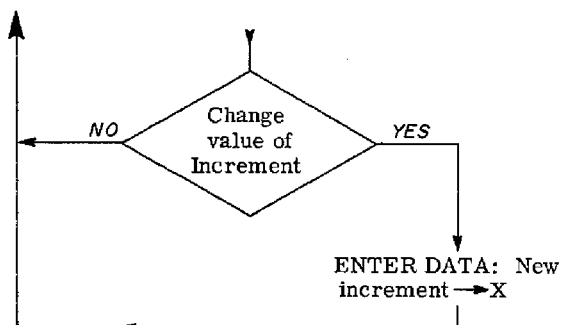
ENTER DATA: $F_L \rightarrow Z$, $F_U \rightarrow Y$,Increment $\rightarrow X$

PRESS: CONTINUE

DISPLAY

A_{db}	—	Z
f	—	Y
Increment	—	X

USER INSTRUCTIONS (con't)



Note (1): When the frequency being used is incremented enough to exceed the value of F_H entered, the calculator will return to the initial display.

Note (2): Substitution of "Pause" instead of "Stop" in step 9 - 0 will provide continuous incrementing and attenuation evaluation without use of "continue" key.

EXAMPLE

SET: digit dial to 8

SET: FIXED POINT

(A) $R = 50$
 $f_2 = 3000$
 $f_1 = 300$

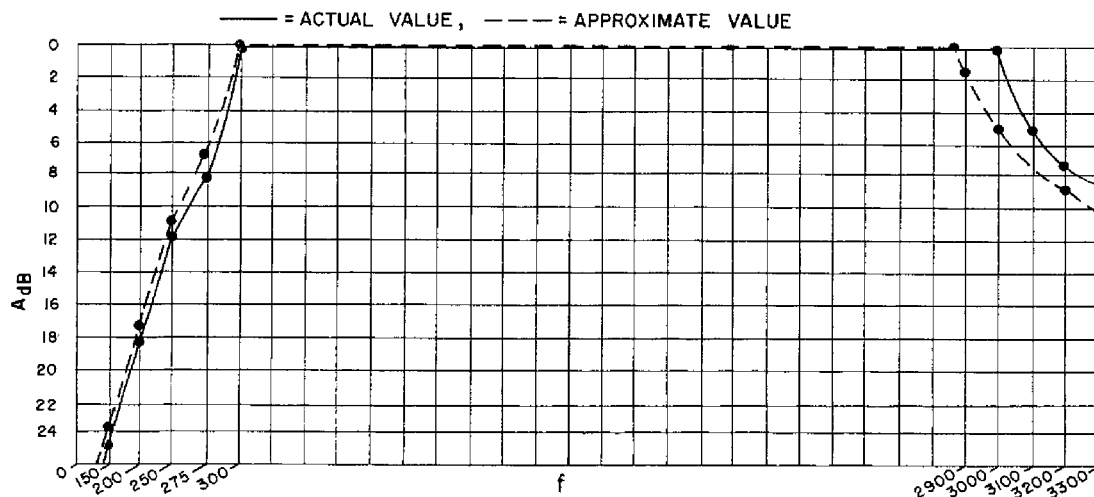
Results: $L_a = 5.89 \text{ mh}$
 $C_a = 4.77 \mu\text{f}$
 $L_b = 11.94 \text{ mh}$
 $C_b = 2.36 \mu\text{f}$

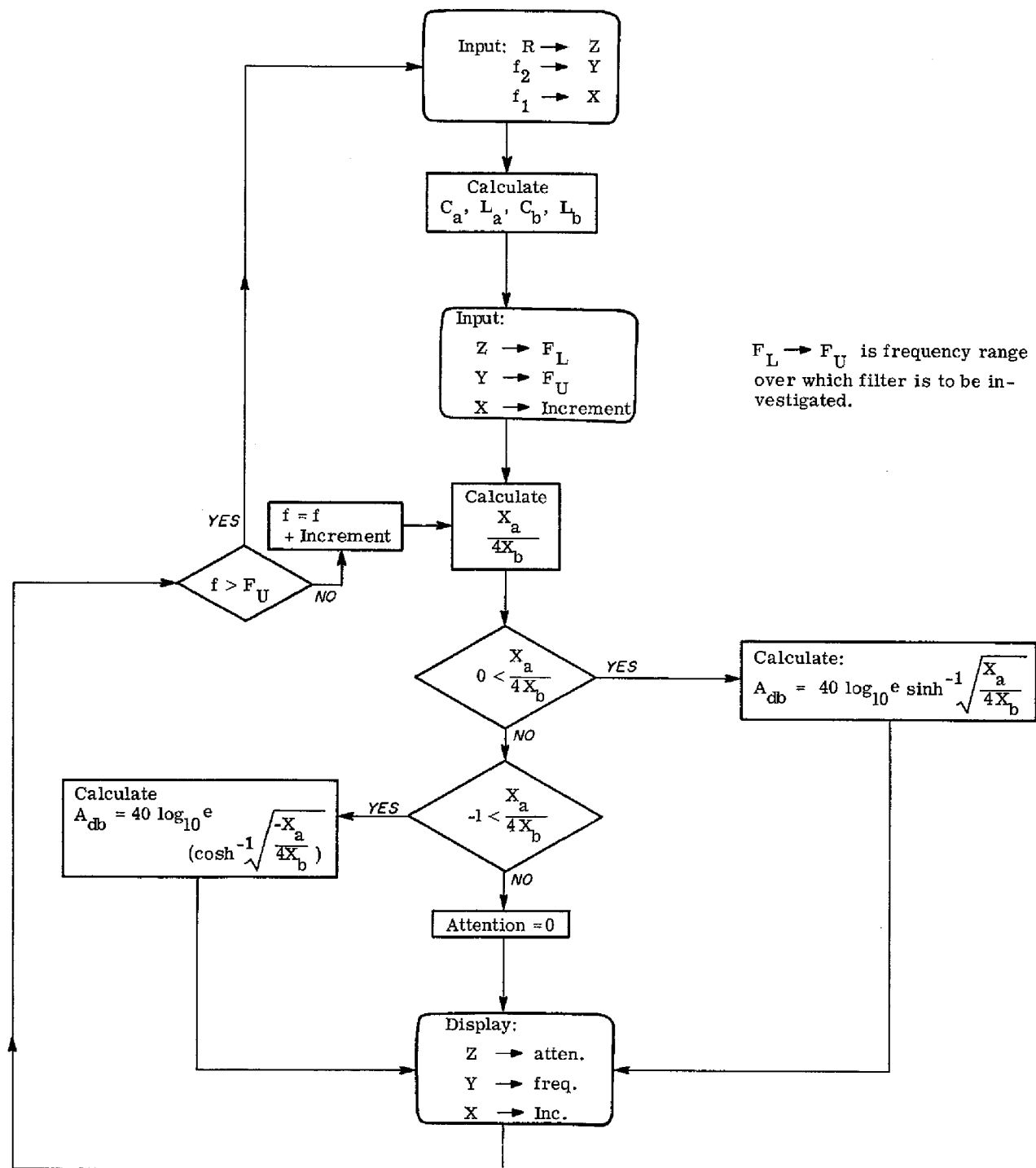
ENTER DATA: $F_U = 3500$, $F_L = 150$
 Increment

(B) Reset problem - use same values as part (A)

After displaying L_a and C_a set in approximate values of; $C_a = 5 \text{ f}$, $L_a = 6 \text{ mh}$
 (realistic component values)

After displaying L_b and C_b set in approximate values of; $L_b = 12 \text{ mh}$, $C_b = 2.5 \text{ f}$
 (realistic component values)





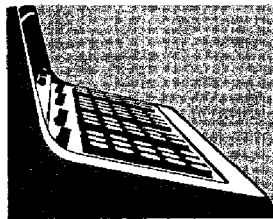
[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	ROLL ↑	22								
	1	÷	35								
	2	d	17								
	3	X	36								
	4	2	02								
	5	STOP	41	2	L _b	C _b	DISPLAY				
	6	ROLL ↓	31								
	7	X	36	CALCULATE AND STORE C _b L _b							
	8	y _z ()	24								
	9	a	13								
	a	X	36								
	b	4	04								
	c	X	36	CALCULATE AND STORE 4C _d L _b							
	d	y _z ()	40								
4	0	b	14								
	1	CLEAR	20								
	2	3	03								
	3	STOP	41	INCREMENT	F _u	F _L	ENTER F _L , F _u , INCREMENT				
	4	ACC +	60								
	5	ROLL ↓	31								
	6	2	02								
	7	X	36								
	8	π	56								
	9	X	36								
	a	↓	25								
	b	↑	27								
	c	X	36								
	d	y _z ()	40								
5	0	d	17								
	1	c	16								
	2	X	36								
	3	1	01								
	4	-	34	CALCULATE $\frac{x_a}{4x_b}$							
	5	b	14								
	6	÷	35								
	7	d	17								
	8	÷	35								
	9	↑	27								
	a	a	13								
	b	X	36								
	c	1	01								
	d	x _z y	30								

FROM 9-7

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	—	34								
	1	ROLL ↓	31								
	2	X	36								
	3	CLEAR X	37								
	4	IF x < y	52								
	5	7	07								
	6	7	07								
	7	1	01								
	8	CHG SIGN	32								
	9	IF x < y	52								
7	a	8	10	IF $-1 < \frac{X_a}{4X_b} < 0$, ENTER 0 FOR A _{dB} AT 8-4							
	b	4	04								
	c	ROLL ↓	31								
	d	CHG SIGN	32								
	0	√x	76	CALCULATE $\cosh^{-1} \sqrt{\frac{-X_a}{4X_b}}$							
	1	arc ∇	72								
	2	hyper ∇	67								
	3	cos x	73								
	4	GO TO () ()	44								
	5	7	07								
8	6	C	16								
	7	x ² y	30	CALCULATE $\sinh^{-1} \sqrt{\frac{X_a}{4X_b}}$							
	8	√x	76								
	9	arc ∇	72								
	a	hyper ∇	67								
	b	sin x	70								
	c	↑	27								
	d	1	01								
	0	e ^x	74	CALCULATE A _{dB} FOR $\frac{X_a}{4X_b} > 0$ OR $\frac{X_a}{4X_b} < -1$							
	1	log x	75								
9	2	X	36								
	3	4	04								
	4	0	00								
	5	X	36								
	6	d	17								
	7	√x	76								
	8	↑	27								
	9	2	02	CALCULATE f FOR EACH ATTENUATION AND RECALL INCREMENT							
	a	÷	35								
	b	π	56								
10	c	÷	35								
	d	F	15								

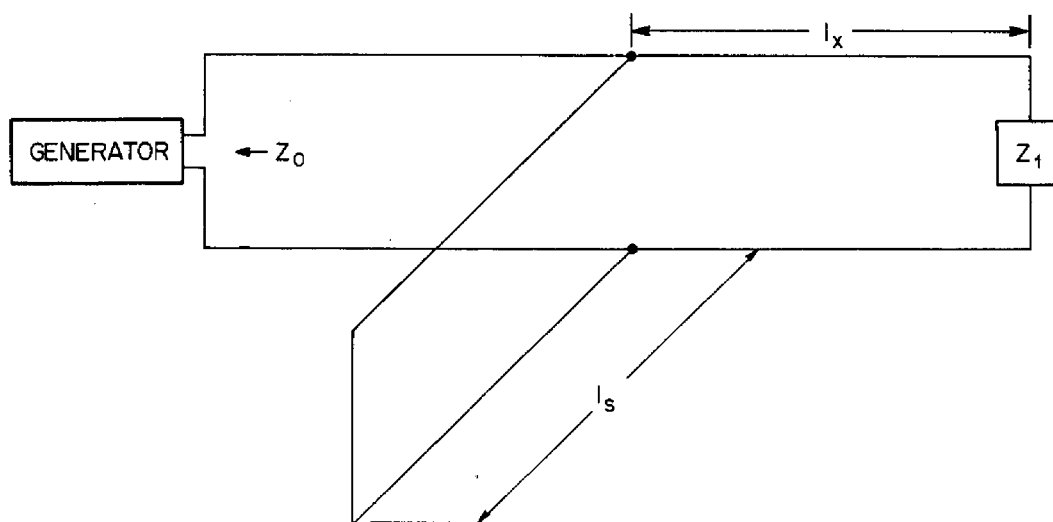
[illegible]



PART NO.
09100-71008

STUB MATCHED TRANSMISSION LINE

This program solves for l_x , the distance from the load to the point where $Y_{in}/Y_o = 1 + jb_{in}/Y_o$ in wavelengths and meters and for l_s , the length of a shorted stub to match the line in wavelengths and meters.



The equations used are:

$$\frac{Y_{in}}{Y_o} = \frac{\frac{g_1}{Y_o} + j \left(\frac{b_1}{Y_o} + \tan \beta l \right)}{1 - \frac{b_1}{Y_o} \tan \beta l + j \frac{g_1}{Y_o} \tan \beta l}$$

The iteration technique solves for:

$$\frac{Y_{in}}{Y_o} = 1 + j \frac{b_{in}}{Y_o}$$

The length of the shorted stub in:

$$l_s = \left(.25 - \frac{\tan^{-1} \frac{b_{in}}{Y_o}}{360} \right)$$

Reference: Microwave Theory and Measurements
Hewlett-Packard Microwave Division
Prentice-Hall, Inc., 1962

USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

1	—	Z
0	—	Y
0	—	X

ENTER DATA: $Z_0 \rightarrow Z$, $X_L \rightarrow Y$, $R_L \rightarrow X$

PRESS: CONTINUE

Note: Program pauses at each iteration, stops when completed.

DISPLAY

l_x	—	Z
b_{in}	—	Y
g_{in}	—	X

(In Wavelengths)

PRESS: CONTINUE

DISPLAY

2	—	Z
l_s	—	Y
l_x	—	X

(X contains distance from load in wavelengths)
(Y contains lengths of shorted stub in wavelengths)ENTER DATA: Frequency (f) $\rightarrow$ Y, Propagation
Constant (k) $\rightarrow$ X (k = 1 for air)

PRESS: CONTINUE

DISPLAY

3	—	Z
l_s	—	Y
l_x	—	X

(In meters)

USER INSTRUCTIONS (con't)

(X contains the distance from load in meters, Y contains the length of shorted stub in meters)

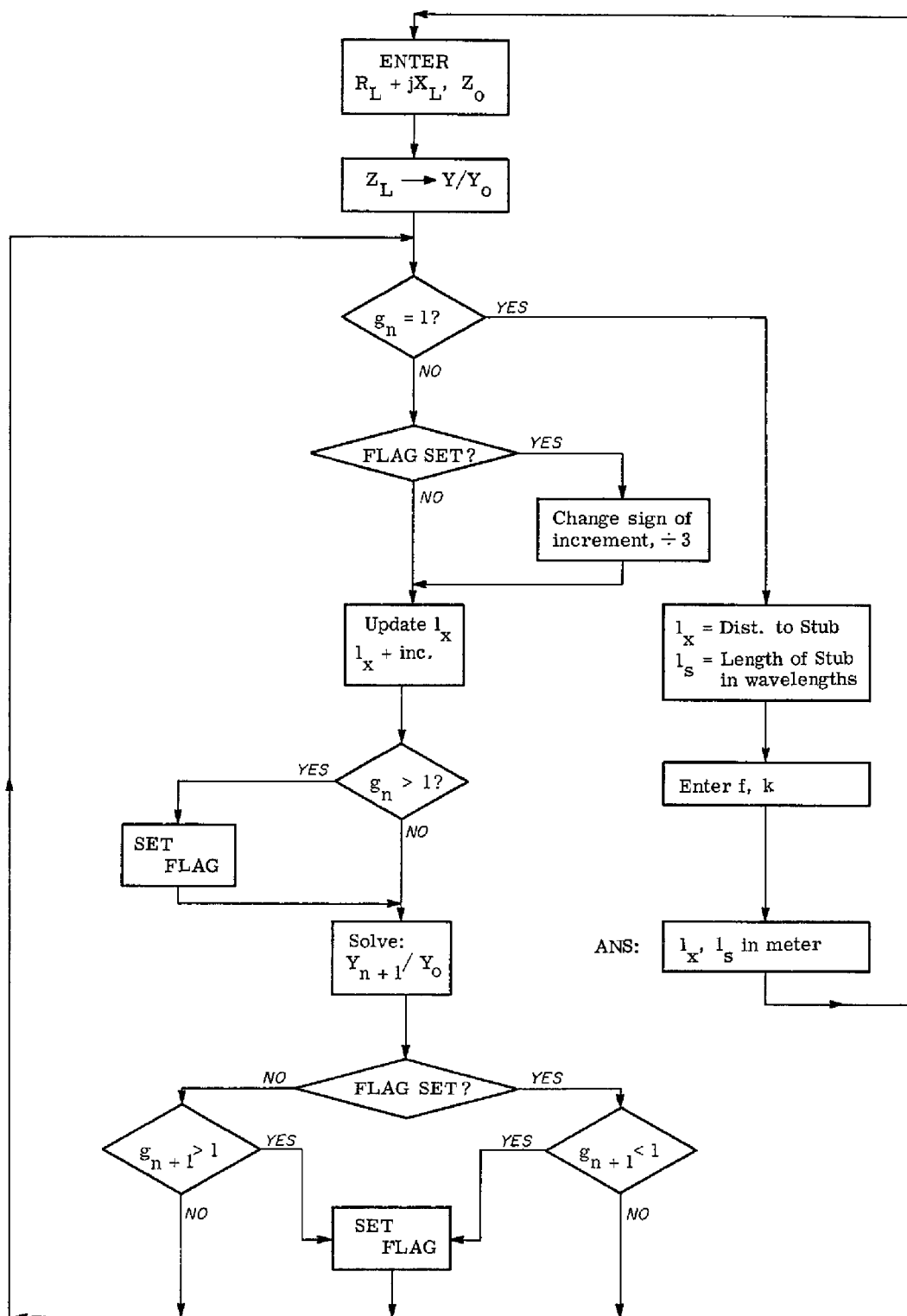
PRESS: CONTINUE to enter new problem

EXAMPLE

 $Z_0 = 50 \Omega$ $k = 1.000$
 $X_L = 25 \Omega$ $f = 1 \times 10^6$
 $R_L = 50 \Omega$
 $g_{in} = 1.000$ METERS
 $b_{in} = .500$ $l_x = 74.944$
 $l_s = 52.823$

WAVELENGTHS

 $l_x = .250$
 $l_s = .176$





Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20									
1	$x \rightarrow ()$	23									
2	$\square$	16									
3	$\cdot$	21									
4	2	02									
5	$x \rightarrow ()$	23									
6	d	17									
7	1	01									
8	ROLL $\downarrow$	31									
9	STOP	41	R_L	X_L	$Z_0(1)$	ENTER Z_0, X_L, R_L					
a	TO POLAR	62									
b	$\ln x$	65									
c	ACC $-$	63									
d	RCL	61									
1	0 ACC $-$	63	CONVERT Z TO Y								
1	e^x	74									
2	ROLL $\uparrow$	22									
3	$\times$	36									
4	$\downarrow$	25									
5	TO RECT	66									
6	ACC $+$	60									
7	RCL	61									
8	$\uparrow$	27									
9	$ y $	55									
a	ENTER EXP	26									
b	8	10									
c	$\times$	36	ROUND g_n TO 8 SIGNIFICANT DIGITS								
d	$x \rightarrow y$	30									
2	0 $\text{int } x$	64									
1	$x \rightarrow y$	30									
2	$\div$	35									
3	1	01									
4	IF $x=y$	50									
5	7	07	BRANCH IF ITERATION COMPLETED								
6	d	17									
7	d	17									
8	$\uparrow$	27									
9	IF FLAG	43									
a	SET FLAG	54									
b	3	03	CHANGE INCREMENT ($\div 3$, CHANGE SIGN IF CROSSOVER OCCURED)								
c	IF FLAG	43									
d	CHG SIGN	32									

HEWLETT-PACKARD
FROM 6-2

HEWLETT-PACKARD

HEWLETT-PACKARD
FROM 7-4, 7-8, 7-c

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	÷	35								
	1	y→()	40								
	2	d	17								
	3	C	16								
	4	+	33								
	5	y→()	40								
	6	C	16								
	7	1	01								
	8	ROLL ↑	22								
	9	IF x>y	53								
	a	SET FLAG	54								
	b	SET FLAG	54								
	c	d	17								
	d	↑	27								
4	0	3	03								
	1	6	06								
	2	0	00								
	3	x	36								
	4	↓	25								
	5	tan x	71								
	6	↑	27								
	7	E	12								
	8	y→()	40								
	9	E	12								
	a	↑	27								
	b	ROLL ↑	22								
	c	+	33								
	d	F	15								
5	0	TO POLAR	62								
	1	ln x	65								
	2	y↔()	24								
	3	E	12								
	4	x↔y	30								
	5	y↔()	24								
	6	F	15								
	7	x	36								
	8	ROLL ↑	22								
	9	CHG SIGN	32								
	a	x	36								
	b	1	01								
	c	+	33								

UPDATE λ_x

$$\text{SOLVE } \frac{Y}{Y_0} = \frac{\frac{g_1}{Y_0} + j \frac{b_1}{Y_0} + \text{TAN } \lambda_x}{(1 - \frac{b_1}{Y_0} \text{TAN } \lambda_x) + j \frac{g_1}{Y_0} \text{TAN } \lambda_x}$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	ROLL ↓	31								
	1	TO POLAR	62								
	2	ln x	65								
	3	ACC —	63								
	4	RCL	61								
	5	ACC —	63								
	6	e^x	74								
	7	TO RECT	66								
	8	ACC +	60								
	9	PAUSE	57	g_{n+1}	b_{n+1}	l_{n+1}	DISPLAY IN WAVELENGTHS				
	a	$x \div y$	30								
	b	1	01								
	c	y	55								
	d	IF FLAG	43								
7	0	7	07								
	1	6	06								
	2	IF $x > y$	53								
	3	1	01								
	4	7	07								
	5	SET FLAG	54								
	6	IF $x < y$	52								
	7	1	01								
	8	7	07								
	9	SET FLAG	54								
	a	GO TO () ()	44								
	b	1	01								
	c	7	07								
	d	C	16								
8	0	ROLL ↓	31								
	1	RCL	61								
	2	ACC —	63								
	3	STOP	41	$g_{in}=1$	b_{in}	l_x	ANSWER: Y_{in} AT l_x WAVELENGTHS FROM LOAD				
	4	↓	25								
	5	arc v	72								
	6	$\tan x$	71								
	7	↑	27								
	8	3	03								
	9	6	06	CONVERT FROM WAVELENGTHS TO METERS							
	a	0	00	FIND LENGTH OF STUB $l_s = (.25 - \frac{\tan^{-1} Y_0}{360})$							
	b	÷	35								
	c	.	21								
	d	2	02								

HEWLETT-PACKARD

HEWLETT-PACKARD

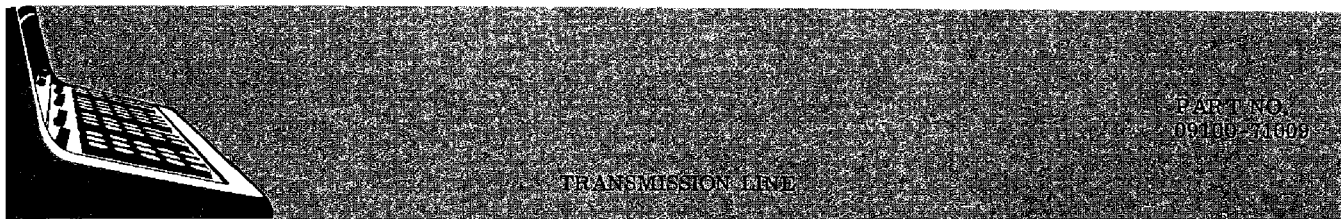
HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

FROM 2-6

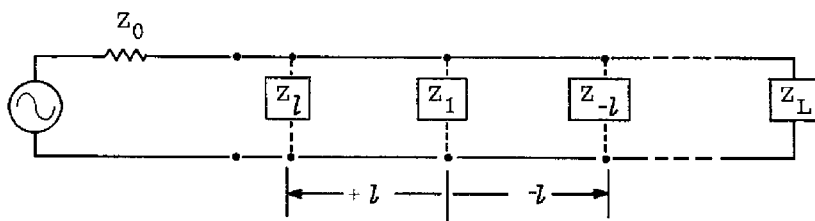
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	5	05								
	1	$x \leftrightarrow y$	30								
	2	—	34								
	3	2	02								
	4	ROLL ↓	31								
	5	$x \leftrightarrow y$	30								
	6	ACC +	60								
	7	STOP	41	I_x	I_s	2	ANSWER: DISTANCE TO STUB IN X, LENGTH OF SHORTED MATCHING STUB IN Y				
	8	÷	35	k	f	0					
	9	2	02				ENTER: FREQUENCY(f) IN Y PROP. CONSTANT(k) IN X				
	a	9	11								
	b	9	11								
	c	7	07								
	d	7	07								
a	0	6	06								
	1	ENTER EXP	26								
	2	8	10								
	3	$x \leftrightarrow y$	30	CONVERT FROM WAVELENGTHS TO METERS							
	4	÷	35								
	5	E	12								
	6	$x \leftrightarrow y$	30								
	7	X	36								
	8	↑	27								
	9	f	15								
	a	X	36								
	b	3	03								
	c	ROLL ↓	31								
	d	STOP	41	I_x (meters)	I_s (meters)	3	ANSWER: DISTANCE TO STUB IN X, LENGTH OF STUB IN Y				
b	0	GO TO ()	44								
	1	0	00								
	2	0	00								
	3	END	46								
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										



PART NO.
09100-21000

TRANSMISSION LINE

Given the characteristic line impedance, generator frequency, measured impedance at some point on the line and propagation constant, the program solves for the impedance at any other point on the line either toward the generator or toward the load, the voltage reflection coefficient (magnitude and phase) at the point where impedance is determined, and the VSWR on the line.



Given: Characteristic impedance (Z_0) of the line
 Frequency (f)
 Propagation constant (k) ($k = 1$ for air)
 Measured impedance (Z_1) at some point on the line

The Lossless Equations used are:

$$Z_l = Z_0 \frac{Z_1 + jZ_0 \tan \beta l}{Z_0 + jZ_1 \tan \beta l}$$

$$\text{where: } \beta = \frac{2\pi}{\lambda} = \frac{2\pi f}{ck}$$

c = velocity of light

$$Z_1 = R_1 + jX_1$$

NOTE: $+l$ implies toward the generator
 $-l$ implies toward the load

For the case: $\tan \beta l = \infty$, i.e., $\beta l = \pi \left(\frac{2N-1}{2} \right)$ where $N = 0, \pm 1, \pm 2 \dots$;

$$\text{Then } Z_l = \frac{Z_0^2}{Z_1}$$

The reflection coefficient is:

$$\rho_v = \frac{Z_l - Z_0}{Z_l + Z_0} = |\rho_v| e^{j\theta_{\rho_v}}$$

$$\text{VSWR} = \frac{1 + |\rho_v|}{1 - |\rho_v|}$$

Reference: Microwave Theory and Measurements, Hewlett-Packard Microwave Division
 Prentice-Hall, Inc. 1962

USER INSTRUCTIONS

SET:	DEGREES	
------	---------	--

ENTER PROGRAM: (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $Z_0 \rightarrow Z$, $f \rightarrow Y$, $k \rightarrow X$

PRESS: CONTINUE

DISPLAY

1	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $X_1 \rightarrow Y, R_1 \rightarrow X (Z_1 = R_1 + jX_1)$

PRESS: CONTINUE

DISPLAY

2	_____	Z
0	_____	Y
0	_____	X

(1) ENTER DATA: $l \rightarrow X$ ($+l \rightarrow$ Generator
 $-l \rightarrow$ Load)

l in meters?

YES

PRESS: SET FLAG

PRESS: CONTINUE

PRESS: CONTINUE

(2)

USER INSTRUCTIONS (C on't)

DISP LAY

(2)

3	_____	Z
X _l	_____	Y
R _l	_____	X

$$Z_L = R_L + jX_L$$

PRESS: CONTINUE

DISPLAY

4	_____	Z
θ_{p_v}	_____	Y
$ p_v $	_____	X

PRESS: CONTINUE

FINAL DISPLAY

5	_____	Z
0	_____	Y
VSWR	_____	X

PRESS: CONTINUE to enter new
X₁, R₁, or *l*.

EXAMPLE

$$Z_s = 50 \text{ ohms}$$
$$f^0 = 1 \times 10^6 \text{ hertz}$$
$$k = 1$$
$$\left. \begin{array}{l} X_1 = 50 \\ R = 50 \end{array} \right\} \text{where } Z_1 = R_1 + jX_1$$
$$R_1 = 50 \text{ J}$$
$$l = 1.75$$

In Wavelengths	In Meters
$X_L = -25.000$	51.757
$R_L = 25.000$	53.876
$\theta_p = -116.565$	59.232
$ \rho_v = .447$	.447
VSWR= 2.618	2.618

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	$x \rightarrow ()$	23									
2	b	14									
3	$x \rightarrow ()$	23									
4	a	13									
5	STOP	41	k	f	Z_0	ENTER Z_0, f, k					
6	$\div$	35									
7	2	02									
8	9	11									
9	9	11									
10	7	07									
11	7	07									
12	6	06									
13	ENTER EXP	26									
1	0	10									
2	$\div$	35									
3	$y \rightarrow ()$	40									
4	$\square$	16									
5	ROLL $\uparrow$	22									
6	$x \rightarrow ()$	23									
7	d	17									
8	1	01									
9	$\uparrow$	27									
10	a	13									
11	$\uparrow$	27									
12	b	14									
13	STOP	41	R_1	X_1	1	ENTER X_1, R_1					
14	$x \rightarrow ()$	23									
2	0	14									
1	$y \rightarrow ()$	40									
2	a	13									
3	2	02									
4	ROLL $\downarrow$	31									
5	RCL	61									
6	STOP	41	± 1	0	2	ENTER ± 1					
7	$\uparrow$	27									
8	3	03									
9	6	06									
10	0	00	CALCULATE $\tan \beta 1$								
11	X	36									
12	$\square$	16									
13	IF FLAG	43									

FROM 8-9

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
3	0	X	36									
1	CLEAR X	37										
2	↓	25										
3	tan x	71										
4	↑	27										
5	↑	27										
6	y	55										
7	ENTER EXP	26										
8	9	11										
9	IF x < y	52	TEST FOR $\tan \beta l > 10^9$, IF SO, SOLVE $Z_l = \frac{Z_0^2}{Z_1}$									
a	8	10										
b	a	13										
c	↓	25										
d	d	17										
4	0	X	36									
1	a	13										
2	+	33										
3	b	14										
4	TO POLAR	62										
5	In x	65										
6	ACC +	60										
7	b	14										
8	ROLL ↑	22										
9	X	36										
a	↑	27										
b	a	13										
c	CHG SIGN	32										
d	X	36										
5	d	17										
1	+	33										
2	↓	25	CALCULATE $Z_l = Z_0 \left[\frac{Z_1 + jZ_0 \tan \beta l}{Z_0 + jZ_1 \tan \beta l} \right]$									
3	TO POLAR	62										
4	In x	65										
5	ACC -	63										
6	RCL	61										
7	ACC -	63										
8	e^x	74										
9	↑	27										
a	d	17										
b	X	36										
c	3	03										
d	ROLL ↓	31										

FROM 9-9

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	TO RECT	66								
1	STOP	41	R_L	X_L	3	DISPLAY					
2	↑	27									
3	d	17									
4	—	34									
5	ROLL ↓	31									
6	TO POLAR	62									
7	$\ln x$	65									
8	ACC +	60									
9	e^x	74									
0	TO RECT	66									
b	ROLL ↑	22	CALCULATE REFLECTION COEFFICIENT R_v								
c	+	33									
d	+	33									
7	0	4	04								
1	ROLL ↓	31									
2	TO POLAR	62									
3	$\ln x$	65									
4	ACC —	63									
5	RCL	61									
6	e^x	74									
7	STOP	41	$ R_v $	θ_{R_v}	4	DISPLAY					
8	↑	27									
9	↑	27									
0	1	01									
b	+	33									
c	ROLL ↑	22	CALCULATE VSWR								
d	—	34									
8	0	5	05								
1	ROLL ↓	31									
2	÷	35									
3	CLEAR x	37									
4	$x \leftrightarrow y$	30									
5	STOP	41	VSWR	0	5	DISPLAY					
6	CLEAR	20									
7	GOTO () ()	44									
8	1	01									
9	7	07									
0	d	17									
b	↑	27									
c	$\times$	36									
d	θ	13									

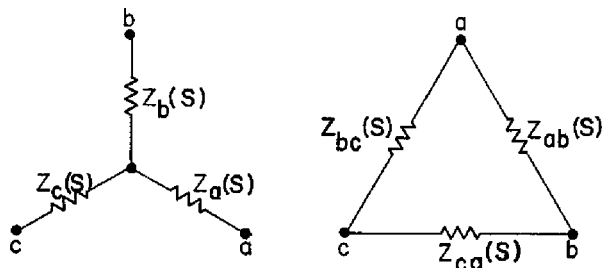
FROM 3-b

[illegible]

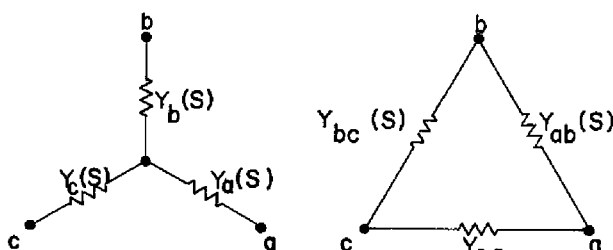
WYE → DELTA and/or DELTA → WYE CONVERSION

The following notation is used:

Delta → Wye Conversion:



Wye → Delta Conversion:



By loop and nodal equations the following equations may be obtained:

Delta → Wye:

$$Z_a(S) = \frac{Z_{ab}(S) Z_{ca}(S)}{Z_{ab}(S) + Z_{bc}(S) + Z_{ca}(S)}$$

$$Z_b(S) = \frac{Z_{bc}(S) Z_{ab}(S)}{Z_{ab}(S) + Z_{bc}(S) + Z_{ca}(S)}$$

$$Z_c(S) = \frac{Z_{bc}(S) Z_{ca}(S)}{Z_{ab}(S) + Z_{bc}(S) + Z_{ca}(S)}$$

Wye → Delta:

$$Y_{ab}(S) = \frac{Y_a(S) Y_b(S)}{Y_a(S) + Y_b(S) + Y_c(S)}$$

$$Y_{bc}(S) = \frac{Y_b(S) Y_c(S)}{Y_a(S) + Y_b(S) + Y_c(S)}$$

$$Y_{ca}(S) = \frac{Y_c(S) Y_a(S)}{Y_a(S) + Y_b(S) + Y_c(S)}$$

Because of the similarity of the two sets of formulas, the same basic relationship is used in the program for either wye to delta or delta to wye conversion. Thus, circuit values are given as impedances when converting from Delta to Wye, and as admittances when converting from Wye to Delta.

Reference: Introductory Circuit Analysis - S. Ivar Pearson and George J. Maler
Publisher - John Wiley & Sons, Inc. 1965

USER INSTRUCTIONS

Notes: To convert from Delta to Wye, the inputs must be in ohms (Ω) and in rectangular form, i.e. $Z = R + jX$.

To convert from Wye to Delta, the inputs must be in mhos ($\mathcal{U}$) and in rectangular form, i.e. $Y = G + jB$.

Outputs are in the same dimensions as the inputs and are in rectangular form.

If one wishes to transform impedances from Wye to Delta or admittances from Delta to Wye then the data must be inverted before input by displaying each input in Polar form, (use TO POLAR key), taking the inverse of the magnitude, changing the sign of the angle and after placing these quantities in the X and Y registers respectively pressing the TO RECT key.

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

ENTER DATA: X_{ab} } R_{ab} }
 or } $\rightarrow Y$, or } $\rightarrow X$
 B_b } G_b }

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
2	_____	X

ENTER DATA: X_{bc} } R_{bc} }
 or } $\rightarrow Y$, or } $\rightarrow X$
 B_c } G_c }

PRESS: CONTINUE

USER INSTRUCTIONS (cont)

DISPLAY

0	_____	Z
0	_____	Y
3	_____	X

ENTER DATA: X_{ca} } R_{ca} }
 or } $\rightarrow Y$, or } $\rightarrow X$
 B_a } G_a }

PRESS: CONTINUE

DISPLAY

1	_____	Z
B_{ab} or X_a	_____	Y
G_{ab} or R_a	_____	X

PRESS: CONTINUE

2	_____	Z
B_{bc} or X_b	_____	Y
G_{bc} or R_b	_____	X

PRESS: CONTINUE

3	_____	Z
B_{ca} or X_c	_____	Y
G_{ca} or R_c	_____	X

Note: To reset problem, re-enter program card and proceed with user instructions.

EXAMPLES

(A) Wye $\rightarrow$ Delta

Input: $Y_b = 2 + j0 \mathcal{U}$ Solution: $Y_{ab} = .3333 \mathcal{U}$
 $Y_c = 3 + j0 \mathcal{U}$ $Y_{bc} = 1.0000 \mathcal{U}$
 $Y_a = 1 + j0 \mathcal{U}$ $Y_{ca} = .5000 \mathcal{U}$

(B) Delta $\rightarrow$ Wye

Input: $Z_{ab} = 0 + j5 \Omega$ Solution: $Z_a = 2.5 + j2.5 \Omega$
 $Z_{bc} = 0 + j5 \Omega$ $Z_b = -1.25 + j1.25 \Omega$
 $Z_{ca} = 10 + j0 \Omega$ $Z_c = 2.5 + j2.5 \Omega$

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	$x \rightarrow ()$	23									
	2	7	07									
	3	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
	4	STOP	41	R_{ab} or G_b	X_{ab} or B_b	0	ENTER X_{ab}, R_{ab} or G_b, B_b					
	5	ACC +	60									
	6	TO POLAR	62									
	7	$x \rightarrow ()$	23									
	8	d	17	STORE Z_{ab} OR Y_b IN POLAR FORM								
	9	$y \rightarrow ()$	40									
	a	c	16									
	b	↓	25									
1	c	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	d	STOP	41	R_{bc} or G_c	X_{bc} or B_c	0	ENTER X_{bc}, R_{bc} or G_c, B_c					
	0	ACC +	60	CALCULATE PARTIAL DENOMINATOR								
	1	TO POLAR	62									
	2	$x \rightarrow ()$	23									
	3	8	10	STORE Z_{bc} OR Y_c IN POLAR FORM								
	4	$y \rightarrow ()$	40									
	5	9	11									
	6	↓	25									
	7	3	03	DISPLAY 3 TO INDICATE THIRD ENTRY								
	8	STOP	41	R_{ca} or G_a	X_{ca} or B_a	0	ENTER X_{ca}, R_{ca} or G_a, B_a					
	2	9	ACC +	60	FINISH CALCULATING DENOMINATOR							
a		TO POLAR	62									
b		$x \rightarrow ()$	23									
c		b	14	STORE Z_{ca} OR Y_a IN POLAR FORM								
d		$y \rightarrow ()$	40									
0		a	13	RECALL DENOMINATOR IN RECTANGULAR FORM AND CLEAR ACCUMULATORS								
1		RCL	61									
2		ACC -	63	STORE DENOMINATOR IN POLAR FORM								
3		TO POLAR	62									
4		ACC +	60									
5		c	16									
6		↑	27									
7	a	13	CALCULATE ANGLE OF EQUIVALENT ELEMENT									
8	+	33										
9	B	12										
a	-	34										
b	$y \rightarrow ()$	24										
c	7	07	INCREMENT AND STORE COUNT FOR DISPLAY									
d	1	01										

FROM 5-7

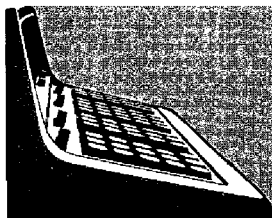
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	+	33								
	1	$y \rightarrow ()$	24								
	2	7	07								
	3	d	17								
	4	↑	27								
	5	b	14								
	6	x	36								
	7	f	15								
	8	÷	35								
	9	ROLL ↑	22								
	a	$y \rightarrow ()$	24								
	b	7	07								
4	c	$y \rightarrow ()$	40								
	d	7	07								
	0	ROLL ↑	22								
	1	TO RECT	66								
	2	STOP	41	X_a	Y_a	0	DISPLAY				
	3	$y \rightarrow ()$	24								
	4	8	10								
	5	$y \rightarrow ()$	24								
	6	d	17								
	7	$y \rightarrow ()$	24								
	8	b	14								
	9	$y \rightarrow ()$	40								
5	a	8	10								
	b	$y \rightarrow ()$	24								
	c	9	11								
	d	$y \rightarrow ()$	24								
	0	c	16								
	1	$y \rightarrow ()$	24								
	2	a	13								
	3	$y \rightarrow ()$	40								
	4	9	11								
	5	GO TO ()	44								
	6	2	02								
	7	5	05								
	8	END	46								
	9										
	a										
	b										
	c										
	d										

CALCULATE MAGNITUDE OF EQUIVALENT ANGLE

RECALL COUNT, POSITION, AND DISPLAY ELEMENT IN RECTANGULAR FORM

ROTATE REGISTER CONTENTS IN PREPARATION FOR NEXT EQUIVALENT ELEMENT

BRANCH TO CALCULATE NEXT ELEMENT



PART NO.
09100-71011

S-PARAMETER TO Y-PARAMETER CONVERSION

This program converts S parameters for linear (active or passive) circuits to Y parameters. The equations used are as follows:

$$y_{11} = \frac{s_{22} + 1}{D} - \frac{1}{R_0} \quad y_{21} = \frac{-s_{21}}{D}$$

$$y_{12} = \frac{-s_{12}}{D} \quad y_{22} = \frac{s_{11} + 1}{D} - \frac{1}{R_0}$$

$$D = \frac{1}{2} R_0 \left[(1 + s_{11})(1 + s_{22}) - s_{12} s_{21} \right]$$

where R_0 is the characteristic impedance of the S parameter measuring system.

The Matrix form

$$R_0 Y = 2 (S + I)^{-1} - I$$

thus $S = 2 (R_0 Y + I)^{-1} - I$

A similar program can be used for the reverse transformation; only the input and output sections need be changed since S will usually be expressed in dB and degrees and Y is Siemens (Mho) in rectangular coordinators.

Similar programs could be written to convert S to Z or Z to S as follows:

$$Z = R_0 \left[2 (I - S)^{-1} - I \right]$$

$$S = I - 2 \left(\frac{1}{R_0} Z + I \right)^{-1}$$

or convert from Z to Y or Y to Z as follows:

$$Z = Y^{-1}$$

$$Y = Z^{-1}$$

This program requires

$$\left. \begin{matrix} s_{11} \\ s_{12} \\ s_{21} \\ s_{22} \end{matrix} \right\} \text{ in dB and degrees}$$

and R_0 in ohms

Reference: Hewlett-Packard Journal
February, 1967

USER INSTRUCTIONS

SET: ENTER: Program 1 (Starting Address is 0-0)
This program is self-destructive.

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
11	—	X

ENTER DATA: $\theta_{11}^0 \rightarrow Y$, $R_{11} \text{ dB} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
12	—	X

ENTER DATA: $\theta_{12}^0 \rightarrow Y$, $R_{12} \text{ dB} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
21	—	X

ENTER DATA: $\theta_{21}^0 \rightarrow Y$, $R_{21} \text{ dB} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
22	—	X

ENTER DATA: $\theta_{22}^0 \rightarrow Y$, $R_{22} \text{ dB} \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: $R_0 \rightarrow X$

PRESS: CONTINUE

USER INSTRUCTIONS (con't)

DISPLAY

0	—	Z
0	—	Y
2	—	X

SET:

ENTER: Program 2 (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

11	—	Z
B_{11}	—	Y
G_{11}	—	X

$$Y_{11} = G_{11} + jB_{11}$$

PRESS: CONTINUE

DISPLAY

12	—	Z
B_{12}	—	Y
G_{12}	—	X

$$Y_{12} = G_{12} + jB_{12}$$

PRESS: CONTINUE

DISPLAY

21	—	Z
B_{21}	—	Y
G_{21}	—	X

$$Y_{21} = G_{21} + jB_{21}$$

PRESS: CONTINUE

DISPLAY

22	—	Z
B_{22}	—	Y
G_{22}	—	X

$$Y_{22} = G_{22} + jB_{22}$$

To restart reload program 1 and proceed as before.

EXAMPLE

S parameters for 2N3478 transistor in common emitter configuration, at 100 MHz $I_c = 10$ ma
 $V_{ce} = 5$ V

General form

$$\begin{aligned}
 S_{ij} &= R_{ij} \angle \theta_{ij} \text{ dB} \\
 S_{11} &= -10.09 \angle -103^\circ \text{ dB} \\
 S_{12} &= -29.63 \angle 60^\circ \text{ dB} \\
 S_{21} &= 17.21 \angle 102^\circ \text{ dB} \\
 S_{22} &= -1.67 \angle -8^\circ \text{ dB} \\
 R_o &= 50\Omega
 \end{aligned}$$

General form

$$\begin{aligned}
 y_{ij} &= (G_{ij} + jB_{ij}) \\
 y_{11} &= (14.34 + j10.97) \text{ mS} \\
 y_{12} &= (-98.49 - j645.94) \mu\text{S} \\
 y_{21} &= (78.91 - j119.99) \text{ mS} \\
 y_{22} &= (-657.70 + j1070.83) \mu\text{S}
 \end{aligned}$$



HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	GOTO ()	44	BRANCH TO FUTURE STORAGE AREA WHICH IS SELF-DESTRUCTIVE							
	1	5	05								
	2	$\bar{c}$	16								
	3	TO RECT	66	CONTINUE CONVERSION AND STORAGE							
	4	$x \rightarrow ()$	23								
	5	$\bar{a}$	13								
	6	$\uparrow$	27								
	7	CLEAR x	37								
	8	ROLL $\downarrow$	31								
	9	2	02	SELF-DESTRUCT REGISTER 0 AND POSITION DISPLAY							
	$\bar{a}$	2	02								
	$\bar{b}$	$x \rightarrow y$	30								
	$\bar{c}$	$x \rightarrow ()$	23								
	$\bar{d}$	0	00								
1	0	$\downarrow$	25	ENTER θ_{22}° AND r_{22} dB							
	1	STOP	41								
	2	$\uparrow$	27								
	3	$\bar{b}$	14								
	4	$\times$	36								
	5	$\downarrow$	25								
	6	e^x	74								
	7	TO RECT	66								
	8	$\uparrow$	27								
	9	1	01								
	$\bar{a}$	+	33								
	$\bar{b}$	$\downarrow$	25								
2	$\bar{c}$	TO POLAR	62								
	$\bar{d}$	ACC +	60								
	0	$\uparrow$	27								
	1	$\bar{d}$	17								
	2	$\times$	36								
	3	$\bar{c}$	16								
	4	ROLL $\uparrow$	22								
	5	+	33								
	6	$\downarrow$	25								
	7	$x \rightarrow y$	30								
	8	TO RECT	66								
	9	$\uparrow$	27								
	$\bar{a}$	$\bar{a}$	13								
	$\bar{b}$	-	34								
	$\bar{c}$	ROLL $\uparrow$	22	CALCULATE $(S_{22}+1)(S_{11}+1) + S_{12}S_{21}$							
	$\bar{d}$	$y \rightarrow ()$	24								

FROM a-c

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	00									
1	—	34									
2	$x \leftrightarrow y$	30									
3	CHG SIGN	32									
4	ROLL $\uparrow$	22									
5	TO POLAR	62									
6	$x \rightarrow ()$	23									
7	b	14									
8	$y \rightarrow ()$	40									
9	a	13									
a	CLEAR x	37									
b	GO TO () ()	44									
c	5	05	BRANCH TO SELF-DESTRUCTIVE AREA								
d	0	00									
4	0	40									
1	b	14									
2	1	01									
3	ROLL $\uparrow$	22									
4	$\div$	35									
5	$y \rightarrow ()$	40									
6	5	05									
7	CLEAR x	37									
8	$\uparrow$	27									
9	$\uparrow$	27									
a	2	02									
b	STOP	41									
c	STOP	41									
d	STOP	41									
5	$\uparrow$	27									
1	$\uparrow$	27									
2	STOP	41	R_0	0	0	ENTER R_0					
3	$\uparrow$	27									
4	$\uparrow$	27									
5	b	14									
6	x	36									
7	2	02									
8	$\div$	35									
9	GO TO () ()	44									
a	4	04									
b	0	00									
c	1	01									
d	0	00									

BRANCH TO SELF-DESTRUCTIVE AREA

STORE D

CALCULATE $\frac{1}{R}$

POSITION AND DISPLAY 2 INDICATING ENTRY OF PROGRAM NO. 2

CLEAR DISPLAY

ENTER R_0

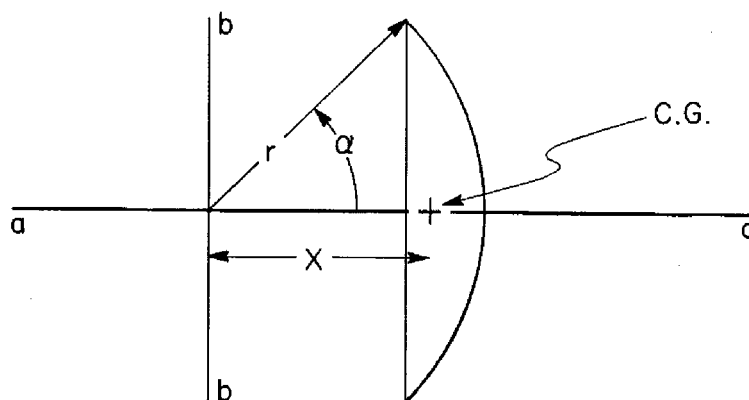
CALCULATE D

FROM 0-2

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	E	12								
	1	↑	27								
	2	a	13								
	3	—	34								
	4	f	15								
	5	↑	27								
	6	b	14								
	7	÷	35								
	8	↓	25								
	9	TO RECT	66								
	a	ROLL ↓	31								
	b	y2()	24								
	c	5	05								
	d	y→()	40								
				CALCULATE Y_{11}							
1	0	E	12								
	1	ROLL ↓	31								
	2	—	34								
	3	1	01								
	4	1	01								
	5	ROLL ↓	31								
	6	STOP	41	G_{11}	B_{11}	11	DISPLAY $Y_{11} = G_{11} + jB_{11}$				
	7	y2()	24								
	8	7	07								
	9	a	13								
	a	—	34								
	b	↑	27								
	c	y2()	24								
	d	6	06								
				CALCULATE Y_{12}							
2	0	b	14								
	1	CHG SIGN	32								
	2	÷	35								
	3	1	01								
	4	2	02								
	5	ROLL ↓	31								
	6	TO RECT	66								
	7	STOP	41	G_{12}	B_{12}	0	DISPLAY $Y_{12} = G_{12} + jB_{12}$				
	8	y2()	24								
	9	9	11								
	a	a	13								
	b	—	34								
	c	↑	27								
	d	y2()	24								

MOMENT OF INERTIA OF A CIRCULAR SEGMENT

This program calculates the moment of inertia of a circular segment of the shape



where r = radius of the arc
 α = angle in radians
 X = distance to the center of gravity (c.g.)
 A = area of segment
 J_{aa} = moment of inertia about axis (aa)
 J_{bb} = moment of inertia about axis (bb)

The equations used are

$$X = \frac{2}{3} \left[\frac{r^3 \sin^3 \alpha}{A} \right] \text{ WHERE } -\pi \leq \alpha \leq \pi$$

$$A = \frac{1}{2} r^2 (2\alpha - \sin 2\alpha)$$

$$J_{aa} = \frac{1}{4} Ar^2 \left[1 - \frac{2}{3} \left(\frac{\sin^3 \alpha \cos \alpha}{\alpha - \sin \alpha \cos \alpha} \right) \right]$$

$$J_{bb} = \frac{1}{4} Ar^2 \left[1 + \frac{2 \sin^3 \alpha \cos \alpha}{\alpha - \sin \alpha \cos \alpha} \right]$$

Reference: The Engineer's Manual
 by Ralph G. Hudson
 Second Edition

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0 - 0)

SET: RADIANS

PRESS: END

PRESS: CONTINUE

ENTER DATA: $\alpha \rightarrow Y, r \rightarrow X$
(α is in radians)

PRESS: CONTINUE

DISPLAY

X	—	Z
A	—	Y
1	—	X

PRESS: CONTINUE

DISPLAY

J_{aa}	—	Z
J_{bb}	—	Y
2	—	X

 $r = 100$

$$\alpha = \frac{\pi}{4}$$

$$X = 82.587$$

$$A = 2853.982$$

$$J_{aa} = 2.968 \times 10^6$$

$$J_{bb} = 1.963 \times 10^7$$

 $r = 100$

$$\alpha = \frac{\pi}{2}$$

$$X = 42.441$$

$$A = 15707.963$$

$$J_{aa} = 3.927 \times 10^7$$

$$J_{bb} = 3.927 \times 10^7$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20									
1	1 STOP	41	r	α	0	ENTER r AND α					
2	2 ACC +	60									
3	3 2	02									
4	4 X	36									
5	5 ROLL ↓	31									
6	6 ↑	27									
7	7 sin x	70									
8	8 —	34									
9	9 f	15									
10	10 ↑	27	CALCULATE $A = \frac{1}{2} r^2 (2\alpha - \sin 2\alpha)$								
11	11 CONTINUE	47									
12	12 X	36									
13	13 ROLL ↓	31									
1	1 0	36									
2	2 2	02									
3	3 ÷	35									
4	4 y→()	40									
5	5 d	17									
6	6 E	12									
7	7 sin x	70									
8	8 ↑	27									
9	9 X	36									
10	10 X	36									
11	11 y→()	40									
12	12 C	16									
13	13 f	15									
14	14 ↑	27	CALCULATE $X = \frac{2}{3} \left[\frac{r^3 \sin^3 \alpha}{A} \right]$								
2	2 0	36									
1	1 X	36									
2	2 C	16									
3	3 X	36									
4	4 d	17									
5	5 ÷	35									
6	6 2	02									
7	7 X	36									
8	8 3	03									
9	9 ÷	35									
10	10 d	17									
11	11 ROLL ↑	22									
12	12 1	01	DISPLAY 1 TO INDICATE FIRST ANSWER								
13	13 STOP	41	1	A	X	DISPLAY					

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

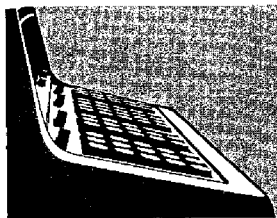
HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	F	15								
	1	↑	27								
	2	X	36								
	3	d	17								
	4	X	36								
	5	4	04								
	6	÷	35								
	7	y→()	40								
	8	d	17								
	9	E	12								
	a	cos x	73								
	b	↑	27								
	c	C	16								
	d	X	36								
4	0	2	02								
	1	X	36								
	2	y→()	40								
	3	C	16								
	4	E	12								
	5	sin x	70								
	6	↑	27								
	7	E	12								
	8	cos x	73								
	9	X	36								
	a	E	12								
	b	x↔y	30								
	c	—	34								
	d	ROLL ↑	22								
5	0	↓	25								
	1	3	03								
	2	X	36								
	3	C	16								
	4	x↔y	30								
	5	÷	35								
	6	1	01								
	7	x↔y	30								
	8	—	34								
	9	d	17								
	a	X	36								
	b	C	16								
	c	ROLL ↑	22								
	d	÷	35								

CALCULATE $J_{aa} = \frac{1}{4} Ar^2 \left[1 - \frac{2}{3} \left(\frac{\sin^3 \alpha \cos \alpha}{\alpha - \sin \alpha \cos \alpha} \right) \right]$

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											



PART NO.
09100-72002

TRANSCENDENTAL EQUATION
(ARC INVOLUTE IN GEAR DESIGN)

This program solves the following equation for ϕ in radians for a given value of the involute of ϕ , $\text{INV}(\phi)$.

$$\text{INV}(\phi) = \text{TAN } \phi - \phi$$

The method of solution is an iteration technique using the Newton-Raphson equation $\phi_{n+1} = \phi_n - \frac{f(\phi_n)}{f'(\phi_n)}$.

The range of $\text{INV}(\phi)$ is $1 \times 10^{-17} \leq \text{INV}(\phi) \leq 1 \times 10^6$

resulting in ϕ in the range $4.085 \times 10^{-6} \text{ RAD} \leq \phi \leq 1.571 \text{ RAD}$

EXAMPLES

$\text{INV}(\phi) = .35 \text{ rad}$ $\phi = .894 \text{ rad}$
 $\text{INV}(\phi) = 1 \times 10^{-17} \text{ rad}$ $\phi = 4.085 \times 10^{-6} \text{ rad}$
 $\text{INV}(\phi) = 1 \times 10^6 \text{ rad}$ $\phi = 1.571 \text{ rad}$

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

SET:

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

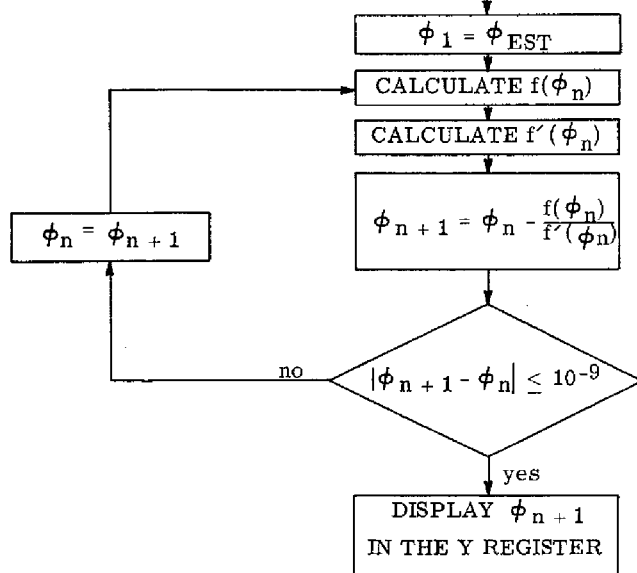
ENTER DATA: $\text{INV}(\phi) \rightarrow X$

PRESS: CONTINUE

DISPLAY

$|\phi_{n+1} - \phi_n| \text{ — Z}$
 $\phi_{n+1} \text{ — Y}$
 $\text{INV}(\phi) \text{ — X}$

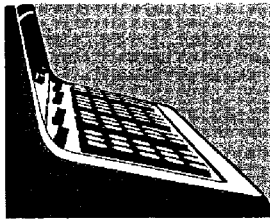
FLOWCHART OF ITERATION TECHNIQUE



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	STOP	41	INV(ϕ)	0	0	ENTER	INV(ϕ)			
	2	ACC +	60								
	3	↑	27								
	4	3	03								
	5	X	36								
	6	ROLL ↓	31								
	7	ln x	65								
	8	ROLL ↑	22								
	9	÷	35								
	a	↓	25								
	b	e^x	74								
	c	↑	27								
	d	2	02								
1	0	↑	27	CALCULATE ϕ_{EST} IN SOME NEWTON-RAPHSON SOLUTIONS							
	1	ENTER EXP	26	IT MAY BE NECESSARY TO MAKE A ROUGH SKETCH OF THE FUNCTION							
	2	6	06	TO DETERMINE A GOOD ESTIMATE. HERE THE FIRST TWO TERMS OF							
	3	CHG SIGN	32	THE SERIES REPRESENTING THE TANGENT WERE USED TO							
	4	+	33	CALCULATE AN ESTIMATE, ϕ_{EST} , BASED ON INV(ϕ).							
	5	π	56								
	6	$x \div y$	30								
	7	÷	35								
	8	↓	25								
	9	IF $x > y$	53								
	a	CONTINUE	47								
	b	$x \div y$	30								
	c	↑	27	BEGINNING OF ITERATION LOOP							
	d	↑	27								
2	0	$\tan x$	71								
	1	-	34								
	2	ROLL ↑	22								
	3	$x \rightarrow ()$	23	CALCULATE $-f(\phi_n) = -\tan \phi_n + \phi_n + \text{INV}(\phi)$							
	4	E	12								
	5	F	15								
	6	$x \div y$	30								
	7	ROLL ↓	31								
	8	+	33								
	9	↓	25								
	a	ROLL ↓	31	CALCULATE $f'(\phi_n)$							
	b	X	36								
	c	↓	25	CALCULATE $-\frac{f(\phi_n)}{f'(\phi_n)}$							
	d	÷	35								

FROM 4-4

[illegible]



PART NO.
09100-72003

SPRING DESIGN - COMPRESSION & EXTENSION SPRINGS

This program calculates one of three variables (d - diameter of wire, N - number of turns of wire, and D - mean coil diameter), the remaining two being set, and calculates the maximum allowable stress. Other inputs are set to predetermined values.

Basic relationships:

$$S = \frac{8 PD}{\pi d^3} K_{w_2} ; K_{w_2} = 1 + \frac{.5d}{D}$$

assuming the spring is all set out; K_{w_2} is used as the most accurate coefficient when considering the maximum stress.

$$K = \frac{G d^4}{8 N D^3}$$

S = Maximum stress

P = Maximum load

d = Wire diameter

D = Mean coil diameter

N = No. of active coils

G = Modulus of rigidity

K = Spring constant

P, K, G are set to predetermined or desired values for a given application.

With two of the three variables d, N, and D set to predetermined values, the 3rd is calculated from the expression

$$K = \frac{G d^4}{8 N D^3}$$

Dimensions:

S, G in lbs/in^2 ; K in lbs/in .

N dimensionless

P in lbs.

D, d in inches

Reference: Design Handbook
Associated Spring Corporation
Bristol, Connecticut

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0 — Z
0 — Y
0 — X

ENTER DATA: P → Z, K → Y, G → X

PRESS: CONTINUE

DISPLAY

0 — Z
0 — Y
0 — X

ENTER DATA: d → Z, D → Y, N → X
(Enter unknown as zero)

PRESS: CONTINUE

DISPLAY

(1)

S — Z
0 — Y
0 — X

PRESS: CONTINUE

DISPLAY

(2)

d — Z
D — Y
N — X

Note: To alter solution, enter new set of data (d, N, D) after display (2), setting unknown to zero.

To reset complete problem with new P, K, and G;

PRESS: END

PRESS: CONTINUE

We wish to use music wire ($G = 11.5 \times 10^6$ psi) to make a spring which will compress 1/4" with 5 lb. load ($k = 20$ lb/in.). The spring must fit over 1/2" pin. Maximum load will be 10 lbs.

$$P = 10$$

$$k = 20$$

$$G = 1.15 \times 10^7$$

$$d = 0 \text{ (d selected as the unknown)}$$

$$D = .625 \text{ (Choose to allow clearance)}$$

$$N = 10 \text{ (Reasonable number for maximum compression of 1/2 in.)}$$

ANSWERS:

$$S = 37,955.01$$

$$d = .0763 \text{ (Calculated value)}$$

$$D = .625 \text{ (Given values)}$$

$$N = 10$$

Enter: New data for 14 gauge wire (good correlation)

$$d = .0736 \text{ (Standard wire size, 14 ga)}$$

$$D = .625 \text{ same}$$

$$N = 0 \text{ (New unknown)}$$

ANSWERS:

$$S = 42,270.12$$

$$\left. \begin{array}{l} d = .0736 \\ D = .625 \end{array} \right\} \text{ Given}$$

$$N = 8.6387 \text{ (Calculated N)}$$

Therefore, for 14 gauge wire with 10 lbs. maximum load and other variables as specified, the number of turns should be 8.64 and the maximum stress is 42,270.12 lbs.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	STOP	41	G	k	P	ENTER DATA; P,k,G				
	2	÷	35								
	3	8	10								
	4	X	36								
	5	↓	25	CALCULATE $\frac{8k}{6}$ AND STORE WHICH IS USED TO CALCULATE							
	6	x→()	23	N,D OR d							
	7	⌈	16								
	8	y→()	40	STORE P							
	9	b	14								
	0	CLEAR	20								
	b	STOP	41	N	D	d	ENTER 2 OF 3 CONSTANTS, SET UNKNOWN TO ZERO				
	⌈	ACC +	60	STORE N AND D							
	d	ROLL ↑	22								
1	0	x→()	23	STORE d							
	1	d	17								
	2	CLEAR x	37								
	3	IF x=y	50								
	4	4	04	BRANCH TO SOLUTION FOR N IF N IS UNKNOWN							
	5	7	07								
	6	ROLL ↑	22								
	7	IF x=y	50								
	8	2	02	BRANCH TO SOLUTION FOR D IF D IS UNKNOWN							
	9	b	14								
	0	↑	27								
	b	X	36								
	⌈	X	36								
	d	f	15								
2	0	X	36	CALCULATE d							
	1	⌈	16								
	2	X	36								
	3	↓	25								
	4	√x	76								
	5	√x	76								
	6	x→()	23	STORE d							
	7	d	17								
	8	GO TO () ()	44								
	9	5	05	BRANCH TO SOLUTION FOR S							
	0	6	06								
	b	d	17								
	⌈	↑	27								
	d	X	36								

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

FROM 7-5

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	X	36								
	1	X	36								
	2	C	16								
	3	÷	35								
	4	F	15								
	5	÷	35								
	6	1	01								
	7	↑	27								
	8	3	03								
	9	÷	35								
	a	↓	25								
	b	$x \div y$	30								
	c	$\ln x$	65								
4	d	X	36								
	0	↓	25								
	1	e^x	74								
	2	$x \rightarrow ()$	23								
	3	E	12								
	4	GOTO () ()	44								
	5	5	05								
	6	6	06								
	7	d	17								
	8	ROLL ↑	22								
	9	÷	35								
	a	↓	25								
	b	↑	27								
5	c	X	36								
	d	X	36								
	0	d	17								
	1	X	36								
	2	C	16								
	3	÷	35								
	4	$y \rightarrow ()$	40								
	5	F	15								
	6	b	14								
	7	↑	27								
	8	4	04								
	9	X	36								
	a	π	56								
	b	÷	35								
	c	d	17								
	d	÷	35								

CALCULATE D

STORE D

BRANCH TO SOLUTION FOR S

CALCULATE N

STORE N

FROM 1-5

FROM 2-a & 4-6

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	÷	35								
	1	↑	27								
	2	↓	25								
	3	÷	35								
	4	2	02								
	5	x	36								
	6	E	12								
	7	x	36								
	8	↓	25								
	9	+	33								
	a	CLEAR x	37								
	b	↑	27	0	0	S	DISPLAY				
7	c	STOP	41								
	d	d	17								
	0	ROLL ↓	31								
	1	RCL	61	N	D	d	DISPLAY				
	2	ACC —	63								
	3	GO TO () ()	44								
	4	0	00								
	5	b	14								
	6	END	46								
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

CALCULATE S

DISPLAY

DISPLAY

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
e											
f											
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b											
c											
d											
e											
f											
0											
1											
2											
3											
4											

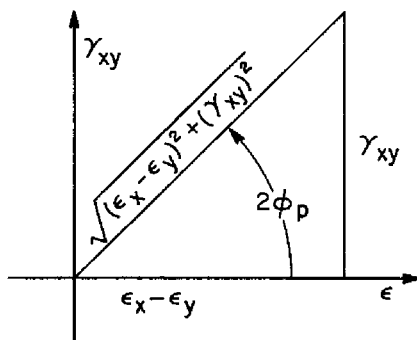
STRESS AND STRAIN FROM A RECTANGULAR ROSETTE

PART NO.
09100-72004

The basic equation obtained from graphical representation of a set of strains is

$$(1) \quad \epsilon_{\phi} = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2\phi + \frac{\gamma_{xy}}{2} \sin 2\phi$$

The strains can be displayed graphically in the following manner



with $2\phi_p$ is the angle from the ϵ axis to the principal strains.

By writing equations for $\sin 2\phi_p$ and $\cos 2\phi_p$ and substituting into equation (1) the following equations are obtained:

$$\epsilon_{\max}, \epsilon_{\min} = \frac{\epsilon_x + \epsilon_y}{2} \pm \sqrt{\left(\frac{\epsilon_x - \epsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2} \quad \left(\begin{array}{c} \text{max} + \\ \text{min} - \end{array} \right)$$

$$\phi_p = \frac{1}{2} \tan^{-1} \frac{\gamma_{xy}}{\epsilon_x - \epsilon_y} \quad (\text{from the figure})$$

$$\gamma_{\max} = \sqrt{(\epsilon_x - \epsilon_y)^2 + (\gamma_{xy})^2}$$

Using a rectangular rosette gives $\phi_1 = 0^\circ$, $\phi_2 = 45^\circ$, and $\phi_3 = 90^\circ$ then from equation (1) it is found that

$$\epsilon_x = \epsilon_1, \quad \epsilon_y = \epsilon_3, \quad \gamma_{xy} = 2\epsilon_2 - (\epsilon_1 + \epsilon_3).$$

Then writing the principal strains in terms of ϵ_1 , ϵ_2 , and ϵ_3 we obtain:

$$\epsilon_{\max}, \epsilon_{\min} = 1/2 (\epsilon_1 + \epsilon_3) \pm 1/2 \sqrt{(\epsilon_1 - \epsilon_3)^2 + [2\epsilon_2 - (\epsilon_1 + \epsilon_3)]^2} \quad \left(\begin{matrix} \max \\ \min \end{matrix} + \right)$$

$$\gamma_{\max} = \sqrt{(\epsilon_1 - \epsilon_3)^2 + [2\epsilon_2 - (\epsilon_1 + \epsilon_3)]^2}$$

$$\phi_p = 1/2 \tan^{-1} \frac{2\epsilon_2 - (\epsilon_1 + \epsilon_3)}{\epsilon_1 - \epsilon_3}$$

The principal stresses are then related by the following equations which may be obtained from investigation of a Mohr's circle for strain.

$$\sigma_{\max} = \frac{E}{1 - \mu^2} (\epsilon_{\max} + \mu \epsilon_{\min})$$

$$\sigma_{\min} = \frac{E}{1 - \mu^2} (\epsilon_{\min} + \mu \epsilon_{\max})$$

$$\tau_{\max} = \frac{E}{2(1 + \mu)} \gamma_{\max}$$

ϵ = strain (in. per in.)

σ = stress (psi)

$\gamma_{\max}$ = maximum shearing strain (radian)

$\tau_{\max}$ = maximum shearing stress (psi)

ϕ_p = angle between the ϵ axis and the principal strain axis. (degrees)

μ = Poisson's ratio (dimensionless)

E = Modulus of elasticity (psi)

Reference: The Strain Gage Primer
Perry & Lissner

McGraw-Hill
New York, 1962

USER INSTRUCTIONS

EXAMPLE

SET:

ENTER PROGRAM (Starting Address 0 - 0)

PRESS: GO TO 3 - d

SET: ENTER: Program steps for constant μ SET:

PRESS: GO TO 5 - c

SET:

ENTER: Program steps for constant E

SET:

→ PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: $\epsilon_3 \rightarrow Z$, $\epsilon_2 \rightarrow Y$, $\epsilon_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

ϵ min	—	Z
ϵ max	—	Y
γ max	—	X

PRESS: CONTINUE

DISPLAY

ϕ_p	—	Z
0	—	Y
0	—	X

PRESS: CONTINUE

DISPLAY

σ min	—	Z
σ max	—	Y
τ max	—	X

Note: μ and E are included in the program as constants dependent on the materials being used.

$$\mu = .3, \quad E = 30 \times 10^6 \text{ psi}$$

$$\text{Given: } \epsilon_1 = 285 \times 10^{-6} \text{ in. per in.}$$

$$\epsilon_2 = 65 \times 10^{-6} \text{ in. per in.}$$

$$\epsilon_3 = 102 \times 10^{-6} \text{ in. per in.}$$

Result of calculations:

$$\epsilon_{\min} = 3.5752 \times 10^{-5} \text{ in. per in.}$$

$$\epsilon_{\max} = 3.5125 \times 10^{-4} \text{ in. per in.}$$

$$\gamma_{\max} = 3.1550 \times 10^{-4} \text{ radian}$$

$$\phi_p = -27.2734^\circ$$

$$\sigma_{\min} = 4.65251 \times 10^3 \text{ psi}$$

$$\sigma_{\max} = 11.93320 \times 10^3 \text{ psi}$$

$$\tau_{\max} = 3.64034 \times 10^3 \text{ psi}$$



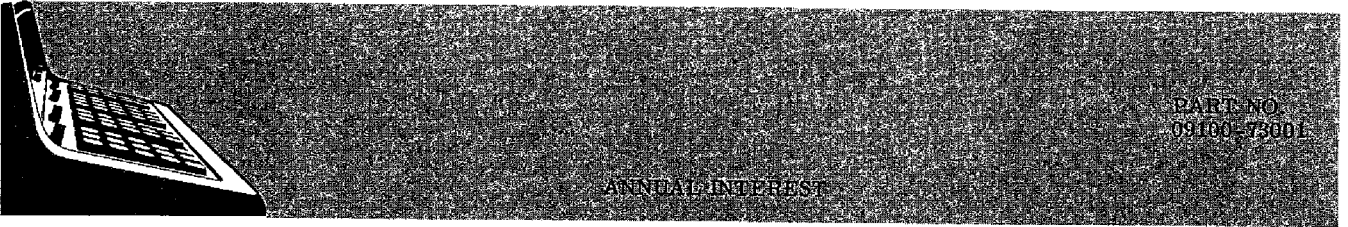
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	STOP	41	ϵ_1	ϵ_2	ϵ_3	ENTER $\epsilon_3, \epsilon_2, \epsilon_1$					
2	$y \rightarrow ()$	40									
3	F	15	STORE ϵ_2								
4	ROLL $\uparrow$	22									
5	$\uparrow$	27									
6	$\downarrow$	25	CALCULATE AND STORE $-\epsilon_1 - \epsilon_3$								
7	-	34									
8	$y \rightarrow ()$	40									
9	E	12									
10	ROLL $\uparrow$	22									
11	+	33									
12	F	15									
13	$\uparrow$	27									
1	0	02									
1	X	36	CALCULATE $(\epsilon_1 + \epsilon_3)$ AND $[2\epsilon_2 - (\epsilon_1 + \epsilon_3)]$								
2	$\downarrow$	25	AND STORE $[2\epsilon_2 - (\epsilon_1 + \epsilon_3)]$								
3	$x \leftrightarrow y$	30									
4	-	34									
5	E	12									
6	$y \rightarrow ()$	40									
7	F	15									
8	TO POLAR	62	CALCULATE $\gamma_{MAX.}$								
9	ROLL $\uparrow$	22									
10	$\uparrow$	27									
11	$\downarrow$	25									
12	+	33									
13	ROLL $\uparrow$	22									
2	-	34									
1	$x \rightarrow ()$	23									
2	d	17									
3	2	02	CALCULATE $\epsilon_{MIN.}$ AND $\epsilon_{MAX.}$								
4	$\div$	35	AND STORE $\gamma_{MAX.}, \epsilon_{MIN.},$ AND $\epsilon_{MAX.}$								
5	$y \rightarrow ()$	40									
6	C	16									
7	ROLL $\uparrow$	22									
8	$x \leftrightarrow y$	30									
9	$\div$	35									
10	$y \rightarrow ()$	40									
11	b	14									
12	d	17									
13	STOP	41	$\gamma_{MAX.}$	$\epsilon_{MAX.}$	$\epsilon_{MIN.}$	DISPLAY					

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Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	F	15								
	1	↑	27								
	2	E	12								
	3	÷	35								
	4	↓	25								
	5	arc v	72	CALCULATE θ_p							
	6	tan x	71								
	7	↑	27								
	8	2	02								
	9	÷	35								
	E	CLEAR x	37								
	b	↑	27								
	C	STOP	41	0	0	θ_p	DISPLAY				
	D	CONTINUE	47								
4	0	CONTINUE	47	ENTER μ AS A CONSTANT							
	1	CONTINUE	47								
	2	CONTINUE	47								
	3	x→()	23								
	4	F	15								
	5	↑	27								
	6	↑	27								
	7	b	14								
	8	x	36								
	9	C	16								
	E	+	33								
	b	y→()	40	CALCULATE AND STORE $\epsilon_{MAX.} + \mu \epsilon_{MIN.}$							
	C	E	12	AND $\epsilon_{MIN.} + \mu \epsilon_{MAX.}$							
	D	ROLL ↑	22								
5	0	x	36								
	1	↑	27								
	2	b	14								
	3	ROLL ↑	22								
	4	+	33								
	5	y→()	40								
	6	C	16								
	7	↓	25								
	8	1	01								
	9	+	33								
	E	2	02								
	b	x	36								
	C	CONTINUE	47								
	D	CONTINUE	47								

[illegible]

[illegible]



PART NO.
09100-73001

ANNUAL INTEREST

This program calculates i that satisfies the equation

$$R = P \frac{i(1+i)^n}{(1+i)^n - 1}$$

for a given R , P , and n .

where R = monthly payment

P = principal amount

n = number of monthly payments

i = monthly interest rate

The program uses this i and calculates and displays an annual interest.

The solution is based on a Newton-Raphson iteration technique which converges to a point which satisfies the condition

$$|i_K - i_{K-1}| \leq 10^{-9}$$

Note i_K is the K^{th} estimate of i and i_{K-1} is the $(K-1)^{\text{th}}$ estimate of i . The initial estimate of i is R/P unless otherwise specified. If the solution does not converge it may be necessary to enter a better initial estimate.

The value of i that satisfies the equation

$$f(i) = (1+i)^n (R - Pi) - R = 0$$

is found. The annual interest is displayed.

Reference: Principles of Engineering Economy
by E.L. Grant

Ronald Press, N.Y. 1950

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: P → Z, R → Y, n → X

NO

Initial Estimate for i
to be Entered?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: (estimated i percent)

 $i_{est} \% \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
i	—	X

(i is annual interest)

P = \$10,000

R = \$276.45

n = 40 months

i = 5.999% (Note: This is annual interest)

P = \$2500

R = \$81.95

n = 36 months

i = 11.087%

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
	2	STOP	41	N	R	P	ENTER N,R, AND P					
	3	ACC +	60	BRANCH FOR i_{est} ENTRY								
	4	ROLL ↑	22									
	5	$x \rightarrow ()$	23									
	6	d	17									
	7	IF FLAG	43									
	8	1	01									
	9	3	03									
a	ROLL ↑	22	GENERATE $i_{est} = \frac{R}{P}$									
b	$x \rightarrow y$	30										
c	÷	35										
d	↓	25										
1	0	GO TO (11)	44									
	1	2	02	BRANCH TO ITERATION								
	2	1	01									
	3	CLEAR x	37									
	4	↑	27									
	5	↑	27									
	6	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	7	STOP	41	i_{est}	0	0	ENTER i_{est} IN PERCENT					
	8	↑	27	CONVERT ANNUAL INTEREST RATE IN PERCENT TO MONTHLY RATE .								
	9	1	01									
a	2	02										
b	0	00										
c	0	00										
d	÷	35										
2	0	↓	25	CALCULATE AND STORE $(i_k + i)^n$								
	1	$x \rightarrow ()$	23									
	2	b	14									
	3	↑	27									
	4	1	01									
	5	+	33									
	6	↓	25									
	7	↑	27									
	8	ln x	65									
	9	ROLL ↑	22									
a	f	15										
b	x	36										
c	↓	25										
d	e^x	74										

FROM 6-c

Storage

Display

Step	Key	Code	x	y	z	f	e	d	c	b	a
3	0	$x \rightarrow ()$	23								
	1	$\square$	16								
	2	1	01								
	3	$x \leftrightarrow y$	30								
	4	$\div$	35								
	5	d	17								
	6	ROLL $\uparrow$	22								
	7	b	14								
	8	$\times$	36								
	9	e	12								
	$\oplus$	$x \leftrightarrow y$	30								
	b	$-$	34								
	$\square$	$\downarrow$	25								
	d	$\times$	36								
4	0	ROLL $\downarrow$	31								
	1	$x \leftrightarrow y$	30								
	2	f	15								
	3	$\times$	36								
	4	d	17								
	5	$-$	34								
	6	$\square$	16								
	7	$\times$	36								
	8	$x \leftrightarrow y$	30								
	9	ROLL $\downarrow$	31								
	$\oplus$	$\times$	36								
	b	e	12								
	$\square$	$-$	34								
	d	ROLL $\downarrow$	31								
5	0	$x \leftrightarrow y$	30								
	1	$\div$	35								
	2	b	14								
	3	$x \leftrightarrow y$	30								
	4	$-$	34								
	5	$x \leftrightarrow y$	30								
	6	$x \rightarrow ()$	23								
	7	b	14								
	8	$\uparrow$	27								
	9	1	01								
	$\oplus$	2	02								
	b	0	00								
	$\square$	0	00								

CALCULATE $f'(i_K) = (1+i_K)^n \left(\frac{n(R-Pi_K)}{1+i_K} - P \right)$

CALCULATE $f(i_K)$

CALCULATE $\frac{f(i_K)}{f'(i_K)}$

CALCULATE $i_{K+1} = i_K - \frac{f(i_K)}{f'(i_K)} = i_K - \Delta_K$

CONVERT i_{K+1} TO ANNUAL PERCENTAGE FOR DISPLAY

[⁶⁰] HEWLETT·PACKARD

HEWLETT-PACKARD

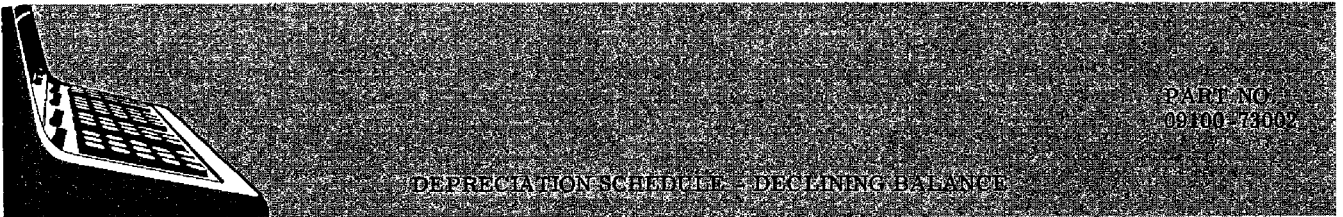
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[illegible]

[illegible]



DEPRECIATION SCHEDULE - DECLINING BALANCE

PART NO.
09100-73002

This program uses the declining balance technique for deriving the depreciation schedule for an asset,

Given: IC = Initial Cost, (dollars)
S = Salvage Value, (dollars)
N = Asset Life, (periods)

The program will pause, displaying the number, i, of the depreciation period, then display:

DC_i = Depreciation charge for period i.
AD_i = Accum. depreciation at end of period i.
BV_i = Book asset value at end of period i.

After each period's display, CONTINUE will cause the values for the next period to appear. After period N, CONTINUE will enable the program to receive another set of input data.

The equations used are

Depreciation charge for period i:

$$DC_i = R \times BV_{i-1}$$

$$\text{where } R = 1 - \sqrt[N]{\frac{S}{IC}}$$

(N, S, and IC given above)

BV_{i-1} = Book Value at beginning of period

i = No. of Period

Reference: Financial Accounting
by E.A. Spiller Jr.

Irwin, Inc. 1966

USER INSTRUCTIONS

EXAMPLES

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: N → Z, K → Y, S → X

Z = 0 Put N periods in Z

Y = 0 Put Initial Cost \$ in Y

X = 0 Put Salvage Value \$ in X

i = 1

PRESS: CONTINUE

NO

N > i?

YES

DISPLAY
(PAUSE)

Z = i

Y = i

X = i

i =

No. of Period

DISPLAY

Z = DC_i

Y = AD_i

X = BV_i

PRESS: CONTINUE

increment i

Given: N = 5

IC = \$10,000

S = \$1,000

Then, when i = 1; $DC_1 = \$3690.43$

$AD_1 = 3690.43$

$BV_1 = 6309.57$

i = 2; $DC_2 = \$2328.50$

$AD_2 = 6018.93$

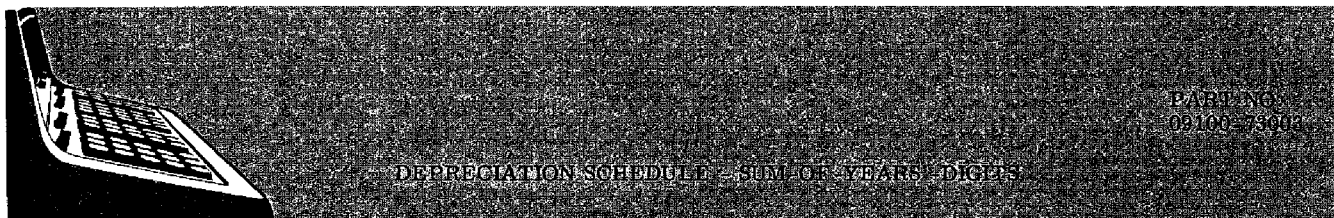
$BV_2 = 3981.07$

i = 5; $DC_5 = \$ 584.89$

$AD_5 = 9000.00$

$BV_5 = 1000.00$

[illegible]



PART NO.
09100-73003

DEPRECIATION SCHEDULE - SUM-OF-YEARS' DIGITS

This program uses the sum-of-the-years'-digits technique for deriving the depreciation schedule for an asset.

Given: IC = Initial Cost, (dollars)
S = Salvage Value, (dollars)
N = Asset Life, (periods)

The program will pause, displaying the number, i, of the depreciation period, then display:

DC_i = Depreciation charge for period i.
 AD_i = Accum. depreciation, to date (i).
 BV_i = Book asset value at end of period i.

After each period's display, CONTINUE will cause the values for the next period to appear. After period N, CONTINUE will enable the program to receive another set of input data.

Equations used are:

Depreciation charge for period i:

$$DC_i = (N - i + 1) \cdot \frac{DB}{SYD}$$

where:

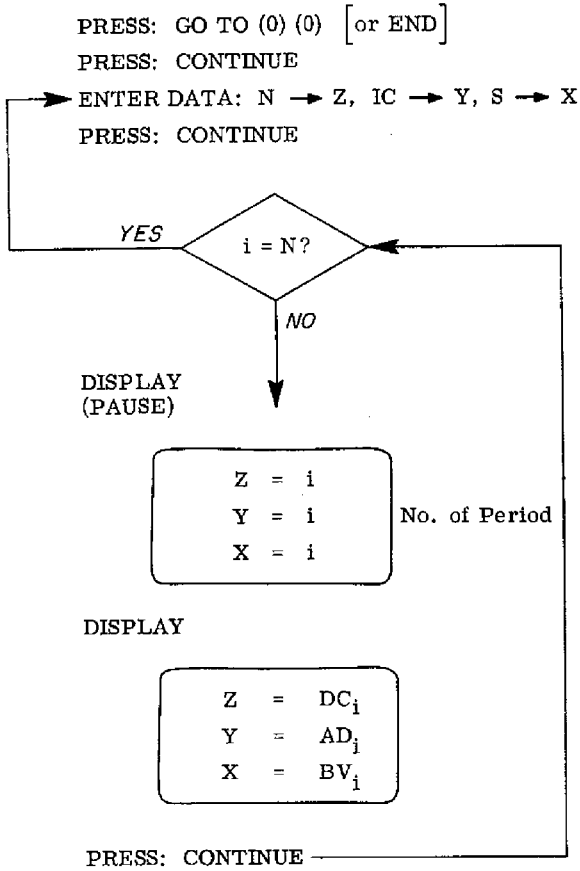
N = Asset Life, periods
i = No. of period
DB = Depreciation Base
= Initial Cost, less salvage
= IC - S
SYD = Sum of Years' Digits
= $\frac{N(N+1)}{2}$

Reference: Financial Accounting
by E.A. Spiller Jr.

Irwin, Inc. 1966

USER INSTRUCTIONS

EXAMPLES



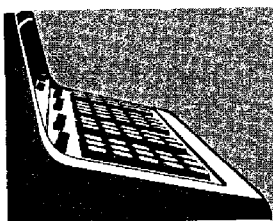
Given: $N = 5$
 $IC = \$10,000$
 $S = \$1,000$

Then, when $i = 3$:

$DC_i = \$1,800$
 $AD_i = \$7,200$
 $BV_i = \$2,800$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	STOP	41	S	IC	N	ENTER	N, IC, S			
2	2	$y \rightarrow ()$	40	STORE IC							
3	3	F	15								
4	4	-	34								
5	5	1	01								
6	6	ROLL $\uparrow$	22								
7	7	$x \rightarrow ()$	23								
8	8	d	17	CALCULATE SYD							
9	9	+	33								
a	a	x	36								
b	b	2	02								
c	c	$\div$	35								
d	d	0	00								
1	0	$x \rightarrow ()$	23	INITIALIZE COUNTER							
1	c		16								
2	2	ROLL $\downarrow$	31	CALCULATE $\frac{DB}{SYD}$							
3	3	$\div$	35								
4	4	$y \rightarrow ()$	40								
5	5	b	14								
6	6	b	14								
7	7	$\uparrow$	27								
8	8	d	17								
9	9	$\uparrow$	27								
a	a	c	16	BRANCH IF $i - 1 = N$							
b	b	IF $x = y$	50								
c	c	0	00								
d	d	0	00								
2	0	-	34	CALCULATE DC_i							
1	1	ROLL $\downarrow$	31								
2	2	x	36								
3	3	$\downarrow$	25	CALCULATE $BV_i = BV_{i-1} - DC_i$							
4	4	$\uparrow$	27	AND $AD_i = AD_{i-1} + DC_i$							
5	5	CHG SIGN	32								
6	6	ACC +	60								
7	7	$y \rightarrow ()$	40								
8	8	a	13								
9	9	$\downarrow$	25								
a	a	1	01								
b	b	+	33	INCREMENT i AND							
c	c	$\downarrow$	25	POSITION i IN X, Y, AND Z							
d	d	$\uparrow$	27								

FROM 4-0



PART NO.
69100-73004

COMPOUND INTEREST

This program uses compound interest factors to compute present and future worth and a uniform series of payments. Given:

i = Interest rate in percent per period

n = Time in no. of periods

plus one of the following amounts, the program will solve for the other two amounts, displaying all three.

P = Present Sum

R = End-of-Period Payment

S = Future Sum

After computation, the program can be directed to accept another value of P , R , or S at the same i and n .

Single Payment Compound Amount

$$S = P(1 + i)^n$$

Single Payment Present Worth

$$P = S \frac{1}{(1 + i)^n}$$

Sinking Fund

$$R = S \left[\frac{i}{(1 + i)^n - 1} \right]$$

Capital Recovery

$$R = P \left[\frac{i(1 + i)^n}{(1 + i)^n - 1} \right]$$

Uniform Series Compound Amount

$$S = R \left[\frac{(1 + i)^n - 1}{i} \right]$$

Uniform Series Present Worth

$$P = R \left[\frac{(1 + i)^n - 1}{i(1 + i)^n} \right]$$

Reference: Principles of Engineering Economy
by E.L. Grant

Ronald Press

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

Z - 0
Y - 0
X - 1

ENTER DATA: $i\%$ → X

PRESS: CONTINUE

DISPLAY

Z - 0
Y - 0
X - 2

ENTER DATA: n → X

PRESS: CONTINUE

DISPLAY

Z - 0
Y - 0
X - 3

ENTER DATA: P → X (Enter 0 if P not given)

PRESS: CONTINUE

DISPLAY

Z - 0
Y - P
X - 4

ENTER DATA: R → X (Enter 0 if R not given)

PRESS: CONTINUE

DISPLAY

Z - P
Y - R
X - S

ENTER DATA: S → X (Enter 0 if S not given)

PRESS: CONTINUE

DISPLAY

Z - P
Y - R
X - S

new i and n ?

NO

PRESS: CONTINUE

YES

PRESS: SET FLAG

PRESS: CONTINUE

EXAMPLES

- 1 Given P , Find R and S (i and n are always given)

$i = 5\%$
 $n = 10$ periods
 $P = \$100$
 $R = \$12.95$
 $S = \$162.89$

- 2 Given R , Find P and S

$i = 6\%$
 $n = 15$ periods
 $R = \$15.00$
 $P = \$145.68$
 $S = \$349.14$

- 3 Given S , Find P and R

$i = 6\%$
 $n = 15$ periods
 $S = \$1000$
 $P = \$417.27$
 $R = \$42.92$

} same as example 2

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	STOP	41	i%	0	0	ENTER i%					
3	↑	27									
4	1	01									
5	0	00									
6	0	00	CONVERT i% TO A DECIMAL EQUIVALENT								
7	÷	35									
8	y→()	40									
9	d	17									
	CLEAR	20									
	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	STOP	41	n	0	0	ENTER n PERIODS					
	↑	27									
1	d	17									
	↑	27									
	1	01									
	+	33									
	ROLL ↓	31									
	ln x	65	CALCULATE $(1+i)^n$								
	x	36									
	↓	25									
	e^x	74									
	x→()	23									
	C	16									
	ROLL ↑	22									
	-	34	CALCULATE $(1+i)^n - 1$								
	y→()	40									
2	0	14									
	CLEAR	20									
	3	03	DISPLAY 3 TO INDICATE THIRD ENTRY								
	STOP	41	P	0	0	ENTER P					
	↑	27									
	4	04	DISPLAY 4 TO INDICATE FOURTH ENTRY								
	STOP	41	R	P	0	ENTER R					
	↑	27									
	5	05	DISPLAY 5 TO INDICATE FIFTH ENTRY								
	STOP	41	S	R	P	ENTER S					
	IF x=y	50									
	5	05									
	4	04	TEST TO DETERMINE UNKNOWN								
	IF x < y	52									

HEWLETT-PACKARD
FROM 6-3

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD
FROM 6-6

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	4	04								
	1	2	02								
	2	$x \rightarrow ()$	23								
	3	f	15								
	4	$\uparrow$	27								
	5	c	16								
	6	$\div$	35								
	7	d	17	GIVEN S, CALCULATE P AND R							
	8	$\uparrow$	27								
	9	b	14								
	a	$\div$	35								
	b	f	15								
	c	x	36								
	d	GOTO (X)	44								
4	0	6	06	BRANCH TO DISPLAY							
	1	0	00								
	2	$y \rightarrow ()$	40								
	3	f	15								
	4	b	14								
	5	x	36								
	6	d	17								
	7	$\div$	35								
	8	$y \rightarrow ()$	40	GIVEN R, CALCULATE P AND S							
	9	e	12								
	a	c	16								
	b	$\div$	35								
	c	f	15								
	d	$\uparrow$	27								
5	0	e	12								
	1	GOTO () ()	44								
	2	6	06	BRANCH TO DISPLAY							
	3	0	00								
	4	$\downarrow$	25								
	5	c	16								
	6	x	36								
	7	$y \rightarrow ()$	40								
	8	f	15	GIVEN P, CALCULATE R AND S							
	9	d	17								
	a	x	36								
	b	b	14								
	c	$\div$	35								
	d	f	15								

FROM 2-c

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	STOP	41	S	R	P	DISPLAY					
1	IF FLAG	43									
2	0	00	BRANCH TO INITIAL ENTRY								
3	0	00									
4	GOTO ()	44									
5	2	02	BRANCH FOR P,R, AND S ENTRIES WITH SAME AND n								
6	1	01									
7	END	46									
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

HEWLETT-PACKARD
FROM 4-1 AND 5-3

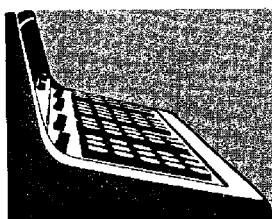
HEWLETT-PACKARD

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HEWLETT-PACKARD

HEWLETT-PACKARD

[illegible]



PART NO.
09100-78006

PRESENT VALUE OF A SERIES OF CASH FLOWS

This program evaluates the present value of a series of cash flows. The equation used is:

$$\text{Present Value (P.V.)} = \sum_{K=1}^N \frac{CF_K}{(1+i)^K}$$

CF_K = Cash flow per period

i = Discount rate per period

This program will accomodate any number of different cash flows. Each flow can be an inflow, outflow or zero.

Reference: Financial Management - An Analytical Approach
by J. Robert Lindsay
Arnold W. Sametz

Richard D. Irwin, Inc. 1967

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA: $i\%$ $\rightarrow$ X

PRESS: CONTINUE

DISPLAY

0 — Z
0 — Y
K — X

(K indicates cash flow to be entered)

ENTER DATA: CF_K $\rightarrow$ X

PRESS: CONTINUE

NO

Last Entry?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0 — Z
N — Y
P.V. — X

Number of periods in Y
Present value in X

Sample Data

 $i = 6\%$

Cash Flow

Year-K	Amount in $\$-C_K$
1	25,000
2	17,500
3	10,000
4	5,000
5	19,000

N = 5

P. V. = \$65,714.41

Sample Data

 $i = 5.75\%$

Cash Flow

Year-K	Amount in $\$-C_K$
1	-5,000
2	-2,500
3	0
4	4,000
5	10,000
6	25,000

N = 6

P. V. = \$21,671.60

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	$x \rightarrow ()$	23									
2	$\bar{a}$	13	CLEARS DISPLAY AND STORAGE REGISTERS								
3	$x \rightarrow ()$	23									
4	$\bar{c}$	16									
5	STOP	41	i%	0	0	ENTER i%					
6	$\uparrow$	27									
7	ENTER EXP	26									
8	2	02									
9	$\div$	35	CALCULATE AND STORE $(1+i)$								
$\bar{a}$	1	01									
$\bar{b}$	+	33									
$\bar{c}$	$y \rightarrow ()$	40									
$\bar{d}$	$\bar{d}$	17									
1	0	$\bar{c}$	16								
1	$\uparrow$	27									
2	1	01	CALCULATE AND STORE K								
3	+	33									
4	$y \rightarrow ()$	40									
5	$\bar{c}$	16									
6	$\bar{d}$	17									
7	$\ln x$	65									
8	$\times$	36	CALCULATE AND STORE $(1+i)^K$								
9	$x \rightarrow y$	30									
$\bar{a}$	e^x	74									
$\bar{b}$	$x \rightarrow ()$	23									
$\bar{c}$	$\bar{b}$	14									
$\bar{d}$	CLEAR	20									
2	0	$\bar{c}$	16	DISPLAY K TO INDICATE CF_K ENTRY							
1	STOP	41	CF_K	0	0	ENTER CF_K					
2	IF FLAG	43									
3	3	03	BRANCH AFTER LAST ENTRY								
4	1	01									
5	$\uparrow$	27									
6	$\bar{b}$	14									
7	$\div$	35	CALCULATE AND STORE PARTIAL SUM								
8	$\bar{a}$	13									
9	+	33									
$\bar{a}$	$y \rightarrow ()$	40									
$\bar{b}$	$\bar{a}$	13									
$\bar{c}$	GO TO ()	44									
$\bar{d}$	1	01	RETURN FOR NEXT ENTRY								

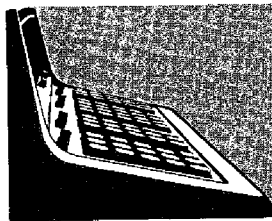
FROM 3-1

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	00									
1	CLEAR	20									
2	C	16									
3	↑	27									
4	1	01									
5	—	34									
6	B	13									
7	END	46	PRESENT VALUE	n	0	DISPLAY					
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

FROM 2-4

POSITION DISPLAY

DISPLAY



SINGLE AND DOUBLE EXPONENTIAL SMOOTHING AND FORECASTING

PART NO.
09100-73006

This program provides a means of smoothing input data (number of orders, etc.), up-dating past smoothed data by entering new orders, and obtaining future estimates of orders at any time for any number of time periods in the future.

Development

Single smoothed data is obtained by adding the previous number of orders to a fraction of the amount by which orders this period (month, year, etc.) differ from the old average. This result is then corrected for any trend which appears in the order data to obtain double smoothed data. In the case of single exponential smoothing, the single smoothed data for the current month is the estimate of orders for the next period; for this case only one future estimate (that of the next period) can be obtained. For double exponential smoothing, additional calculations are made to obtain a future estimate of orders, and an estimate for any period in the future may be obtained.

The following notations are used:

X_n = orders $[n]$ = this period's orders

α = smoothing constant

$S_n(X)$ = single smoothed result of this period's orders

$S_n^{[2]}(X)$ = double smoothed result of this period's orders

$EO[n+i]$ = the double smoothed estimated orders for some period in the future (the period is identified by the number $[n+i]$ where $i = 0, 1, 2, 3, \dots, n$).

The following equations used are:

$$S_n(X) = \alpha X_n + \beta S_{(n-1)}(X) \text{ where } \beta = 1 - \alpha$$

$$S_n^{[2]}(X) = \alpha S_n(X) + \beta S_{(n-1)}^{[2]}(X)$$

$$\hat{a}_n = 2S_n(X) - S_n^{[2]}(X)$$

$$\hat{b}_n = \frac{\alpha}{\beta} [S_n(X) - S_n^{[2]}(X)]$$

$$EO[n+i] = \hat{a}_n + \hat{b}_n(i) \quad (\text{double smoothed estimate})$$

NOTE: Subscripts $(n-1)$ imply the period immediately preceding the current period (n) .

The smoothing constant (α) is the fraction by which current orders are weighted with respect to past order information. If $\alpha = .3$, then the current observation has weight .3 and past smoothed information has weight .7; i.e., the current observation has 3/7 as much importance as the previous average. In application, if one has a great deal of confidence in the prediction of initial conditions, (past smoothed information) a small value of α will be used. If one has little confidence in an initial prediction, then a larger α will be used so that the initial conditions will quickly be discounted.

Both single and double smoothing techniques require at least one past observation. Usually the past period's orders or an average of the orders of several past periods is used, in conjunction with the current period's orders, as a starting point. In this case, it is normally assumed that there is no trend associated with the first order input and therefore orders $[1] = S_1(X) = S_1^{[2]}(X)$. If one has previously smoothed data to use as a reference and/or if an initial trend of zero is undesirable, then initial smoothed data $[S_0(X) \text{ and } S_0^{[2]}(X)]$ may be used (the procedure is outlined in the User Instructions). If no previous smoothed data is available, then $[S_0(X) \text{ and } S_0^{[2]}(X)]$ may be estimated by the following equations:

$$S_0(X) = \hat{a}_0 - \beta/\alpha \hat{b}_0$$

$$S_0^{[2]}(X) = \hat{a}_0 - 2\beta/\alpha \hat{b}_0$$

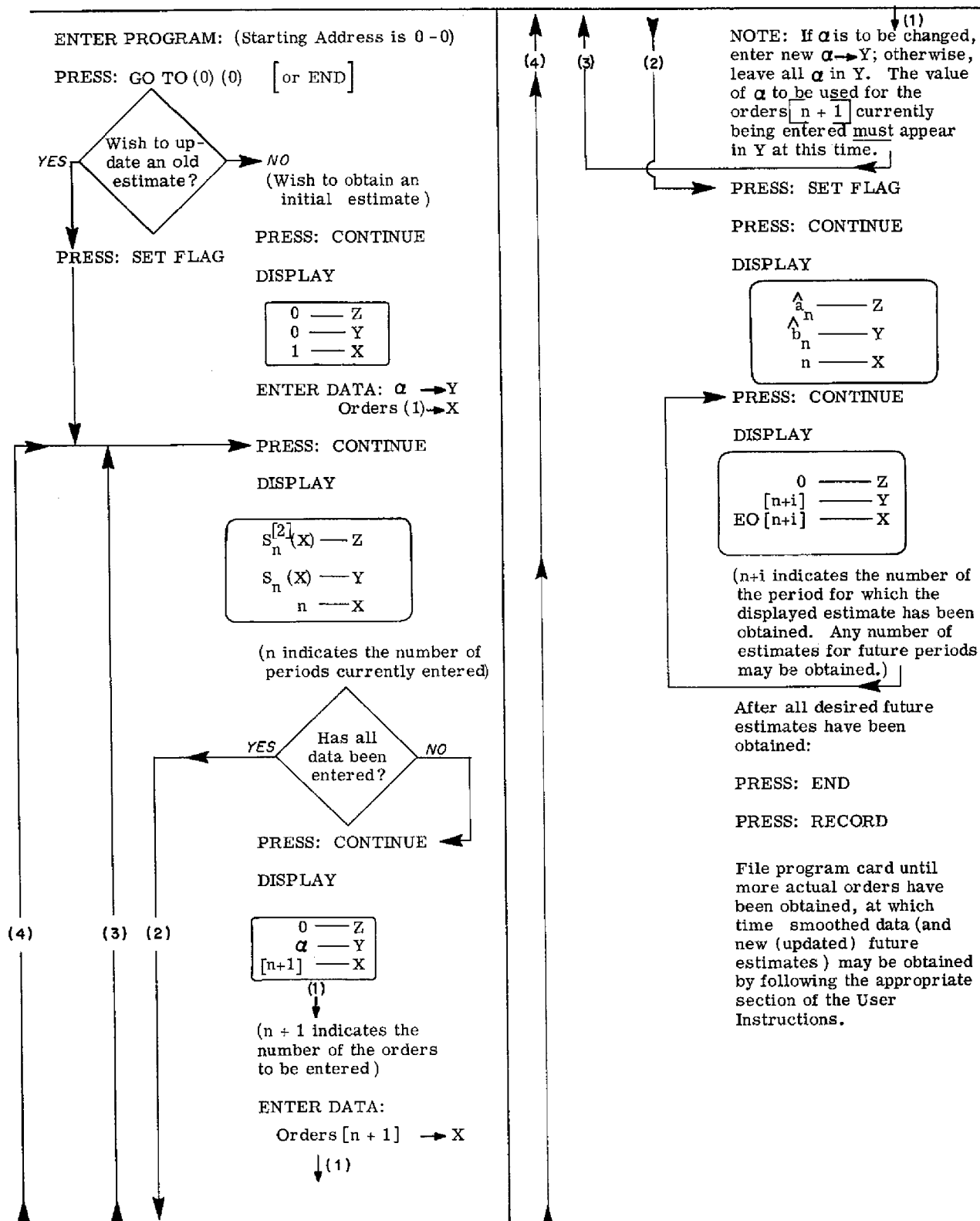
where the values of $\hat{a}_0$, $\hat{b}_0$, and α are chosen by the user as he deems appropriate.

Reference: Smoothing, Forecasting and Predication of Discrete Time Series

Robert Goodell Brown
Prentice-Hall, Inc.

USER INSTRUCTIONS

USER INSTRUCTIONS (Con't)



ALTERNATE USER INSTRUCTIONS

EXAMPLE

If one has previously evaluated smoothed data and therefore does not wish to assume the linear coefficient is equal to zero (when entering data to obtain an initial estimate), use the following instructions:

ENTER PROGRAM: (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

(4)

0	—	Z
0	—	Y
1	—	X

ENTER DATA: S_0 (X) $\rightarrow$ Y, $S_0^{[2]}$ (X) $\rightarrow$ X

(1 indicates the initial value of the smoothed data)

PRESS: Y $\rightarrow$

PRESS: b

PRESS: X $\rightarrow$

PRESS: 9

ENTER DATA: n $\rightarrow$ X

(n is the number of the order that is to be entered next; n must not be equal to 1)

PRESS: X $\rightarrow$

PRESS: $\exists$

ENTER DATA: a $\rightarrow$ Y, orders [n] $\rightarrow$ X

Data:	Period	Orders
	1	196.6
	2	189
	3	244
	4	209
($\alpha = .1$)	5	207
	6	211

Results:	Period	Smoothed Data	Double Smoothed Data
	1	196.60	196.60
	2	195.84	196.52
	3	200.66	196.94
	4	201.49	197.39
	5	202.04	197.86
	6	202.94	198.37

$$\hat{a}_6 = 207.51; \hat{b}_6 = .51$$

Estimates for future periods:

Period	Double Smoothed Estimate
7	208.02
8	208.53
9	209.03
10	209.54
11	210.05
12	210.56

After obtaining the twelfth estimate, record the obtained results on the program card. Now assume that after a period of time, more actual orders have been obtained and we wish to up-date the last smoothed value and make new future estimations.

Re-enter the program card and follow the USER INSTRUCTIONS for up-dating an old estimate.

New Data:	Period	Orders
	7	250
($\alpha = .1$)	8	210
	9	236

Results:	Period	Smoothed Data	Double Smoothed Data
	7	207.64	199.29
	8	207.88	200.15
	9	210.69	201.21

$$\hat{a}_9 = 220.18; \hat{b}_9 = 1.05$$

Estimates for future orders:

Period	Double Smoothed Estimate
10	221.23
11	222.28
12	223.34

[769] HEWLETT-PACKARD [762] HEWLETT-PACKARD [749] HEWLETT-PACKARD [746] HEWLETT-PACKARD [745] HEWLETT-PACKARD

Step	Key	Code	Display			Storage															
			x	y	z	f	e	d	c	b	a										
0	0	IF FLAG	43	BRANCH TO OBTAIN THE LAST SMOOTHED DATA																	
	1	3	03																		
	2	4	04																		
	3	CLEAR	20																		
	4	$x \rightarrow ()$	23	CLEAR APPROPRIATE STORAGE REGISTERS.																	
	5	C	16																		
	6	$x \rightarrow ()$	23																		
	7	B	13																		
	8	↑	27	INCREMENT COUNTER (n)																	
	9	1	01																		
a	+	33																			
b	$y \rightarrow ()$	40																			
1	c	B	13	FROM 4-5																	
	d	C	16																		
	0	$x \rightleftharpoons y$	30										DISPLAY n AND α AND ENTER ORDERS [n]								
	1	STOP	41																		
	2	$x \rightleftharpoons y$	30																		
	3	$x \rightarrow ()$	23	STORE α																	
	4	C	16																		
	5	1	01																		
	6	↑	27																		
	7	B	13	BRANCH IF n=1 TO STORE $S_1(X)$, $S_1^{[2]}(X)$																	
8	IF $x=y$	50																			
9	4	04																			
a	6	06																			
2	b	C	16	ROLL ↑																	
	c	-	34																		
	d	ROLL ↑	22																		
	0	X	36										CALCULATE AND STORE $S_n(X)$ AND $S_n^{[2]}(X)$								
	1	b	14																		
	2	ROLL ↑	22																		
	3	X	36																		
	4	ROLL ↓	31	ROLL ↑																	
	5	+	33																		
	6	$y \rightarrow ()$	40																		
7	b	14																			
8	C	16	CALCULATE AND STORE $S_n(X)$ AND $S_n^{[2]}(X)$																		
9	X	36																			
a	ROLL ↑	22																			
b	$y \rightarrow ()$	24																			
	c	9	11	ROLL ↑																	
	d	X	36																		

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	ROLL ↓	31								
	1	+	33								
	2	y→()	40								
	3	9	11								
	4	y←()	24								
	5	9	11								
	6	y→()	40								
	7	9	11								
	8	b	14								
	9	↑	27								
	a	a	13								
	b	STOP	41								
	c	IF FLAG	43								
	d	5	05								
	0	0	00								
	1	CLEAR x	37								
	2	↑	27								
	3	GOTO () ()	44								
	4	0	00								
	5	7	07								
	6	↓	25								
	7	y→()	40								
	8	b	14								
	9	y→()	40								
	a	9	11								
	b	GOTO () ()	44								
	c	3	03								
	d	a	13								
	0	2	02								
	1	x←y	30								
	2	x	36								
	3	ROLL ↑	22								
	4	-	34								
	5	CHG SIGN	32								
	6	ROLL ↑	22								
	7	+	33								
	8	y←()	24								
	9	c	16								
	a	1	01								
	b	x←y	30								
	c	-	34								
	d	÷	35								

RECALL $S_n(X)$ AND n
FOR DISPLAY

BRANCH TO CALCULATE $\hat{a}_n$
AND $\hat{b}_n$ IF FLAG IS SET

BRANCH TO ENTER
NEW DATA (ORDERS n)

STORE $S_1(X)$ AND $S_1^{[2]}X$ AND BRANCH TO
ENTER NEXT DATA (ORDERS $[2]$)

CALCULATE $\hat{a}_n$ AND $\hat{b}_n$

DISPLAY

FROM 1-A

4-0

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	$x \div y$	30								
	1	$y \div ()$	24								
	2	C	16								
	3	ROLL $\uparrow$	22								
	4	$x \div y$	30								
	5	$\div$	35								
	6	B	13								
	7	STOP	41	n	$\hat{b}_n$	$\hat{a}_n$	DISPLAY				
	8	ROLL $\downarrow$	31								
	9	$x \rightarrow ()$	23								
	B	E	12	STORE $\hat{a}_n$ AND $\hat{b}_n$							
	b	$y \rightarrow ()$	40								
	C	F	15								
	d	CLEAR X	37								
7	0	$\uparrow$	27								
	1	1	01	INCREMENT COUNTER (n')							
	2	+	33	TO CALCULATE FUTURE ESTIMATES							
	3	$\uparrow$	27								
	4	$\downarrow$	25								
	5	B	13								
	6	+	33								
	7	E	12	CALCULATE $EO[n+n']$							
	8	ROLL $\uparrow$	22								
	9	X	36								
	B	F	15								
	b	+	33								
	C	CLEAR X	37								
	d	ROLL $\downarrow$	31								
8	0	STOP	41	$EO[n+n']$	$n+n'$	0	DISPLAY				
	1	B	13	RESTORE THE VALUE OF n'							
	2	-	34								
	3	GOTO () ()	44	BRANCH TO CALCULATE ANOTHER ESTIMATE							
	4	7	07								
	5	1	01								
	6	END	46								
	7										
	8										
	9										
	B										
	b										
	C										
	d										

HEWLETT-PACKARD

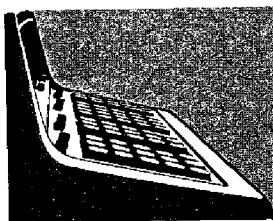
HEWLETT-PACKARD

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[illegible]


 PART NO.
69180-73007

TRIPLE EXPONENTIAL SMOOTHING AND FORECASTING

This program exponentially smooths input data such as a time series, and forecasts future values of the series. The smoothing equation has the following general form:

$$\text{Average [period N]} = \text{average [period (N - 1)]} + \alpha \{ \text{new data [period N]} - \text{average [period (n-1)]} \}$$

The smoothing constant α is the fraction by which current data is weighed with respect to past data. If $\alpha = .3$, the past single exponentially smoothed data has weight .7. The new data entry has weight .3. A value between 0 and 1 is assigned to α depending on how much the user wishes to weight past smoothed data with respect to current data.

The input data is smoothed according to these equations:

$$S_n(X) = \alpha X_n + \beta S_{n-1}(X)$$

$$S_n^{[2]}(X) = \alpha S_n(X) + \beta S_{n-1}^{[2]}(X)$$

$$S_n^{[3]}(X) = \alpha S_n^{[2]}(X) + \beta S_{n-1}^{[3]}(X)$$

where

$$X_n = \text{value of variable of period N}$$

$$S_n = \text{single exponentially smoothed average for period N}$$

$$S_n^{[2]} = \text{double exponentially smoothed average for period N}$$

$$S_n^{[3]} = \text{triple exponentially smoothed average for period N}$$

$$\beta = 1 - \alpha$$

The forecast is based on a quadratic model:

$$EO(n+i) = \hat{a}_0 + \hat{a}_1(i) + 1/2 \hat{a}_2(i^2)$$

$EO(n+i)$ = expected value of the variable (X) i periods in the future.

$\hat{a}_0, \hat{a}_1, \hat{a}_2$ = estimates of the model parameters.

These parameters are estimated from the smoothed data as follows:

$$\hat{a}_0(n) = 3S_n(X) - 3S_n^{[2]}(X) + S_n^{[3]}(X)$$

$$\hat{a}_1(n) = \frac{\alpha}{2\beta^2} \left[(6 - 5\alpha) S_n(X) - 2(5 - 4\alpha) S_n^{[2]}(X) + (4 - 3\alpha) S_n^{[3]}(X) \right]$$

$$\hat{a}_2(n) = \frac{\alpha^2}{\beta^2} \left[S_n(X) - 2S_n^{[2]}(X) + S_n^{[3]}(X) \right]$$

If one does not have previously smoothed data, the program calculates initial values for the smoothed data; it is necessary for the user to input his initial estimates of the model parameters $\hat{a}_0, \hat{a}_1, \hat{a}_2$. These may be estimated from the first few data points.

Letting $a_2 = 0$ simplifies calculation of the initial estimate and usually does not appreciably affect the smoothed data (particularly if α is large). With $\hat{a}_2 = 0$, the model is a linear one where $\hat{a}_1$ is an estimate of the initial slope and $\hat{a}_0$ is an estimate of the Y intercept.

These equations are used to get initial estimates for the smoothed data:

$$S_0(X) = \hat{a}_0(0) - \frac{\beta}{\alpha} \cdot \hat{a}_1(0) + \frac{\beta(2-\alpha)}{2\alpha} \cdot \hat{a}_2(0)$$

$$S_0^{[2]}(X) = \hat{a}_0(0) - \frac{2\beta}{\alpha} \cdot \hat{a}_1(0) + \frac{\beta(3-2\alpha)}{\alpha^2} \cdot \hat{a}_2(0)$$

$$S_0^{[3]}(X) = \hat{a}_0(0) - \frac{3\beta}{\alpha} \cdot \hat{a}_1(0) + \frac{3\beta(4-3\alpha)}{2\alpha^2} \cdot \hat{a}_2(0)$$

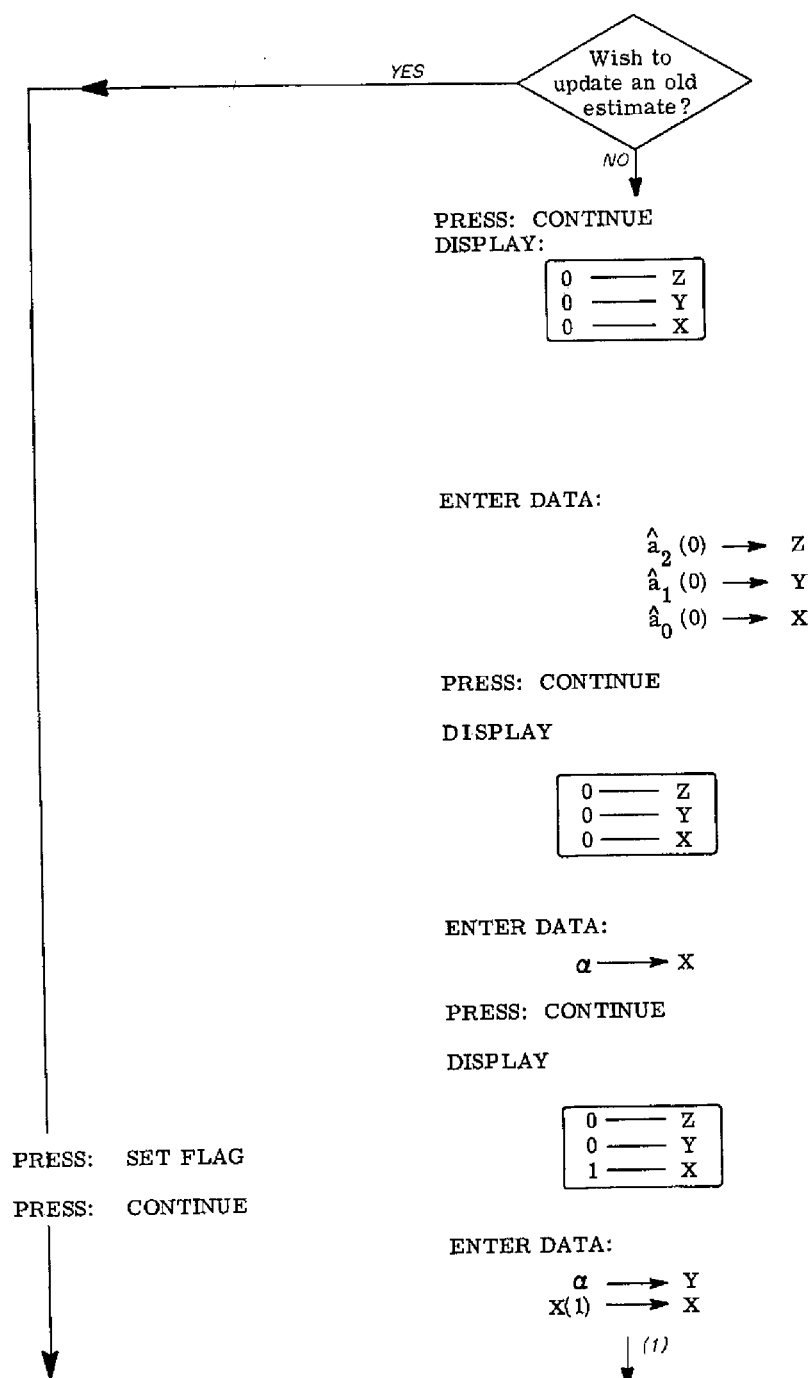
If one has previously smoothed data not recorded on the magnetic card, and hence not stored as part of the program, it is easy to correct this. After recording the program from the magnetic card, manually store $S_0(X)$ in the "a" register, $S_0^{[2]}(X)$ in the "b" register, and $S_0^{[3]}(X)$ in the "c" register. Now follow the instructions as if this data had been recorded from the magnetic card.

Reference:

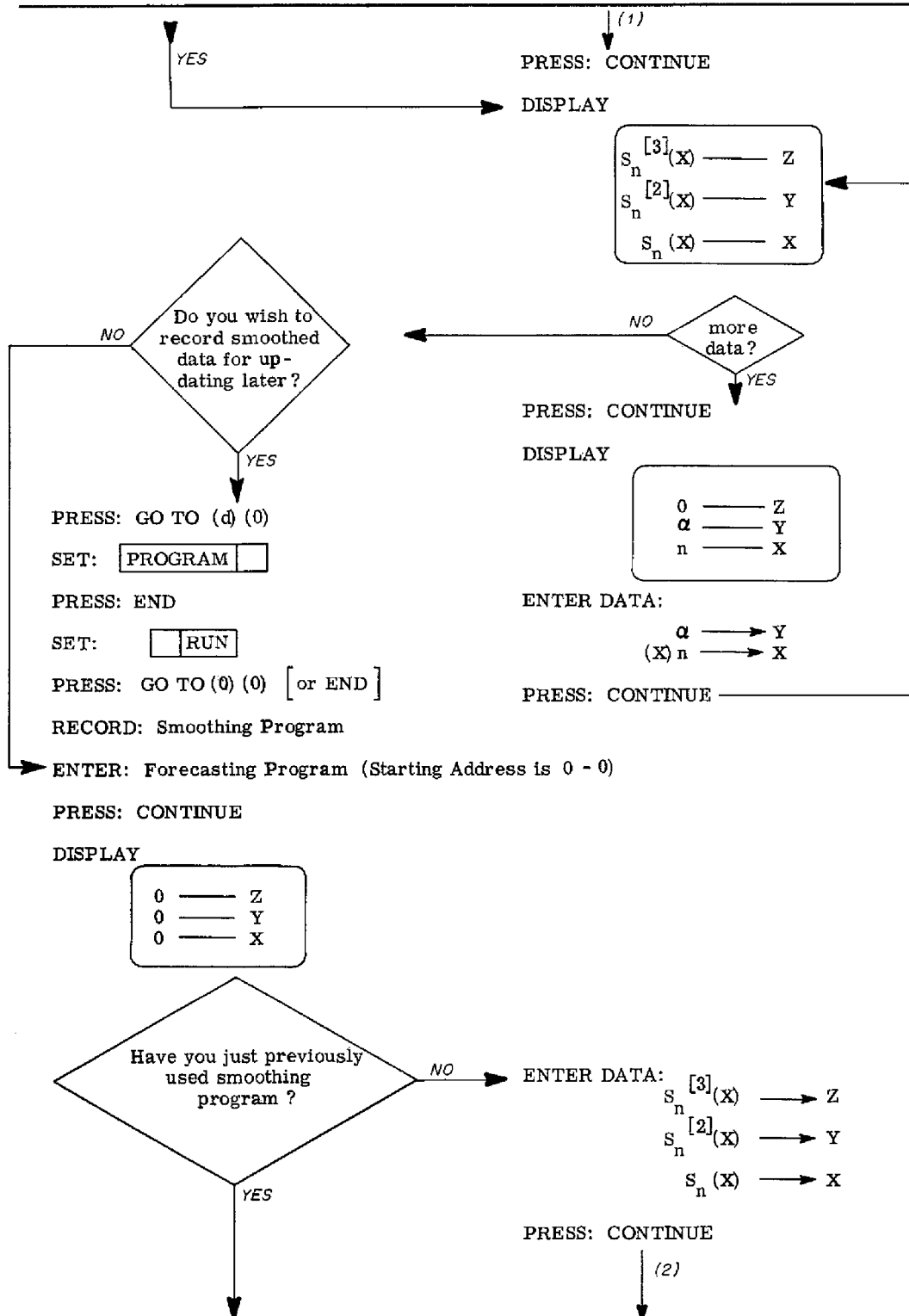
Smoothing, Forecasting & Predication of Discrete Time Series
Robert Goodell Brown
Prentice-Hall

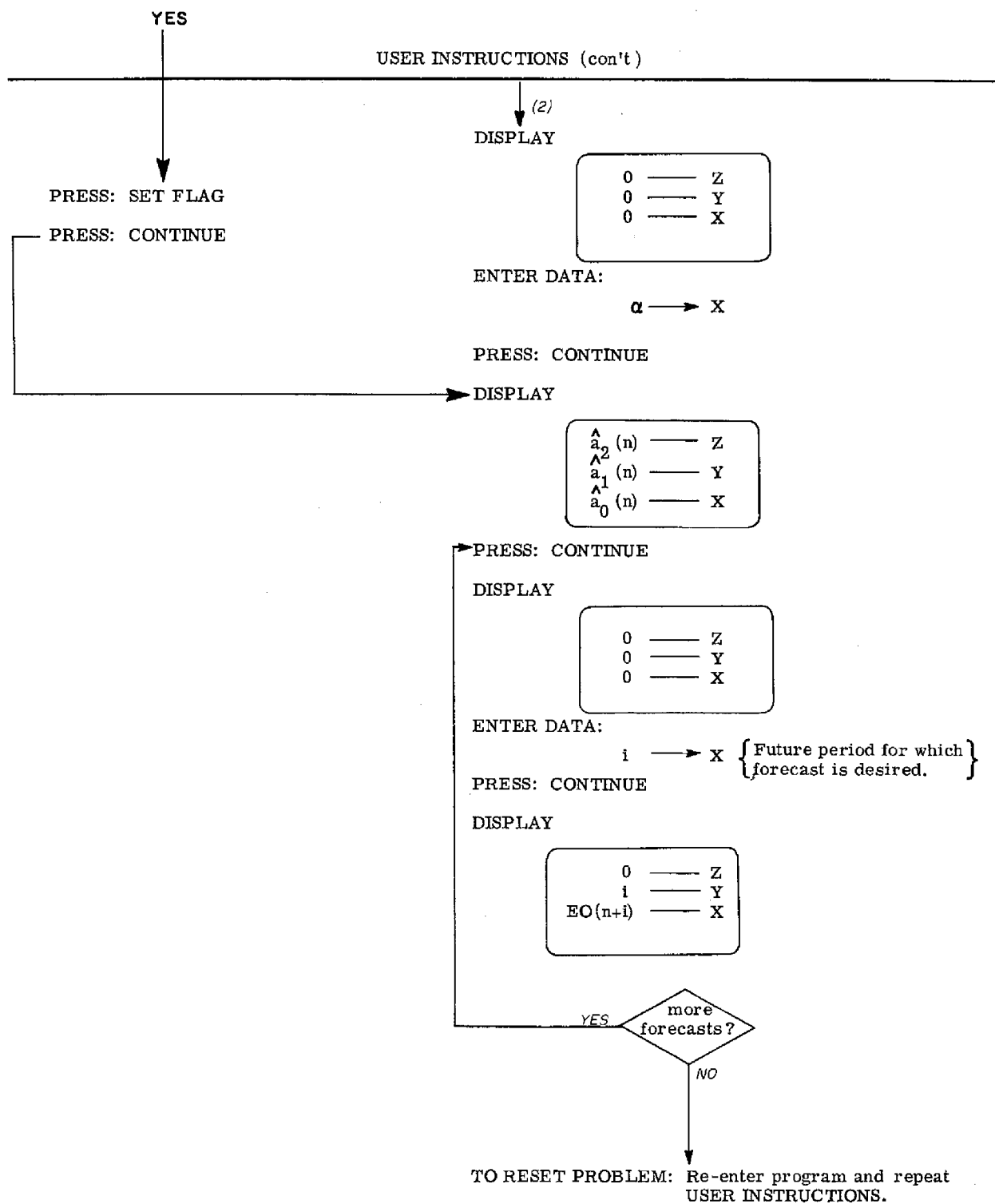
USER INSTRUCTIONS

ENTER: Smoothing Program (Starting Address is 0 - 0)



USER INSTRUCTIONS (con't)





EXAMPLE

Given the following initial conditions and data, calculate the smoothed values, model parameters for the second period, and forecasts for the next two periods.

Data:

$$\begin{aligned}\alpha &= .05 \\ x_1 &= 510.2 \\ x_2 &= 520.8\end{aligned}$$

Initial conditions:

$$\begin{aligned}\hat{a}_0(0) &= 500 \\ \hat{a}_1(0) &= 10 \\ \hat{a}_2(0) &= .4\end{aligned}$$

Solution:

n	x_n	$S_n(X)$	$S_n^{[2]}(X)$	$S_n^{[3]}(X)$	$\hat{a}_n(0)$	$\hat{a}_n(1)$	$\hat{a}_n(2)$
1	510.2	460.8	555.8	795.2			
2	520.8	463.8	551.2	783.0	520.8	10.8	.4
3	528.4	467.0	547.0	771.2	531.3	11.2	.4

Forecasts: General form -- $EO(n+i)$

$$EO(n+1) = EO(3) = 531.8; i = 1$$

$$EO(n+2) = EO(4) = 543.2; i = 2$$

Re-enter Program 1 and update the old smoothed values, using the estimate for period 3.

$$X_3 = 528.4$$

The results are shown in the above table for $n = 3$. The forecast for the fourth period is again:

$$EO(n+1) = EO(4) = 542.7 \quad i = 1$$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	IF FLAG	43	BRANCH TO OBTAIN PREVIOUSLY SMOOTHED DATA							
1	8		10								
2	3		03								
3	CLEAR		20								
4	STOP		41	$\hat{a}_0(0)$	$\hat{a}_1(0)$	$\hat{a}_2(0)$	ENTER DATA				
5	$x \rightarrow ()$		23								
6	C		16								
7	$y \rightarrow ()$		40								
8	b		14	STORE $\hat{a}_0(0)$, $\hat{a}_1(0)$, AND $\hat{a}_2(0)$							
9	↓		25								
a	$y \rightarrow ()$		40								
b	a		13								
c	CLEAR		20								
d	STOP		41	α	0	0	ENTER α				
1	0	↑	27								
1	↑		27								
2	1		01								
3	$x \rightarrow y$		30								
4	-		34								
5	CHG SIGN		32								
6	÷		35								
7	b		14								
8	x		36								
9	$y \rightarrow ()$		40								
a	d		17								
b	÷		35								
c	2		02								
d	ROLL ↑		22								
2	0	-	34								
1	÷		35								
2	↓		25								
3	x		36								
4	↓		25	CALCULATE AND STORE THE INITIAL SMOOTHED ESTIMATES $S_0(x)$, $S_0^{[2]}(x)$, AND $S_0^{[3]}(x)$							
5	ROLL ↓		31								
6	x		36								
7	a		13								
8	x		36								
9	ROLL ↑		22								
a	CHG SIGN		32								
b	x		36								
c	↓		25								
d	+		33								

HEWLETT-PACKARD

HEWLETT-PACKARD

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HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	ACC +	60								
	1	↓	25								
	2	+	33								
	3	3	03								
	4	X	36								
	5	2	02								
	6	÷	35								
	7	d	17								
	8	+	33								
	9	+	33								
	a	+	33								
	b	↑	27								
	c	e	12								
4	d	x↔y	30								
	0	+	33								
	1	+	33								
	2	c	16								
	3	+	33								
	4	y→()	40								
	5	b	14								
	6	ROLL ↑	22								
	7	+	33								
	8	y↔()	24								
	9	c	16								
	a	f	15								
	b	↑	27								
5	c	2	02								
	d	÷	35								
	0	d	17								
	1	+	33								
	2	↓	25								
	3	+	33								
	4	y→()	40								
	5	a	13								
	6	CLEAR	20								
	7	y→()	40								
	8	9	11								
	9	y↔()	24								
	a	9	11								
	b	1	01								
	c	+	33								
	d	y→()	40								

ZERO COUNTER

INCREMENT COUNTER

FROM 8-d

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	9	11								
1	E	12	RECALL α FOR DISPLAY								
2	$x \leftrightarrow y$	30									
3	STOP	41	n	α	0	ENTER PERIOD DATA					
4	$y \rightarrow ()$	40									
5	E	12									
6	$\uparrow$	27									
7	a	13									
8	-	34									
9	E	12									
a	X	36									
b	a	13									
c	+	33									
d	$y \rightarrow ()$	40									
7	0	a	13								
1	b	14									
2	-	34									
3	E	12									
4	X	36	CALCULATE $S_n^{[3]}, S_n^{[2]}, S_n$								
5	b	14									
6	+	33									
7	$y \rightarrow ()$	40									
8	b	14									
9	c	16									
a	-	34									
b	E	12									
c	X	36									
d	c	16									
8	0	+	33								
1	$y \rightarrow ()$	40									
2	c	16									
3	c	16									
4	$\uparrow$	27									
5	b	14									
6	$\uparrow$	27									
7	a	13									
8	STOP	41	S_n	$S_n^{[2]}$	$S_n^{[3]}$	DISPLAY					
9	CLEAR X	37									
a	ROLL $\downarrow$	31									
b	GO TO () ()	44									
c	5	05	BRANCH FOR NEW DATA ENTRY								
d	9	11									

FROM 0-4

[illegible]

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	3	03								
	1	X	36								
	2	4	04								
	3	—	34								
	4	C	16								
	5	X	36								
	6	d	17								
	7	↑	27								
	8	4	04								
	9	X	36								
	a	5	05								
	b	—	34								
	c	b	14								
4	d	X	36								
	0	↓	25								
	1	—	34								
	2	—	34								
	3	d	17								
	4	↑	27								
	5	5	05								
	6	X	36								
	7	6	06								
	8	—	34								
	9	a	13								
	a	X	36								
	b	↓	25								
5	c	+	33								
	d	d	17								
	0	CHG SIGN	32								
	1	X	36								
	2	1	01								
	3	↑	27								
	4	d	17								
	5	—	34								
	6	↓	25								
	7	÷	35								
	8	÷	35								
	9	2	02								
	a	÷	35								
	b	C	16								
	c	↑	27								
	d	b	14								

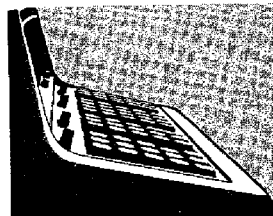
CALCULATE $\hat{a}_0(n)$, $\hat{a}_1(n)$, $\hat{a}_2(n)$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	—	34								
	1	—	34								
	2	—	34								
	3	a	13								
	4	+	33								
	5	+	33								
	6	+	33								
	7	y→()	40								
	8	a	13								
	9	↓	25								
	a	y→()	40								
	b	b	14								
	c	↑	27								
	d	f	15								
7	0	x→()	23								
	1	c	16								
	2	ROLL ↓	31								
	3	STOP	41	$\hat{a}_0(n)$	$\hat{a}_1(n)$	$\hat{a}_2(n)$	DISPLAY				
	4	d	17								
	5	x→()	23								
	6	e	12	RELOCATE α FOR SMOOTHING PROGRAM							
	7	CLEAR x	37								
	8	↑	27								
	9	↑	27								
	a	STOP	41	i	0	0	ENTER i, NUMBER OF PERIODS IN FUTURE FOR WHICH FORECAST IS DESIRED				
	b	x→()	23								
	c	f	15								
	d	↑	27								
8	0	x	36								
	1	c	16								
	2	x	36								
	3	2	02								
	4	÷	35								
	5	b	14								
	6	↑	27	CALCULATE $EO[n+i]$							
	7	f	15								
	8	x	36								
	9	↓	25								
	a	+	33								
	b	a	13								
	c	+	33								
	d	CLEAR x	37								

FROM 9-6

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[illegible]



PART NO.
09100-73008

AMORTIZED LOAN

This program calculates the monthly payment necessary to amortize a loan over a specified number of periods. The principal, annual interest rate, and term of the loan in months are provided by the user.

The program displays (or prints) the calculated monthly payment, showing the amount paid toward principal and the amount of interest for each payment. After each payment, the total principal paid, total interest paid and the remaining loan balance may be displayed. After displaying the last payment, the program ends displaying the total principal paid, the total interest paid and the total interest and principal paid.

The monthly payment is constant. The amount paid in interest is one-twelfth the annual interest rate times the remaining principal. The remainder of the monthly payment is subtracted from the principal balance.

The following equations are used:

$$\text{Percent Monthly Interest } (i') = \frac{\text{Annual interest rate } (i)}{12}$$

$$\text{Monthly Payment } (P') = \frac{\frac{S_i}{1200} (1 + i/1200)^n}{(1 + i/1200)^n - 1}$$

where S is the amount of the loan (original principal) and n is the term of the loan in periods.

$P = P'$ rounded up

Monthly Payment Paid on Principal (P_M) = $P - I$

Monthly Interest Payment (I) = $P_R \times i'$

Remaining Loan Balance (P_R) = $S - P_T$

Total Principal Paid to date (P_T) = $\sum_{a=0}^n P_{M_a}$

Total Interest Paid to date (I_T) = $\sum_{a=0}^n I_a$

Total Amount Paid on loan to date = $P_T + I_T$

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY:

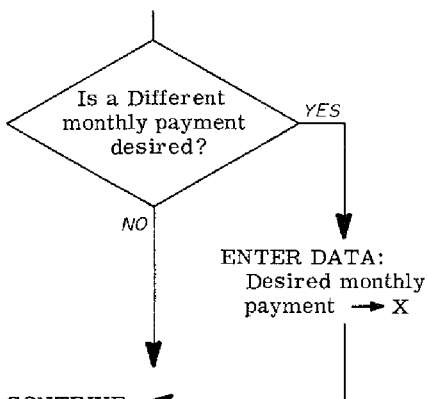
0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: Loan principal in Dollars → Z
Interest Rate in Percent → Y
Term of loan in Monts → X

PRESS: CONTINUE

DISPLAY:

0	_____	Z
0	_____	Y
Calculated Monthly Payment raised to		— X
nearest cent		



PRESS: CONTINUE

DISPLAY: For each month the following brief display occurs:

Amount of Payment toward Principal	_____	Z
Amount of Payment toward Interest	_____	Y
Payment Number	_____	X

To stop display - PRESS: PAUSE

If desired, while stopped,

PRESS: SET FLAG

PRESS: CONTINUE

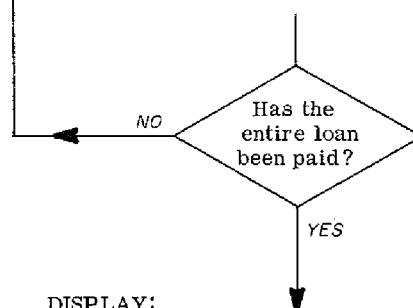
USER INSTRUCTIONS (con't)

DISPLAY:

Total Principal Paid to date	_____	Z
Total Interest Paid to date	_____	Y
Remaining Loan Balance	_____	X

To continue incrementing payments -

PRESS: CONTINUE



DISPLAY:

Amount of Last Payment to Principal	_____	Z
Amount of Last Payment to Interest	_____	Y
Payment Number	_____	X

PRESS: CONTINUE

DISPLAY:

Total Principal Paid	_____	Z
Total Interest Paid	_____	Y
Total Interest and Principal paid	_____	X

Note: To print out, substitute program steps noted in program listing.

EXAMPLES

Example 1

Borrow \$1,000 at 6.25%
for 5 years and 3 months.

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA:

1000 —→ Z
6.25 —→ Y
63 —→ X

PRESS: CONTINUE

DISPLAY:
0 —→ Z
0 —→ Y
18.67 —→ X

Calculated monthly payment = \$18.67

PRESS: CONTINUE

PRESS: PAUSE when display for 36 months
is reached.

DISPLAY:
16.15 — Z - Payment toward Principal
2.52 — Y - Payment toward Interest
36 — X - Payment Number

PRESS: SET FLAG and CONTINUE

DISPLAY:
531.51 — Z - Total Principal Paid to Date
140.61 — Y - Total Interest Paid to Date
468.49 — X - Loan Balance

PRESS: CONTINUE

PROGRAM STOPS TO DISPLAY

17.88 — Z - Final Payment - Principal
.09 — Y - Final Payment - Interest
63 — X - Payment Number

PRESS: CONTINUE

DISPLAY:

1000 —→ Z - Total Paid - Principal
175.51 —→ Y - Total Paid - Interest
1175.51 —→ X - Total Paid

Example 2

Borrow \$1,000 at 6.25%
for 5 years and 3 months.

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

ENTER DATA:

1000 —→ Z
6.25 —→ Y
63 —→ X

PRESS: CONTINUE

DISPLAY:
0 —→ Z
0 —→ Y
18.67 —→ X

ENTER: \$19.00 into X register.

PRESS: CONTINUE

PRESS: PAUSE when display for 36 months
is reached.

DISPLAY:
16.54 —→ Z - Payment - Principal
2.46 —→ Y - Payment - Interest
36 —→ X - Monthly Payment

PRESS: SET FLAG and CONTINUE

DISPLAY:
544.54 —→ Z - Total Principal
Paid to Date
139.46 —→ Y - Total Interest
Paid to Date
455.46 —→ X - Loan Balance

PRESS: CONTINUE

PROGRAM STOPS TO DISPLAY

12.72 —→ Z - Final Payment to
Principal
.07 —→ Y - Final Payment to
Interest
62 —→ X - Payment Number

PRESS: CONTINUE

DISPLAY:

1000 —→ Z - Total Paid - Principal
171.79 —→ Y - Total Paid - Interest
1171.79 —→ X - Total Paid



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	$x \rightarrow ()$	23									
2	9	11									
3	STOP	41	n	i	S	ENTER AMOUNT OF THE LOAN, (S), INTEREST, (i), AND PERIODS, (n).					
4	PRINT $x \rightarrow ()$	23									
5	d	17									
6	1	01									
7	2	02									
8	$\div$	35									
9	$y \rightarrow ()$	40									
10	$\bar{C}$	16									
11	ENTER EXP	26									
12	2	02									
13	$\div$	35									
14	$\downarrow$	25									
15	$y \rightarrow ()$	40									
16	b	14									
17	$\times$	36									
18	$\uparrow$	27									
19	1	01									
20	+	33									
21	d	17									
22	$x \leftrightarrow y$	30									
23	$\ln x$	65									
24	$\times$	36									
25	$\downarrow$	25									
26	e^x	74									
27	$\times$	36									
28	$\uparrow$	27									
29	1	01									
30	-	34									
31	ROLL $\downarrow$	31									
32	$\div$	35									
33	ENTER EXP	26									
34	2	02									
35	$\times$	36									
36	$\downarrow$	25									
37	$\uparrow$	27									
38	$\text{int } x$	64									
39	$x \leftrightarrow y$	30									
40	IF $x > y$	53									

STORE n

CALCULATE MONTHLY
INTEREST AS PERCENTCALCULATE MONTHLY
INTEREST AS FRACTION

STORE S

CALCULATE $(1 + \frac{i}{1200})^n$ CALCULATE MONTHLY
PAYMENT

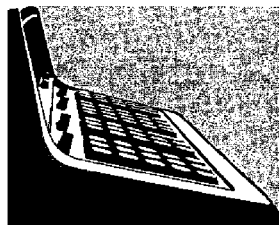
$$P' = \frac{\frac{S i}{1200} (1 + \frac{i}{1200})^n}{(1 + \frac{i}{1200})^n - 1}$$

ROUND UP TO NEAREST CENT

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	25									
	1	+									
	2	ENTER EXP									
	3	2									
	4	÷									
	5	CLEAR x									
	6	↑									
	7	ROLL ↑									
	8	CONTINUE									
	9	START	P	0	0						
	0	CONTINUE									
	1	x→()									
	2	B									
	3										
	4	y→()									
	5										
	6										
	7										
	8										
	9										
	0										
	1										
	2										
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	1										
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	4										

Step	Key	Code	Display			Storage								
			x	y	z	f	e	d	c	b	a			
6	0	IF $x > y$	53	BRANCH WHEN THROUGH i.e., AMOUNT PAID ON PRINCIPAL EXCEEDS AMOUNT OWED.										
1	8		10											
2	1		01											
3	-		34											
4	$y \div x$		24	CALCULATE & STORE CURRENT AMOUNT OWED ON PRINCIPAL										
5	b		14											
6	ROLL $\uparrow$		22	ACCUMULATE AMOUNT PAID ON PRINCIPAL AND INTEREST										
7	ACC +		60											
8	ROLL $\uparrow$		22											
9	PAUSE	57	n	I	P_M	DISPLAY PAYMENT NUMBER, AMOUNT OF PAYMENT FOR INTEREST & PRINCIPAL								
a	print													
b	continue													
c	cont													
d	cont													
7	0	PAUSE	57											
1	IF FLAG	43	BRANCH WHEN FLAG SET TO DISPLAY TOTAL AMOUNT FOR PRINCIPAL & INTEREST PAID IN, & AMOUNT OWED ON PRINCIPAL											
2	7	07												
3	7	07												
4	GO TO ()	44	BRANCH TO CONTINUE CALCULATION											
5	3	03												
6	d	17												
7	RCL	61												
8	$\uparrow$	27												
9	b	14												
a	print	41	P_R	I_T	P_T	DISPLAY REMAINING LOAN BALANCE, TOTAL INTEREST PAID AND TOTAL PRINCIPAL PAID								
b	print	47												
c	GO TO ()	44												
d	3	03												
8	0	d	17											
1	b	14												
2	ROLL $\downarrow$	31	ACCUMULATE TOTAL INTEREST PAID AND TOTAL PAID ON PRINCIPAL											
3	$x \div y$	30												
4	ACC +	60												
5	ROLL $\uparrow$	22												
6	print	41	n	I	P_M	DISPLAY FINAL PAYMENT TO INTEREST, AND FINAL PRINCIPAL PAYMENT								
7	RCL	61												
8	$\uparrow$	27												
9	$\downarrow$	25	CALCULATE TOTAL AMOUNT PAID IN, TOTAL INTEREST, AND TOTAL PRINCIPAL AND DISPLAY											
a	+	33												
b	$x \div y$	30												
c	CONTINUE	47												
d	END	46	T	I_T	P_T									

FROM 4-4

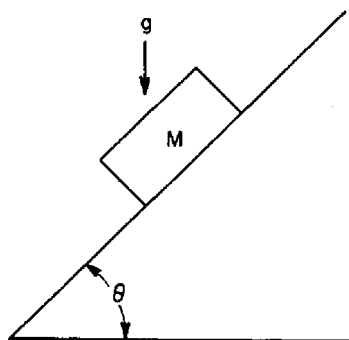


PART NO.
09100-73201

BLOCK ON INCLINE (FRICTION PRESENT)

Given the angle of the incline and the coefficient of friction this program will determine if a block will slide and, if so, the acceleration of the block.

BLOCK ON INCLINE (FRICTION PRESET)



θ = angle of incline

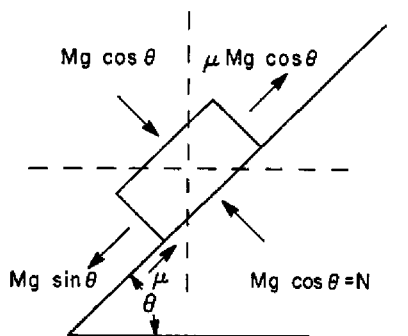
M = mass of body

g = force of gravity

μ = coefficient of friction

A = acceleration of block

FREE-BODY DIAGRAM



Summing forces along the incline:

$$F = MA = -\mu Mg \cos \theta + Mg \sin \theta$$

$$\text{or } A = g (\sin \theta - \mu \cos \theta)$$

Due to μ , a critical angle (θ_c) exists, such that at an incline angle less than θ_c , the block will not slide.

θ_c is determined by equating the opposing forces along the incline;

$$Mg \sin \theta = \mu Mg \cos \theta$$

$$\text{or } \mu = \tan \theta$$

$$\text{So } \theta_c = \tan^{-1} \mu$$

For $\theta < \theta_c$ the block will not slide, and A is therefore zero.

Reference: University Physics, 3rd edition
Sears & Zemansh

USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $\mu \rightarrow Y$, $\theta \rightarrow X$

DISPLAY

0	—	Z
μ	—	Y
θ	—	X

PRESS: CONTINUE

DISPLAY

θ_c	—	Z
A	—	Y
θ	—	X

Note: If $\theta < \theta_c$, a zero will appear in Y, denoting that the block is not slipping.

Dimensions: μ is dimensionless; if g is given in ft./sec.², θ in degrees, then A is given in ft./sec.² and θ_c and θ are in degrees.

EXAMPLES

(A)

$\theta = 30^\circ$

$\mu = .4$

Results: $\theta_c = 21.8^\circ$

$A = 4.95 \text{ ft./sec.}^2$

(B)

$\theta = 15^\circ$

$\mu = .3$

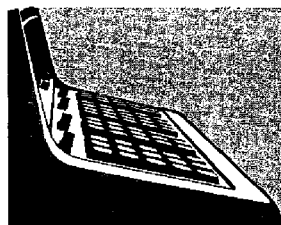
Results: $\theta_c = 16.7^\circ$

$A = 0$

 $(\theta_c > \theta ; \quad \text{The block will not slide})$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	1	01	DISPLAY 1 TO INDICATE FIRST DATA ENTRY								
2	STOP	41	θ	μ	0	ENTER μ, θ					
3	$\uparrow$	27									
4	$x \rightarrow ()$	23	STORE θ								
5	θ	13									
6	$\sin x$	70									
7	$x \leftrightarrow y$	30									
8	$\cos x$	73									
9	ROLL $\uparrow$	22									
10	X	36									
11	ROLL $\downarrow$	31	CALCULATE A								
12	$-$	34									
13	3	03									
1	0	02									
2	.	21									
3	2	02									
4	X	36									
5	CLEAR X	37									
6	ROLL $\uparrow$	22	CALCULATE θ_c								
7	arc $\downarrow$	72									
8	$\tan x$	71									
9	ROLL $\downarrow$	31									
10	IF $x < y$	52									
11	2	02	BRANCH IF BLOCK WILL SLIDE								
12	3	03									
13	$x \leftrightarrow y$	30									
14	θ	13									
2	GO TO () ()	44	BRANCH IF BLOCK WILL NOT SLIDE								
3	2	02									
4	4	04									
5	θ	13									
6	END	46	θ	0 or A	θ_c	DISPLAY					

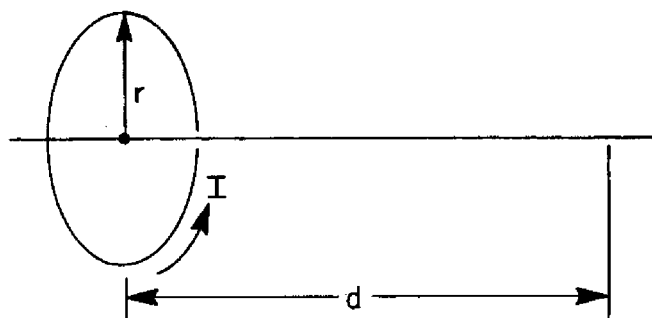
[illegible]



PART NO.
09100-73202

FLUX DENSITY

This program solves for the Flux density along axis of a circular loop.



r = radius of circular loop
 I = current flowing around loop
 d = distance from center of loop
 A = area of loop (πr^2)

In free space $\mu = \mu_0 = 4\pi \times 10^{-7}$

$$B = \frac{2\mu_0 AI}{4\pi (r^2 + d^2)^{3/2}}$$

$$B = \frac{2(4\pi \times 10^{-7}) \pi r^2 I}{4\pi (r^2 + d^2)^{3/2}} = \frac{2\pi r^2 I \times 10^{-7}}{(r^2 + d^2)^{3/2}}$$

If d and r are given in meters, I in amps, then B is given in webers/meter²

This formula for flux density is good for thin-wire, circular loops; as d becomes larger and larger the equation may be approximated by $B = \frac{2\pi r^2 I}{d^3} \times 10^{-7}$ which becomes increasingly accurate as the ratio $\frac{d}{r}$ increases.

Reference: University Physics, 3rd edition
 Sears & Zemansh

Addison - Wesley
 1964

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

→ PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $r \rightarrow Z$, $I \rightarrow Y$, $d \rightarrow X$

PRESS: CONTINUE

DISPLAY

B	—	Z
0	—	Y
0	—	X

(A)

$r = .2m$

$d = 0m$ $B = 6.283 \times 10^{-6} \text{ w/m}^2$

$I = 2 \text{ amps}$

(B)

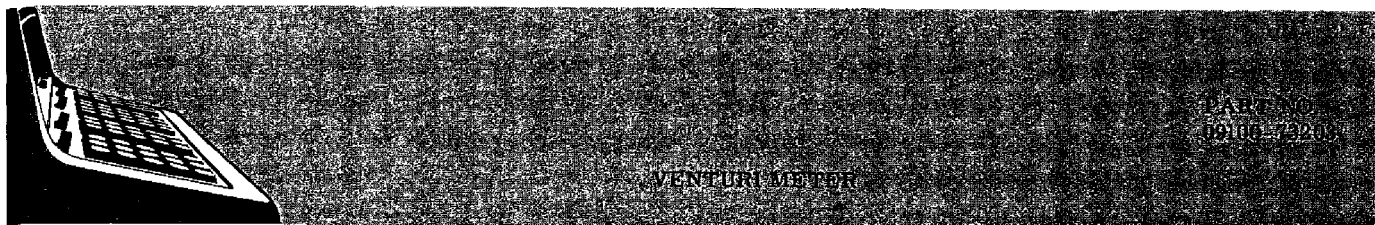
$r = .2m$

$d = .05m$ $B = 5.737 \times 10^{-6} \text{ w/m}^2$

$I = 2 \text{ amps}$

Step	Key	Count	Display
0	CLEAR	20	
1	1	01	DISPLAY 1 TO INDICATE FIRST DATA ENTRY
2	STOP	41	d I r ENTER r,I,d
3	y→()	40	
4	a	13	STORE I
5	ROLL ↑	22	
6	↑	27	
7	X	36	
8	y→()	40	
9	b	14	CALCULATE $(d^2 + r^2)^{3/2}$
10	ROLL ↑	22	
11	TO POLAR	62	
12	↑	27	
13	X	36	
14	X	36	
15	2	02	
16	↑	27	
17	π	56	
18	X	36	
19	b	14	
20	X	36	
21	a	13	CALCULATE $2\pi r^2 I \times 10^{-7}$
22	X	36	
23	ENTER EXP	26	
24	7	07	
25	CHG SIGN	32	
26	X	36	
27	↓	25	
28	x↔y	30	
29	÷	35	CALCULATE B
30	CLEAR x	37	
31	↑	27	
32	END	46	0 0 B DISPLAY

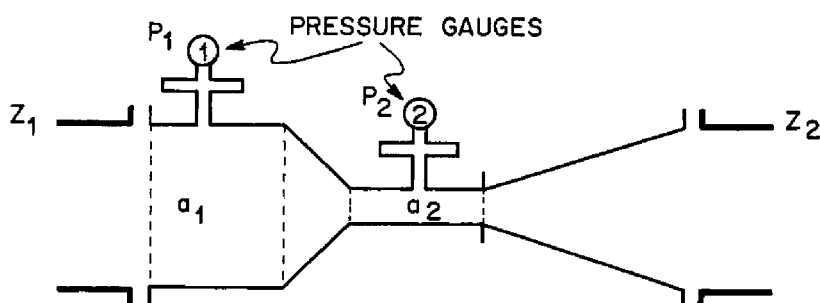
[illegible]



This program measures the rate of flow in a uniform flow tube by use of a Venturi meter.

A venturi meter is simply a constriction in a pipe which causes a pressure variation directly related to flow rate.

The following diagram applies:



Q (rate of flow) is defined by $Q = a_1 V_1 = a_2 V_2$ where a_1, a_2 are measured areas and V_1, V_2 are fluid velocities at the respective points.

Bernoulli's equation relates the flow characteristics at points one (1) and (2).

$$P_1/\gamma + V_1^2/2g + Z_1 = P_2/\gamma + V_2^2/2g + Z_2$$

Assuming the heights $Z_1 = Z_2$

$$\text{then, } P_1/\gamma + V_1^2/2g = P_2/\gamma + V_2^2/2g \quad \text{where } P_1, P_2 = \text{pressure}$$

$\gamma = \text{density}$
 $g = \text{force of gravity}$

Solving for V_1 using the substitution $V_2^2 = (a_1/a_2)^2 V_1^2$

$$\text{we obtain } V_1 = \sqrt{\frac{2g (P_1 - P_2)}{\gamma [(a_1/a_2)^2 - 1]}}$$

$$\text{or } Q = a_1 V_1 = a_1 \sqrt{\frac{2g (P_1 - P_2)}{\gamma [(a_1/a_2)^2 - 1]}}$$

Dimensions:

a_1, a_2 given in inches²

P_1, P_2 given in lbs/in.²

γ given in lbs/in.^3

g given in inches/sec.^2

Then the dimensions of Q are in $\text{in}^3/\text{sec.}$

Reference: Elementary Fluid Mechanics
by John K. Vennard

John Wiley & Sons
New York

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: END

PRESS: CONTINUE

→ DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: $a_1 \rightarrow Y$, $a_2 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

→ ENTER DATA: $\gamma \rightarrow Z$, $P_1 \rightarrow Y$, $P_2 \rightarrow X$

PRESS: CONTINUE

DISPLAY

Q	—	Z
0	—	Y
0	—	X

— To enter new density or pressure; Press CONTINUE

— To reset problem and/or calculate flow for different areas (a_1 & a_2); Press END, Press CONTINUE after display of Q .

EXAMPLE

a_1 and a_2 have respective areas of 0.5 ft.^2 & 0.25 ft.^2 with pressure drop of 10 psi when water flows in the pipe ($\gamma = 62.4 \text{ lb./ft.}^3$ or $62.4/1728 \text{ lbs/in.}^3$)

$$a_1 = 72 \text{ in.}^2$$

$$a_2 = 36 \text{ ft.}^2$$

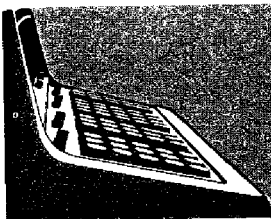
$$\gamma = .03611 \text{ lb./in.}^3$$

$$P_1 = 12 \text{ psi}$$

$$P_2 = 2 \text{ psi}$$

Answer: $19,221.589 \text{ in.}^3/\text{sec.}$

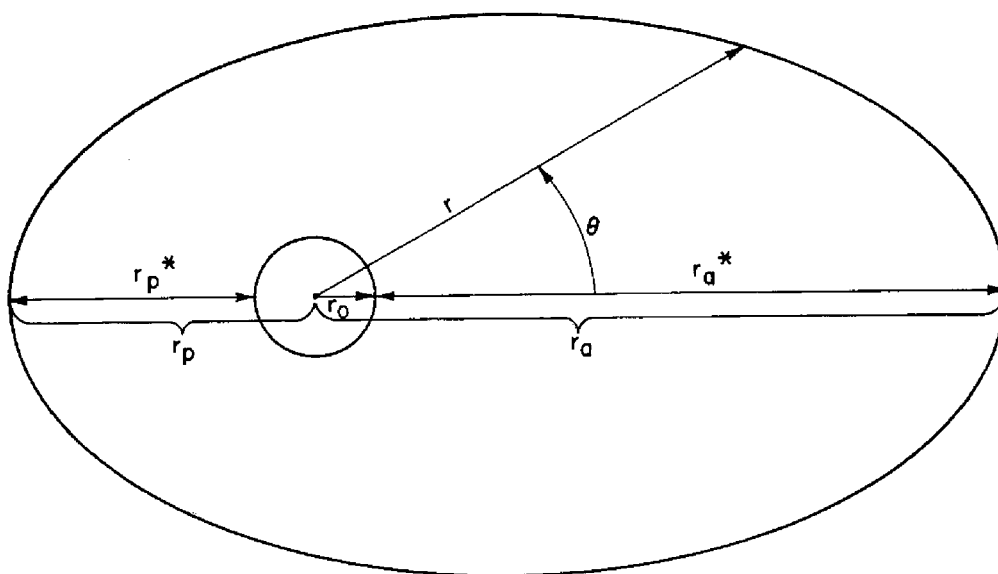
[illegible]



PART NO.
09100-79204

ORBITAL MECHANICS

This program computes the velocity of a satellite at apogee, the velocity at perigee, and the orbital period in seconds of a satellite orbiting a body in space.



Given:

$$r_a^* = \text{radius at apogee measured above } r_o \quad (r_a = r_a^* + r_o)$$

$$r_p^* = \text{radius at perigee measured above } r_o \quad (r_p = r_p^* + r_o)$$

$$r_o = \text{radius of orbited body}$$

$$g_o = \text{acceleration of gravity at } r_o$$

Find:

$$V_a = \sqrt{\frac{2 g_o (r_o)^2 r_p}{r_a (r_a + r_p)}} = \text{velocity at apogee}$$

$$V_p = V_a \cdot \frac{r_a}{r_p} = \text{velocity at perigee}$$

$$p = \frac{\pi (r_a + r_p)^3}{\sqrt{2 g_o (r_o)^2}} = \text{orbital period}$$

USER INSTRUCTIONS

EXAMPLE

SET:

ENTER PROGRAM: (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $g_o \rightarrow Y$, $r_o \rightarrow X$

PRESS: CONTINUE

DISPLAY

1	_____	Z
1	_____	Y
1	_____	X

ENTER DATA: $r_p^* \rightarrow Y$, $r_a^* \rightarrow X$

PRESS: CONTINUE

DISPLAY

p	_____	Z
V_p	_____	Y
V_a	_____	X

To reset problem for same r_o and g_o .

$$g_o = \frac{(32.2)(3600)^2}{5280} = 7.904 \times 10^4$$

for units of miles and hours

$$r_o = 1,080 \text{ miles (moon)}$$

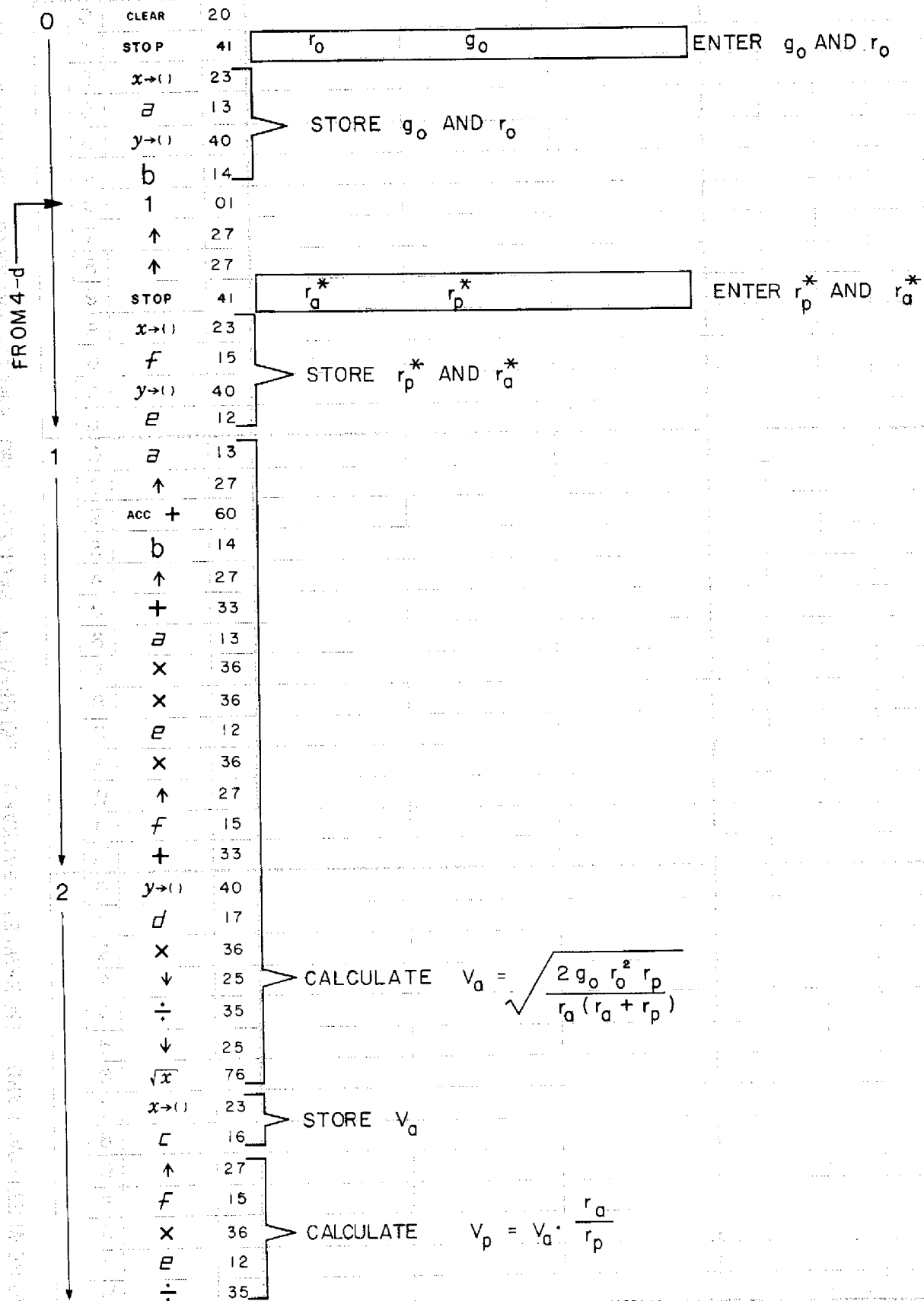
$$r_a^* = 8,000 \text{ miles}$$

$$r_p^* = 2,000 \text{ miles}$$

$$p = 9.810 \text{ sec.}$$

$$V_p = 6685.948 \text{ mi./hr.}$$

$$V_a = 2267.921 \text{ mi./hr.}$$



Step	Key	Code	Display	Storage							
			A	V	Z	F	P	d	e	b	s
3	0	d	17								
1	y→()	40									
2	d	17									
3	↑	27									
4	x	36									
5	x	36									
6	b	14									
7	÷	35									
8	2	02									
9	÷	35									
a	a	13									
b	÷	35									
c	÷	35									
d	π	56									
4	0	x↔y	30								
1	√x	76									
2	x	36									
3	a	13									
4	↑	27									
5	ACC —	63									
6	y↔()	24									
7	d	17									
8	c	16									
9	STOP	41									
a	CLEAR x	37									
b	GOTO() ()	44									
c	0	00									
d	6	06									
5	0	END	46								
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

STORE V_p

CALCULATE $P = \pi \sqrt{\frac{(r_a + r_p)^3}{2g_o(r_o)^2}}$

V_a V_p P DISPLAY

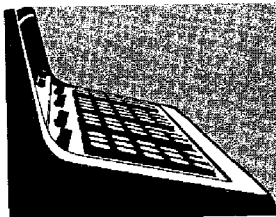
BRANCH TO ENTER NEW r_a^* AND r_p^*

STORE V_p

CALCULATE $P = \pi \sqrt{\frac{(r_a + r_p)^3}{2g_o(r_o)^2}}$

V_a	V_p	P
-------	-------	---

 DISPLAY
BRANCH TO ENTER NEW r_a^* AND r_p^*

PART NO.
09100-73701

TEMPERATURE CONVERSION

This program converts and displays the two temperature equivalents of a temperature in any of the three temperature scales --- Fahrenheit, Centigrade, and Kelvin (absolute).

The following equations are used in the conversion process.

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

$$\text{or } ^{\circ}\text{F} = 9/5 (^{\circ}\text{C} + 32)$$

$$^{\circ}\text{C} = ^{\circ}\text{K} - 273.15$$

$$\text{or } ^{\circ}\text{K} = ^{\circ}\text{C} + 273.15$$

$$^{\circ}\text{K} = 5/9 (^{\circ}\text{F} + 459.67)$$

$$\text{or } ^{\circ}\text{F} = 9/5 (^{\circ}\text{K} - 273.15)$$

Dimensions:

Inputs and results are in decimal degrees.

Reference:

College Chemistry -- 3rd Edition
Paul R. Frey

USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

→PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: °F → Z, °C → Y, °K → X

Note: Enter the two unknowns as zero.

PRESS: CONTINUE

DISPLAY

°K	—	Z
°C	—	Y
°F	—	X

Two of the values given will be calculated values; the known value will be displayed as entered above in data entry.

Note: (1) To obtain the temperature equivalents for 0°F;

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

PRESS: GO TO (0) (d)

PRESS: CONTINUE

(2) To obtain the temperature equivalents for 0°C;

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

PRESS: GO TO (3) (c)

PRESS: CONTINUE

EXAMPLES

(A) Find the Centigrade and Fahrenheit equivalent temperature of 0° Kelvin.

ENTER DATA:

0 —→ Z

0 —→ Y

0 —→ X

(°C and °F are the unknowns)

Results: Centigrade temp. = -273.16°C
Fahrenheit temp. = -459.688°F

(B) Find the Fahrenheit and Kelvin equivalent temperature of 20° Centigrade.

ENTER DATA:

0 —→ Z

20 —→ Y

0 —→ X

Results: Kelvin temperature = 293.16°K
Fahrenheit temp. = 68°F

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	STOP	41	°F	°C	°K	ENTER KNOWN TEMPERATURE, ENTER ZERO FOR UNKNOWN					
2	$x \rightarrow ()$	23									
3	F	15									
4	$y \rightarrow ()$	40									
5	E	12	STORE INPUT DATA								
6	ROLL $\uparrow$	22									
7	$x \rightarrow ()$	23									
8	d	17									
9	CLEAR x	37									
a	IF $x=y$	50									
b	3	03	BRANCH IF °F IS UNKNOWN								
c	8	10									
d	$\downarrow$	25									
1	0	$\uparrow$	27								
1	1	$\uparrow$	27								
2	4	04									
3	5	05									
4	9	11									
5	.	21									
6	6	06									
7	8	10	CALCULATE °K FROM °F								
8	8	10									
9	IF FLAG	43									
a	7	07	BRANCH TO COMPLETE CALCULATION OF °F FROM °K								
b	0	00									
c	+	33									
d	5	05									
2	0	X	36								
1	9	11									
2	$\div$	35									
3	ROLL $\uparrow$	22									
4	$x \rightleftharpoons y$	30									
5	4	04	CALCULATE °C FROM °F								
6	0	00									
7	+	33									
8	IF FLAG	43									
9	4	04	BRANCH TO COMPLETE CALCULATION OF °F FROM °C								
a	c	16									
b	5	05									
c	X	36									
d	9	11									

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

FROM 6-d

FROM 4-b

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	÷	35								
1	4	04									
2	0	00									
3	—	34									
4	f	15	°F	°C (CAL.)	°K (CAL.)	DISPLAY FOR GIVEN TEMPERATURE IN °F					
5	GO TO () ()	44									
6	7	07									
7	3	03									
8	↓	25									
9	IF x=y	50									
10	5	05	BRANCH IF °C IS UNKNOWN								
11	θ	13									
12	2	02									
13	7	07									
4	0	3	03	ENTER CONSTANT							
1	.	21									
2	1	01									
3	6	06									
4	IF FLAG	43									
5	6	06	BRANCH TO CALCULATE °C FROM °K								
6	3	03									
7	+	33	CALCULATE °K FROM °C								
8	SET FLAG	54									
9	GO TO () ()	44	SET FLAG AND BRANCH TO CALCULATE °F FROM °C								
10	2	02									
11	3	03									
12	9	11									
13	x	36									
5	0	5	05	COMPLETE CALCULATION OF °F FROM °C							
1	÷	35									
2	4	04									
3	0	00									
4	—	34									
5	e	12									
6	xzy	30	°F (CAL.)	°C	°K (CAL.)	DISPLAY FOR GIVEN TEMPERATURE IN °C					
7	GO TO () ()	44									
8	7	07									
9	3	03									
10	d	17									
11	↑	27									
12	↑	27									
13	SET FLAG	54									

FROM 0-c

FROM 6-2

FROM 2-c

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
6	0	GOTO () ()	44	SET FLAG AND BRANCH TO PICK UP CONSTANT								
	1	3	03									
	2	L	16									
	3	-	34									
	4	ROLL ↑	22	PARTIAL CALCULATION OF °F FROM °K								
	5	x ÷ y	30									
	6	9	11									
	7	X	36									
	8	5	05	BRANCH TO PICK UP CONSTANT								
	9	÷	35									
	a	SET FLAG	54									
	b	GOTO () ()	44									
	c	1	01	DISPLAY FOR GIVEN TEMPERATURE IN °K								
	d	2	02									
7	0	-	34									
	1	d	17									
	2	ROLL ↓	31	°F (CAL.)	°C (CAL.)	°K						
	3	END	46									
	4											
	5											
	6											
	7											
	8											
	9											
	a											
	b											
	c											
	d											
	0											
	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	a											
	b											
	c											
	d											

HEWLETT-PACKARD
FROM 4-6HEWLETT-PACKARD
FROM 1-bHEWLETT-PACKARD
FROM 3-7 & 5-9

HEWLETT-PACKARD

HEWLETT-PACKARD

[illegible]

HEWLETT-PACKARD
HEWLETT-PACKARD
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HEWLETT-PACKARD
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HEWLETT-PACKARD
HEWLETT-PACKARD



PART NO.
09100-74001

COORDINATE GEOMETRY

This program traverses by bearing and distance and calculates coordinates and the following curve data:

1. Radius
2. Length
3. Chord
4. Central angle in degrees, minutes and seconds.
Note: Central angle over 180° must be divided into smaller increments.
5. Coordinates of tangent points

This program is designed to traverse from point to point on a survey map indicating coordinates of successive points on the survey and also indicating the descriptive features of tangent curved portions. The four quadrants are represented as follows: NE = 1, SE = 2, SW = 3, NW = 4. The operator must enter the distance in both X and Y registers on the course if leaving a radius point on a curve. If the central angle is over 180° the operator must divide the circle into smaller segments.

QUADRANT CODE

4 = NW	1 = NE
3 = SW	2 = SE

USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER COORDINATES: Northing in -Y
Easting in -X

PRESS: ACC +

ENTER BEARING ANGLE DATA:

Degrees → Z

Minutes → Y

Seconds → X

Note: Decimal Degrees, Decimal Minutes or
Decimal Seconds may be entered pro-
vided they are entered in the proper
register.

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: Quadrant Code (1 = NE,
2 = SE, 3 = SW, 4 = NW)
in X register.

PRESS: CONTINUE

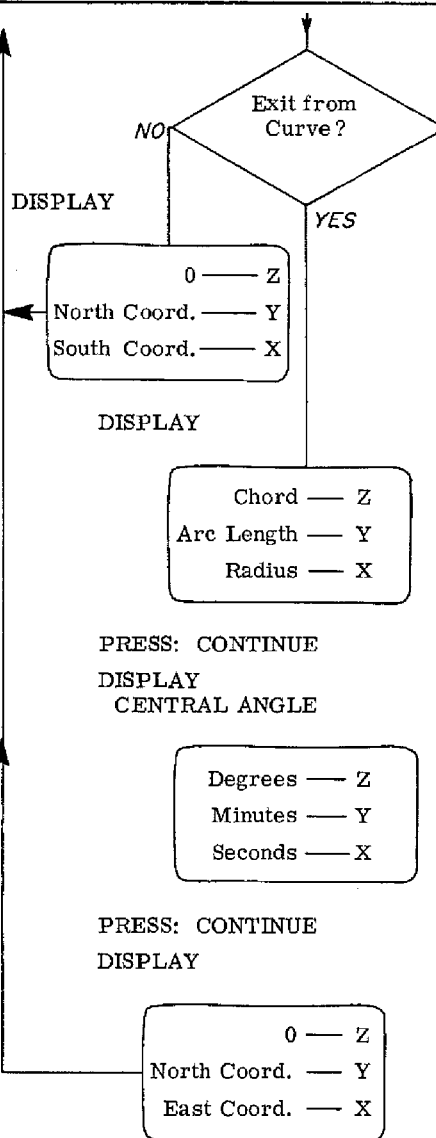
DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER DATA: Distance → X (for normal
traverse line)Distance → X and → Y
(for line from radius point)

PRESS: CONTINUE

USER INSTRUCTIONS (Cont'd)

When all the lines of the figure have been traversed
to the point of beginning the error of closure may be
seen by making the following manual steps.

ENTER BEGINNING COORDINATES:

North → Y, East → X

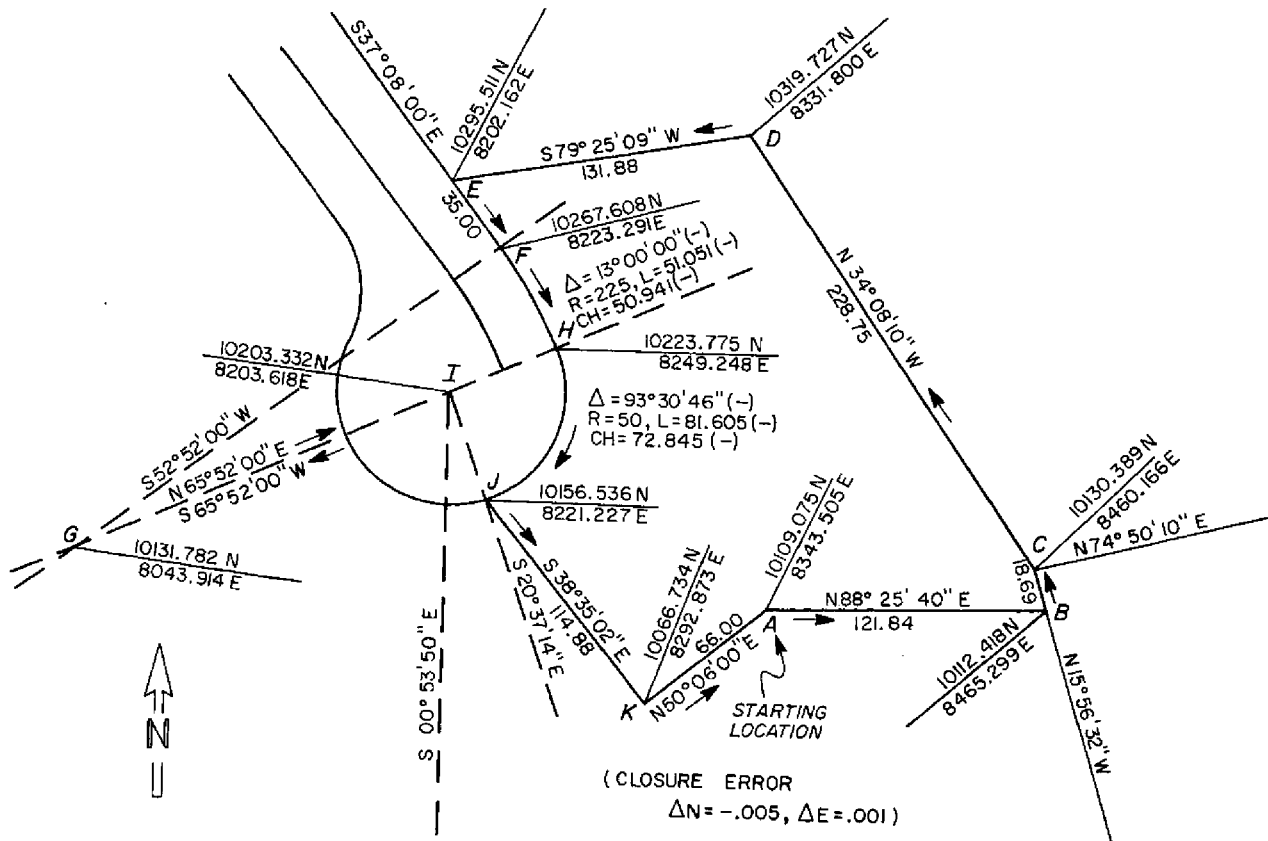
PRESS: ACC -

PRESS: RCL

DISPLAY

0	—	Z
ΔN	—	Y
ΔE	—	X

EXAMPLES



STARTING COORDINATES:

Coordinates of A	10109.075	Northing *
	8343.505	Easting *
	NE 88° 25' 40"	
	Distance 121.84	

Coordinates of B	10112.418	Northing *
	8465.299	Easting *
	NW 15° 56' 32"	
	Distance 18.69	

Coordinates of C	10130.389	Northing *
	8460.166	Easting *
	NW 34° 08' 10"	
	Distance 228.75	

Coordinates of D	10319.727	Northing *
	8331.800	Easting *
	SW 79° 25' 09"	
	Distance 131.88	

EXAMPLES (Cont'd)

Coordinates	10295.511	Northing	*
of E	8202.162	Easting	*

SE 37° 08' 00"
Distance 35.00'

Coordinates	10267.608	Northing	*
of F	8223.291	Easting	*

START OF CURVE:

SW 52° 52' 00"
Distance 225.00'

Coordinates	10131.782	Northing	*
of G	8043.914	Easting	*

NE 65° 52' 00"
Distance 225.00'

NOTE

User must enter radial distance of 225.00' in X and Y registers when traversing from the radius point G.

50.941 (-) - Chord Length *

51.051 (-) - Arc Length *

225.00 - Radius *

Note sign convention:

Negative sign implies concave to south or west.

Positive sign implies concave to north or east.

Central Angle 13° 00' 00" (-)

Coordinates	10223.775	Northing	*
of H	8249.248	Easting	*

SW 65° 52' 00"
Distance 50.00'

Coordinates	10203.332	Northing	*
of I	8203.618	Easting	*

SE 20° 37' 14"
Distance 50.00'

NOTE

User must enter radial distance of 50.00' in X and Y registers when traversing from the radius point I.

72.845 (-) - Chord Length

81.605 (-) - Arc Length

50.00 - Radius

Note sign convention:

Negative sign implies concave to south or west.

Positive implies concave to north or east.

Central angle 93° 30' 46" (-)

Coordinates	10156.536	Northing	*
of J	8221.227	Easting	*

SE 38° 35' 02"
Distance 114.88'

Coordinates	10066.734	Northing	*
of K	8292.873	Easting	*

NE 50° 06' 00"
Distance 66.00'

Coordinates	10109.070	*
of A	8343.508	*

STARTING COORDINATES:

10109.075
8343.505

CLOSURE ERROR

$\Delta N = -.005$

$\Delta E = +.001$

* Coordinate Answers

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
	1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY (STARTING BEARINGS)							
	2	STOP	41	SECONDS	MINUTES	DEGREES	EAST	NORTH	ENTER STARTING COORDINATES AND BEARINGS. ACC + IS USED TO ENTER COORDINATES.		
	3	x→()	23								
	4	d	17								
	5	6	06								
	6	0	00								
	7	÷	35								
	8	ROLL ↓	31								
	9	+	33								
	a	d	17	CONVERT TO DECIMAL DEGREES							
	b	ROLL ↑	22								
1	c	÷	35								
	d	÷	35								
	0	↓	25								
	1	+	33								
	2	y→()	40								
	3	d	17								
	4	CLEAR x	37								
	5	↑	27	CLEAR AND DISPLAY 2 TO INDICATE SECOND ENTRY							
	6	↑	27								
	7	2	02								
	8	STOP	41	QUAD. CODE	0	0	ENTER QUADRANT CODE				
	9	↑	27								
2	a	9	11								
	b	0	00								
	c	x2y	30	CALCULATE QUADRANT CONVERSION CONSTANT							
	d	↑	27								
	0	1	01								
	1	IF x=y	50	BRANCH IF NE							
	2	4	04								
	3	6	06								
	4	2	02								
	5	IF x=y	50	BRANCH IF SE							
	6	3	03								
	7	d	17								
3	8	3	03								
	9	IF x=y	50	BRANCH IF SW							
	a	3	03								
	b	4	04								
	c	d	17	BRANCHES HERE IF NW							
	d	ROLL ↑	22	RECALL ANGLE AND ADD 90°							

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	+	33								
	1	GO TO () ()	44								
	2	4	04	BRANCH TO DISTANCE ENTRY							
	3	a	13								
	4	d	17								
	5	CHG SIGN	32								
	6	ROLL ↑	22	RECALL ANGLE AND SUBTRACT 270°							
	7	+	33								
	8	+	33								
	9	+	33								
4	a	GO TO () ()	44								
	b	4	04	BRANCH TO DISTANCE ENTRY							
	c	a	13								
	d	d	17								
	0	ROLL ↑	22	RECALL ANGLE AND SUBTRACT 90°							
	1	CHG SIGN	32								
	2	+	33								
	3	GO TO () ()	44								
	4	4	04	BRANCH TO DISTANCE ENTRY							
	5	a	13								
5	6	d	17								
	7	CHG SIGN	32								
	8	ROLL ↑	22	RECALL ANGLE AND SUBTRACT FROM 90°							
	9	+	33								
	a	y→()	40								
	b	d	17								
	c	0	00								
	d	↑	27	CLEAR AND DISPLAY 3 TO INDICATE THIRD ENTRY (DISTANCE)							
	0	↑	27								
	1	3	03								
6	2	STOP	41								
	3	IF x=y	50								
	4	6	06	BRANCH IF LEAVING A RADIUS POINT							
	5	3	03								
	6	↑	27								
	7	d	17								
	8	x→()	23								
	9	c	16								
	a	x↔y	30	COMPLETION OF INDIVIDUAL COORDINATES							
	b	TO RECT	66								
7	c	ACC +	60								
	d	RCL	61								

ENTER DISTANCE IN X FOR A
STRAIGHT LINE OR IN X AND Y
FOR A CURVED LINE

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	GOTO () () 44									
1	0	00	BRANCH FOR NEXT COURSE								
2	2	02									
3	y $\rightarrow$ ()	24	BRANCHES HERE FOR CURVE; RECALLS PRESENT AND PREVIOUS DIRECTIONS								
4	d	17									
5	c	16									
6	y $\rightarrow$ ()	40	STORE PRESENT DIRECTION FOR USE WITH CURVE								
7	c	16									
8	-	34									
9	1	01	CALCULATE CENTRAL ANGLE								
a	8	10									
b	0	00									
c	+	33									
d	IF x > y	53									
7	0	7 07	BRANCH IF 180° > CENTRAL ANGLE								
1	9	11									
2	↑	27									
3	+	33									
4	ROLL ↓	31	IF 180° < CENTRAL ANGLE SUBTRACT FROM 360°								
5	x $\rightarrow$ y	30									
6	-	34									
7	ROLL ↓	31									
8	x $\rightarrow$ y	30									
9	y $\rightarrow$ ()	40	CONVERT TO RADIANs								
a	b	14									
b	÷	35									
c	π	56									
d	x	36									
8	0	b 14	RECALL CENTRAL ANGLE AND DIVIDE BY 2								
1	↑	27									
2	2	02									
3	÷	35									
4	d	17	CALCULATE CHORD LENGTH								
5	x $\rightarrow$ y	30									
6	sin x	70									
7	x	36									
8	2	02	CALCULATE ARC LENGTH								
9	x	36									
a	d	17									
b	ROLL ↑	22									
c	x	36	RECALL RADIUS								
d	d	17									

FROM 5-5

[illegible]

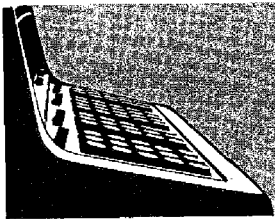
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ANGLE ACCUMULATION

PART NO.
69108-74002

This program accumulates angles given in degrees, minutes, and seconds. Angles can be entered in any combination of decimal parts and added or subtracted as desired.

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

(1 indicates angle to be entered)

ENTER DATA: degrees → Z, minutes → Y,
seconds → X

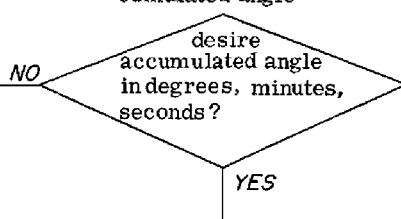
PRESS: CONTINUE

DISPLAY

0	—	Z
accumulated angle in de- — Y cimal degrees		
last angle in decimal de- — X grees		

PRESS: (+) or (-)

+ if adding to previous accumulated
angle
- if subtracting from previous ac-
cumulated angle



PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

accumulated angle

degrees	—	Z
minutes	—	Y
seconds	—	X

EXAMPLES

Example:

+ 52° 07' 30"

+ 29° 44' 41.6"

+ 8.13° 00' 00"

- 36° 52.56' 00"

Result: 53.12389 or 53° 07' 26"

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
1	$x \rightarrow ()$	23										
2	d	17	CLEAR, INITIALIZE REGISTERS AND DISPLAY 1 TO INDICATE FIRST ENTRY									
3	1	01										
4	$x \rightarrow ()$	23										
5	c	16										
6	STOP	41	SECONDS	MINUTES	DEGREES	ENTER DEGREES, MINUTES AND SECONDS						
7	$x \rightarrow ()$	23										
8	b	14										
9	6	06										
a	0	00										
b	$\div$	35										
c	ROLL $\downarrow$	31										
d	+	33	CONVERT DEGREES, MINUTES AND SECONDS TO DECIMAL DEGREES									
1	0	b	14									
1	ROLL $\uparrow$	22										
2	$\div$	35										
3	$\div$	35										
4	$\downarrow$	25										
5	+	33										
6	CLEAR x	37										
7	ROLL $\downarrow$	31	POSITION DISPLAY									
8	$y \rightarrow ()$	24										
9	d	17	DECIMAL AGG. DECIMAL DEGREES DEGREES			0 DISPLAY (PRESS + OR -)						
a	STOP	41										
b	$y \rightarrow ()$	40										
c	d	17										
d	c	16										
2	0	$x \rightarrow y$	30	STORE DECIMAL DEGREES AND INCREMENT COUNTER								
1	1	01										
2	+	33										
3	$y \rightarrow ()$	40										
4	c	16										
5	$\downarrow$	25										
6	IF FLAG	43										
7	2	02	BRANCH IF DEGREES, MINUTES AND SECONDS ARE DESIRED									
8	c	16										
9	GO TO ()	44										
a	0	00	BRANCH TO DATA ENTRY									
b	6	06										
c	d	17										
d	$\uparrow$	27										

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FROM 2-b & 4-6

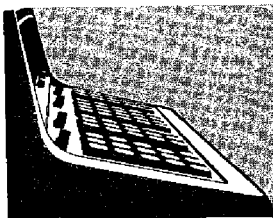
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PART NO.
09100-74003

INVERSE TRAVERSE FROM COORDINATES

This program will calculate bearings and distances between given coordinates. If it is desired to continue on to a new point from the last point entered the operator has only to press CONTINUE and enter coordinates for the new forward point.

The quadrants are denoted by NE = 1, SE = 2, SW = 3 and NW = 4.

QUADRANT CODE

4 = NW

1 = NE

3 = SW

2 = SE

USER INSTRUCTIONS

SET: DEGREES
 PRESS: GO TO (0) (0) [or END]
 ENTER PROGRAM (Starting address is 0-0)
 PRESS: END
 PRESS: CONTINUE
 DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: Point A Northing → Y
 Point A Easting → X

PRESS: CONTINUE

→ DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: Point B Nothing → Y
 Point B Easting → X

PRESS: CONTINUE

DISPLAY

Degrees	—	Z
Minutes	—	Y
Seconds	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
Distance	—	Y
Quadrant	—	X
Code		

—PRESS: CONTINUE to enter a new course

EXAMPLES

1100 North
 800 East
 1300 North
 900 East

Answer:

26° 33' 54.184"
 223.607'
 1 (Quadrant Code)

1300 North
 1200 East

Answer:

90° 00' 00"
 300.000'
 2 (Quadrant Code)

1000 North
 1000 East

Answer:

33° 41' 24.243"
 360.555'
 3 (Quadrant Code)

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
	2	STOP	41	A _E	A _N	0	ENTER A _N , A _E					
	3	ACC +	60	STORE STARTING COORDINATES								
	4	↓	25									
	5	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	6	STOP	41	B _E	B _N	0	ENTER B _N , B _E					
	7	↑	27									
	8	y↔()	24									
	9	F	15									
	a	x↔y	30									
	b	—	34									
	c	E	12									
	d	CHG SIGN	32									
1	0	ROLL ↑	22	STORE FORWARD COORDINATES FOR FUTURE								
	1	x→()	23	INVERSE PROBLEM. (NOTE: IN THE NEXT PROBLEM								
	2	E	12	THESE COORDINATES WILL BE THE STARTING POINT.)								
	3	+	33									
	4	↓	25									
	5	x↔y	30									
	6	TO POLAR	62									
	7	x→()	23									
	8	d	17									
	9	0	00									
	a	IF x < y	52									
	b	3	03									
	c	2	02									
	d	y	55									
2	0	9	11									
	1	0	00									
	2	IF x > y	53									
	3	2	02									
	4	a	13									
	5	—	34									
	6	3	03									
	7	GO TO () ()	44									
	8	4	04									
	9	1	01									
	a	x↔y	30	DETERMINE QUADRANT								
	b	—	34									
	c	2	02									
	d	GO TO () ()	44									

HEWLETT-PACKARD
FROM 6-7

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD FROM 1-C
HEWLETT-PACKARD FROM 2-9
HEWLETT-PACKARD
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HEWLETT-PACKARD
HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	4	04								
	1	1	01								
	2	9	11								
	3	0	00								
	4	IF x>y	53								
	5	3	03								
	6	C	16								
	7	-	34								
	8	4	04								
	9	GO TO () ()	44								
	a	4	04								
	b	1	01								
	c	x<y	30								
	d	-	34								
4	0	1	01								
	1	x->()	23								
	2	C	16								
	3	↓	25								
	4	↑	27								
	5	int x	64								
	6	-	34								
	7	x->()	23								
	8	b	14								
	9	6	06								
	a	0	00								
	b	x	36								
	c	↓	25								
	d	↑	27								
CONVERT DECIMAL DEGREES TO DEGREES, MINUTES, SECONDS											
5	0	int x	64								
	1	-	34								
	2	x->()	23								
	3	a	13								
	4	6	06								
	5	0	00								
	6	x	36								
	7	b	14								
	8	↑	27								
	9	a	13								
	a	ROLL ↑	22								
	b	STOP	41								
	c	0	00								
	d	↑	27								
			SECONDS	MINUTES	DEGREES	DISPLAY					

[07] HEWLETT-PACKARD [08] HEWLETT-PACKARD [09] HEWLETT-PACKARD

Step	Key	Code	Display			Storage							
			x	y	z	f	e	d	c	b	a		
6	0	d	17	} RECALL AND POSITION DISTANCE AND QUADRANT CODE									
1	↑	27											
2	⌈	16											
3	STOP	41	QUAD. CODE	DISTANCE	0	DISPLAY							
4	↓	25											
5	GO TO () ()	44	} BRANCH FOR NEW FORWARD POINT										
6	0	00											
7	5	05											
8	END	46											
9													
a													
b													
c													
d													
0													
1													
2													
3													
4													
5													
6													
7													
8													
9													
a													
b													
c													
d													
0													
1													
2													
3													
4													
5													
6													
7													
8													
9													
a													
b													
c													
d													

[illegible]

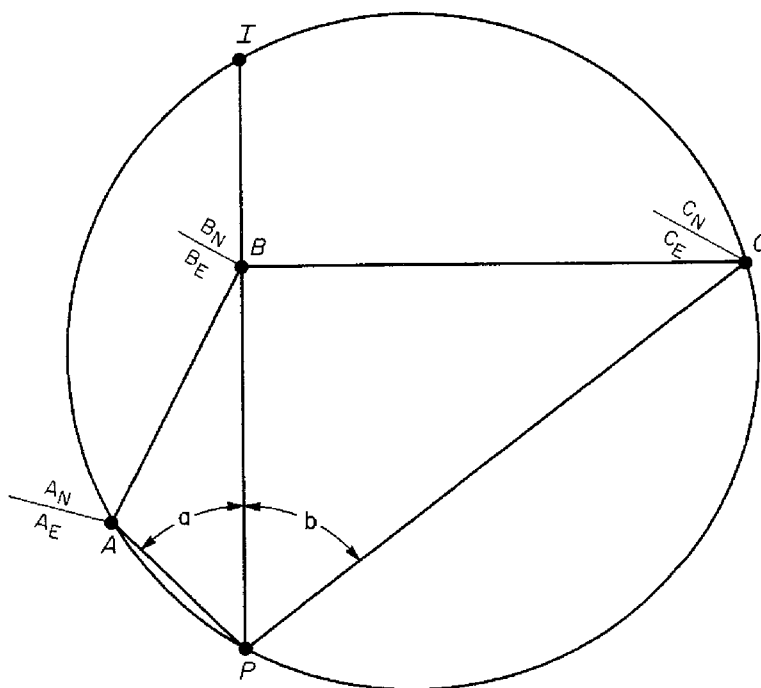
THREE POINT PROBLEM

The three point problem, sometimes known as Italian Resection, involves the determination of coordinates of an observers position (Point P) by measuring only angles a & b . The coordinates of points A, B & C must be known.

To make the solution possible it is necessary:

1. To construct a circle through points A, C, & P.
2. Project line P - B to intersect the circle at point I
(Note: No solution possible if "B" on circle)

See figure below:



USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $A_N \rightarrow Y$, $A_E \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $C_N \rightarrow Y$, $C_E \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER DATA: ANGLE a

 $a^0 \rightarrow Z$, $a' \rightarrow Y$, $a'' \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
4	—	X

USER INSTRUCTIONS (con't)

ENTER DATA: ANGLE b

 $b^0 \rightarrow Z$, $b' \rightarrow Y$, $b'' \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
5	—	X

ENTER DATA: $B_N \rightarrow Y$, $B_E \rightarrow X$

PRESS: CONTINUE

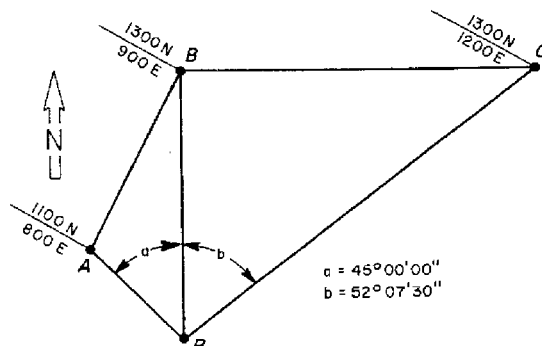
DISPLAY

0	—	Z
P _n	—	Y
P _e	—	X

TO ENTER ANOTHER PROBLEM, PRESS: CONTINUE

EXAMPLE

DATA	ANSWERS
Coordinates, Point A 1100N, 800E	Observers Point (P) Coordinates 1000.00N, 1000.00E
Coordinates, Point C 1300N, 1200E	
Angle a 45° 00' 00"	
Angle b 52° 07' 30"	
Coordinates, Point B 1300N, 900E	



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	STOP	41	A _E	A _N	0	ENTER A _N , A _E					
3	x→()	23									
4	d	17	STORE DATA								
5	y→()	40									
6	C	16									
7	ACC -	63									
8	↓	25									
9	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
a	STOP	41	C _E	C _N	0	ENTER C _N , C _E					
b	ACC +	60	CALCULATE C _N - A _N AND C _E - A _E								
c	↓	25									
d	3	03	DISPLAY 3 TO INDICATE THIRD ENTRY								
1	STOP	41	SECONDS	MINUTES	DEGREES	ENTER DEGREES, MINUTES AND SECONDS					
2	x→()	23									
3	b	14									
4	6	06									
5	0	00									
6	÷	35									
7	ROLL ↓	31									
8	+	33	CONVERT TO DECIMAL DEGREES								
9	b	14									
a	ROLL ↑	22									
b	÷	35									
c	÷	35									
d	↓	25									
2	+	33									
0	IF FLAG	43									
1	2	02									
2	d	17									
3	SET FLAG	54									
4	y→()	40	STORE ANGLE								
5	a	13									
6	CLEAR x	37	CLEAR DISPLAY								
7	↑	27									
8	↑	27									
9	4	04	DISPLAY 4 TO INDICATE FOURTH ENTRY								
a	GOTO() ()	44									
b	1	01	BRANCH FOR b ANGLE ENTRY								
c	0	00									
d	a	13	RECALL ANGLE a								

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	y→()	40	STORE ANGLE b							
	1	b	14								
	2	+	33								
	3	↓	25	CALCULATE sin OF a AND b							
	4	sin x	70								
	5	ROLL ↓	31								
	6	RCL	61	RECALL ΔE AND ΔN OF BASELINE A→C AND CONVERT TO POLAR							
	7	TO POLAR	62								
	8	y→()	40								
	9	E	12	STORE AZIMUTH θ A→C							
	a	x↔y	30								
	b	a	13								
4	c	sin x	70	CALCULATE sin θ _a							
	d	y→()	40								
	0	f	15	STORE BASELINE DISTANCE A→C							
	1	x	36								
	2	x↔y	30								
	3	ROLL ↑	22	COMPLETE LAW OF SINES FOR DISTANCE A→I							
	4	÷	35								
	5	E	12								
	6	↑	27								
	7	b	14								
	8	+	33								
	9	c	16								
5	a	ROLL ↓	31								
	b	x↔y	30								
	c	TO RECT	66	CALCULATE AZIMUTH A→I (FROM A→C) AND CALCULATE COORDINATES POINT I							
	d	ROLL ↓	31								
	0	+	33								
	1	0	00								
	2	y→()	40								
	3	b	14								
	4	ROLL ↓	31								
	5	d	17								
	6	+	33								
	7	y→()	40								
	8	E	12								
	9	↓	25								
	a	5	05	DISPLAY 5 TO INDICATE FIFTH ENTRY							
	b	STOP	41								
	c	↑	27								
	d	E	12								
				B _E B _N 0			ENTER B _N , B _E				

Step	Key	Code	Display			Storage					
			<i>x</i>	<i>y</i>	<i>z</i>	<i>f</i>	<i>e</i>	<i>d</i>	<i>c</i>	<i>b</i>	<i>a</i>
6	0	—	34								
	1	<i>b</i>	14								
	2	ROLL ↑	22								
	3	<i>x</i> ↔ <i>y</i>	30								
	4	—	34								
	5	↓	25								
	6	<i>x</i> ↔ <i>y</i>	30								
	7	TO POLAR	62								
	8	<i>y</i> ↔ <i>()</i>	24								
	9	<i>E</i>	12								
	<i>a</i>	<i>d</i>	17								
	<i>b</i>	<i>x</i> ↔ <i>y</i>	30								
	<i>c</i>	—	34								
	<i>d</i>	<i>c</i>	16								
7	0	↑	27								
	1	<i>b</i>	14								
	2	—	34								
	3	↓	25								
	4	<i>x</i> ↔ <i>y</i>	30								
	5	TO POLAR	62								
	6	↑	27								
	7	<i>a</i>	13								
	8	sin <i>x</i>	70								
	9	÷	35								
	<i>a</i>	<i>c</i>	16								
	<i>b</i>	ROLL ↑	22								
	<i>c</i>	—	34								
	<i>d</i>	↓	25								
8	0	sin <i>x</i>	70								
	1	<i>x</i>	36								
	2	<i>E</i>	12								
	3	↑	27								
	4	<i>a</i>	13								
	5	+	33								
	6	↓	25								
	7	<i>x</i> ↔ <i>y</i>	30								
	8	TO RECT	66								
	9	↑	27								
	<i>a</i>	<i>d</i>	17								
	<i>b</i>	+	33								
	<i>c</i>	ROLL ↑	22								
	<i>d</i>	<i>x</i> ↔ <i>y</i>	30								

CALCULATE LINE EQUATION $B \rightarrow I$ STORE AZIMUTH $B \rightarrow I$ CALCULATE AZIMUTH AND DISTANCE $A \rightarrow I$ COMPLETE LAW OF SINES FOR DISTANCE $A \rightarrow I$ CALCULATE ΔE AND A_N OF LINE $A \rightarrow P$

[illegible]

LINE TO CURVE INTERSECTION

PART NO
09100-74005

This program will complete the missing length of a line intersecting a curve, with the added feature of calculating the bearing of the radial line through the point of intersection. The information necessary to enter in the calculator is as follows:

- 1 - The bearing of the intersecting line
- 2 - Coordinates of the end of the intersecting line
- 3 - Coordinates of the radius point
- 4 - Length of radius
- 5 - The choice of the near or far point of intersection

This solution is ambiguous as there are two possible answers. The program has been written so that the operator always knows which solution he has made. If the deflected angle between the intersecting line and the radius is less than 90° , the bearing of the radial line will be indicated in the direction of the intersection to the radius. If the deflected angle is more than 90° , the bearing of the radial line will be indicated in the direction of the radius to the intersection. The operator will know by inspection which point is desired.

BEARING CODE:

NW = 4	NE = 1
SW = 3	SE = 2

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

SET: DEGREES

SET: FIXED POINT SET DECIMAL
WHEEL TO 3

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: BEARING ANGLE
DEGREES→Z, MINUTES→Y,
SECONDS→X

PRESS: CONTINUE

DISPLAY

DECIMAL	—	Z
ANGLE	—	
2	—	Y
2	—	X

ENTER DATA: BEARING CODE NE = 1,
SE = 2, SW = 3, NW = 4
1, 2, 3, or 4→X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER DATA: COORDINATES OF END OF
LINE (K) NORTH→Y, EAST→X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
4	—	X

ENTER DATA: COORDINATES OF RADIUS
POINT (I) NORTH→Y, EAST→X

PRESS: CONTINUE

USER INSTRUCTIONS

DISPLAY

0	—	Z
0	—	Y
5	—	X

ENTER DATA: RADIUS LENGTH
RADIUS →X

(Note: If far point of intersection is desired
PRESS: SET FLAG)

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
DISTANCE	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
CODE	—	X

(Note: See discussion for meaning of bearing
code)

PRESS: CONTINUE

DISPLAY

DEGREES	—	Z
MINUTES	—	Y
SECONDS	—	X

PRESS: CONTINUE FOR NEW PROBLEM

EXAMPLE

DATA:

Bearing Angle: $N 38^{\circ} 35' 02'' W$

Coordinates Point K: 10066.734N, 8292.873E

Coordinates Point I: 10203.332N, 8203.618E

Radius = 50

ANSWERS:

Near Point (J)

Distance = 114.88

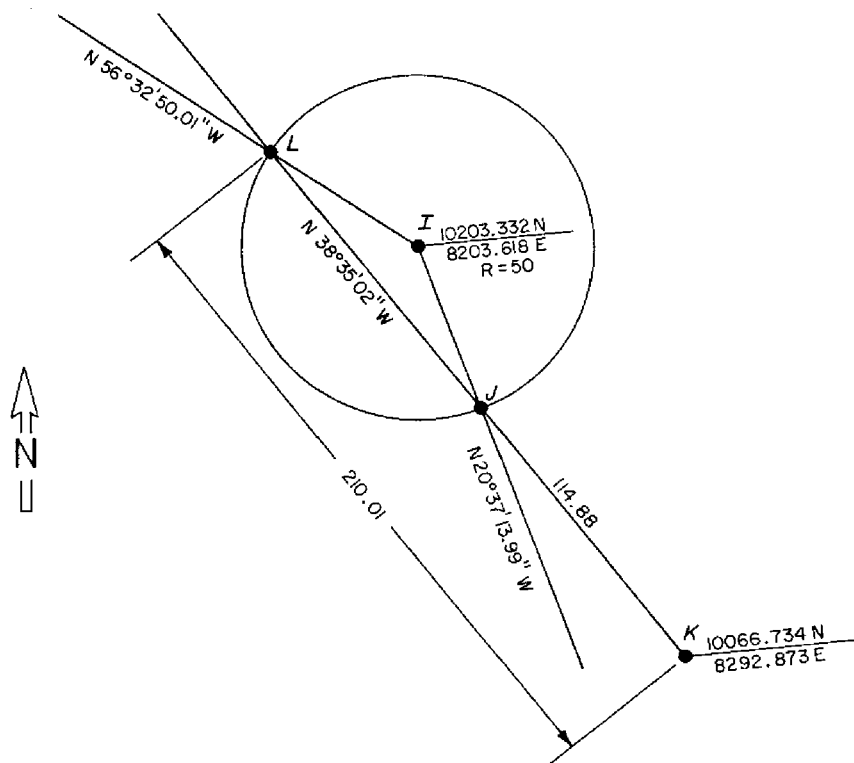
Quadrant Code = 4 (NW)

Bearing $N 20^{\circ} 37' 13.99'' W$

Far Point (L)

Distance = 210.01

Quadrant Code = 4 (NW)

Bearing $N 56^{\circ} 32' 50.01'' W$ 



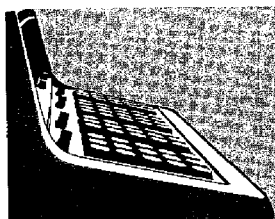
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	d	17								
	1	ROLL ↓	31								
	2	↓	25								
	3	3	03								
	4	STOP	41	K _E	K _N	0	ENTER COORDINATES, POINT K				
	5	ACC —	63								
	6	↓	25								
	7	4	04								
	8	STOP	41	I _E	I _N	0	ENTER COORDINATES, POINT I				
	9	ACC +	60								
	a	RCL	61								
	b	TO POLAR	62								
	c	x→()	23								
	d	f	15								
4	0	d	17	CALCULATE ANGLES							
	1	x↔y	30								
	2	—	34								
	3	y→()	40								
	4	E	12								
	5	↓	25								
	6	5	05								
	7	STOP	41	RADIUS	0	0	ENTER RADIUS				
	8	↑	27								
	9	f	15								
	a	↑	27								
	b	E	12								
	c	sin x	70								
	d	x	36								
5	0	↓	25								
	1	x↔y	30								
	2	÷	35								
	3	E	12								
	4	x↔y	30								
	5	arc °	72								
	6	sin x	70								
	7	IF FLAG	43								
	8	CHG SIGN	32								
	9	CONTINUE	47	MAKE LAW OF SINES SOLUTION, DETERMINE WHICH DISTANCE IS DESIRED, AND CALCULATE DISTANCE							
	a	x↔y	30								
	b	↑	27								
	c	↓	25								
	d	—	34								

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	F	15								
	1	$x \leftrightarrow y$	30								
	2	$\sin x$	70								
	3	X	36								
	4	CLEAR X	37								
	5	ROLL $\downarrow$	31								
	6	$x \leftrightarrow y$	30								
	7	$x \rightarrow ()$	23								
	8	F	15								
	9	$\sin x$	70								
	$\div$	$\div$	35								
	$\downarrow$	$\downarrow$	25								
	STOP	41	DISTANCE	0	0	DISPLAY					
7	d	d	17								
	0	$\uparrow$	27								
	1	F	15								
	2	—	34								
	3	1	01								
	4	TO RECT	66								
	5	TO POLAR	62								
	6	CLEAR X	37								
	7	IF $x < y$	52								
	8	8	10								
	9	d	17								
	$ y $	$ y $	55								
	9	9	11								
8	0	0	00								
	d	IF $x > y$	53								
	0	8	10								
	1	7	07								
	2	—	34								
	3	3	03								
	4	GO TO () ()	44								
	5	9	11								
	6	L	16								
	7	$x \leftrightarrow y$	30								
	8	—	34								
	9	2	02								
	5	GO TO () ()	44								
9	6	9	11								
	7	L	16								
	8	9	11								

CALCULATE MACHINE ANGLE OF RADIAL LINE
AND CONVERT TO BEARING ANGLE AND CODE

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	00									
1	IF $x > y$	53									
2	9	11									
3	9	11									
4	—	34									
5	4	04									
6	GOTO (H)	44									
7	9	11									
8	L	16									
9	$x \rightarrow y$	30									
a	—	34									
b	1	01									
c	$y \rightarrow ()$	40									
d	F	15									
a	↑	27									
1	CLEAR x	37									
2	↑	27									
3	ROLL ↑	22									
4	STOP	41	CODE	0	0	DISPLAY					
5	F	15									
6	↑	27									
7	int x	64									
8	—	34									
9	$x \rightarrow ()$	23									
a	E	12									
b	6	06									
c	0	00									
d	x	36									
b	↓	25	CONVERT TO DEGREES, MINUTES, AND SECONDS								
1	↑	27									
2	int x	64									
3	—	34									
4	$x \rightarrow ()$	23									
5	F	15									
6	6	06									
7	0	00									
8	x	36									
9	E	12									
a	↑	27									
b	F	15									
c	ROLL ↑	22									
d	END	46	SECONDS	MINUTES	DEGREES	DISPLAY					

FROM 8-6 & 8-c



TRUE MERIDIAN
BY ALTITUDE OBSERVATION OF THE SUN

PART NO.
09100-74006

The bearing of a line can be determined to within $\pm 2'$ by a single observation of the sun. The average of several such observations will give a higher accuracy by a minimization of measurement error. The following equation is used:

$$\cos Z = \frac{\sin d - \sin h \sin l}{\cos h \cos l}$$

where:

Z = sun's bearing

d = declination of the sun (from Solar Ephemeris)

h = measured altitude (V) - refraction (R) + parallax (P)

l = latitude scale from map (estimated)

R, P and d are taken from tables corrected for the time of day and the month, week and day of the year.

NOTE: For observations in the northern hemisphere, latitude and declination are taken as positive. For observations in the southern hemisphere, latitude and declination must be taken as minus; Z will then be measured from the north, as before.

Reference:

K & E

1968 Solar Ephemeris and Surveying Instrument Manual

USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM (Starting address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: (P)

Degrees → Z

Minutes → Y

Seconds → X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: (R) Enter as above.

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER DATA: (V) Enter as above.

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
4	—	X

ENTER DATA: (I) Enter as above.

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
5	—	X

USER INSTRUCTIONS (Cont'd)

ENTER DATA: (d) Enter as above.

PRESS: CONTINUE

DISPLAY

Cos Z	—	Z
0	—	Y
0	—	X

(Z in degrees,
minutes and
seconds.)Display
Z in decimal
degrees?

NO

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

Z^0	—	Z
Z'	—	Y
Z''	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
Z^0	—	X

To Reset Problem

EXAMPLE

DATA: P = 00° 00' 07.8"

 R = 00° 01' 24.42"

 V = 32° 59' 24.0"

 I = 38° 10' 06.0"

 d = 16° 44' 54.0"

SOLUTION: Cos Z = -.073

 or

 Z (decimal degrees) = 94.184°

 Z (deg, min, sec) = 94° 11' 1.596"

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	GO TO () ()	44								
1	0	00	BRANCH TO ENTER NEXT SET OF DATA								
2	4	04									
3	↓	25									
4	sin x	70									
5	↑	27									
6	c	16									
7	↑	27									
8	b	14									
9	-	34									
a	a	13									
b	+	33									
c	y → ()	40									
d	E	12									
4	0	↓	25								
1	sin x	70									
2	↑	27	CALCULATE cos Z								
3	d	17									
4	sin x	70									
5	x	36									
6	↓	25									
7	-	34									
8	E	12									
9	cos x	73									
a	↑	27									
b	d	17									
c	cos x	73									
d	x	36									
5	0	↓	25								
1	÷	35									
2	CLEAR x	37									
3	↑	27									
4	STOP	41	0	0	cos Z	DISPLAY					
5	ROLL ↑	22									
6	arc v	72	CALCULATE Z (DECIMAL DEGREES)								
7	cos x	73									
8	IF FLAG	43									
9	6	06	IF FLAG IS SET, BRANCH TO CONVERT Z TO DEGREES, MINUTES AND SECONDS								
a	0	00									
b	GO TO () ()	44									
c	7	07	BRANCH TO DISPLAY Z IN DECIMAL DEGREES								
d	2	02									

FROM 1-6

NEWELL FACNARD

NEWELL FACNARD

NEWELL FACNARD

NEWELL FACNARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	↑	27								
	1	int x	64								
	2	—	34								
	3	x→()	23								
	4	P	12								
	5	6	06								
	6	0	00								
	7	X	36								
	8	x↔y	30								
	9	↑	27								
7	a	int x	64								
	b	—	34								
	c	ROLL ↓	31								
	d	X	36								
	0	P	12								
	1	ROLL ↓	31								
	2	END	46								
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										

CONVERT Z (DECIMAL DEGREES) TO DEGREES, MINUTES AND SECONDS

SECONDS MINUTES DEGREES
DEC. DEGREES 0 0

DISPLAY Z IN DEGREES, MINUTES AND SECONDS OR IN DECIMAL DEGREES

[illegible]

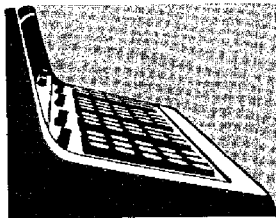
HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD



PART NO.
09100-74007

TRAVERSE WITH LAW OF SINES OPTION

This program will traverse from point to point given initial starting coordinate and successive bearings and distances displaying the coordinates of each point in the traverse. The program will also make a law of sines solution given the starting coordinates, ending coordinates and the bearings of the lines over which the two distances are desired.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or End]

SET: DEGREES

SET: FIXED POINT

PRESS: CONTINUE

DISPLAY

0 — Z

0 — Y

0 — X

ENTER DATA: NORTHING → Y, EASTING → X
(STARTING COORDINATES)

PRESS: CONTINUE

DISPLAY

0 — Z

1 — Y

1 — X

Law of Sines?

YES

NO

ENTER DATA:
99 → X

PRESS: CONTINUE

DISPLAY

2 — Z

2 — Y

2 — X

ENTER DATA: BEARING ANGLE
DEGREES → Z, MINUTES → Y
SECONDS → X

PRESS: CONTINUE

USER INSTRUCTIONS (con't)

DISPLAY

BEARING ANGLE — Z (In decimal degrees)

2 — Y

2 — X

ENTER DATA: QUADRANT CODE → X

Note: NE = 1, SE = 2, SW = 3, NW = 4

PRESS: CONTINUE

DISPLAY

MACHINE ANGLE — Z (In decimal degrees)

1 — Y

3 — X

ENTER DATA: DISTANCE → X

PRESS: CONTINUE

DISPLAY

2 — Z
NORTH COORDINATE — Y
EAST COORDINATE — X

Law of Sines?

NO

YES

PRESS: GO TO (0) (a)

ENTER DATA: 99 → X

PRESS: CONTINUE

DISPLAY

 $\begin{pmatrix} 0 \\ 0 \end{pmatrix}$ or $\begin{pmatrix} 2 \\ 2 \end{pmatrix}$ — Z
— Y
1 — XENTER DATA: (ENDING COORDINATES)
NORTH → Y, EAST → X

PRESS: CONTINUE

DISPLAY

9 — Z

9 — Y

9 — X

USER INSTRUCTIONS (con't)

ENTER DATA: (FIRST BEARING ANGLE)
 DEGREES → Z, MINUTES → Y
 SECONDS → X

PRESS: CONTINUE

DISPLAY

BEARING	_____ Z	(In decimal degrees)
ANGLE		
2	_____ Y	
2	_____ X	

ENTER DATA: QUADRANT CODE → X
 Note: NE = 1, SE = 2, SW = 3, NW = 4

PRESS: CONTINUE

DISPLAY

97	_____ Z
97	_____ Y
97	_____ X

ENTER DATA: (SECOND BEARING ANGLE)
 DEGREES → Z, MINUTES → Y,
 SECONDS → X

PRESS: CONTINUE

DISPLAY

BEARING	_____ Z	(In decimal degrees)
ANGLE		
2	_____ Y	
2	_____ X	

ENTER DATA: QUADRANT CODE → X
 Note: NE = 1, SE = 2, SW = 3, NW = 4

PRESS: CONTINUE

DISPLAY

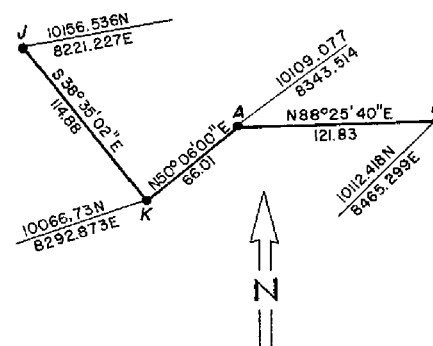
FIRST	_____ Z
DISTANCE	
SECOND	_____ Y
DISTANCE	
0	_____ X

USER INSTRUCTIONS (con't)

In cases where the figure is small and the location of the points of intersection cannot be determined by inspection, enter the bearing as you think it is and the calculator will display the distance as a plus number if you have made the right choice, and as a minus if the point falls on the other side. In case the operator is traversing from point to point and wishes to make a law of sines solution using the coordinates retained in the calculator at the time, he may PRESS: GO TO (0) (a), enter 99 in X, PRESS: CONTINUE and complete the solution by entering the ending coordinates, pressing CONTINUE and proceeding with the two known bearings.

PRESS: CONTINUE FOR NEW STARTING DATA

EXAMPLE



DATA:

STARTING COORDINATES (POINT J)

10156.536N, 8221.227E

BEARING: S38°35'02"E

DISTANCE: 114.88

ENDING COORDINATES (POINT B)

10112.418N, 8465.299E

FIRST BEARING: N 50°06'00"E

SECOND BEARING: N 88°25'40"E

ANSWERS:

COORDINATES POINT K

10066.735N, 8292.873E

FIRST DISTANCE (K TO A)

66.007

SECOND DISTANCE (A TO B)

121.833



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	STOP	41	EAST	NORTH		ENTER STARTING COORDINATES					
2	ACC +	60									
3	↓	25	START COURSE COUNT								
4	1	01									
5	↑	27									
6	STOP	41	1 or 99	0	0	ENTER PROGRAM OPTION, ENTER 1 FOR TRAVERSE OR 99 FOR LAW OF SINES					
7	IF $x=y$	50									
8	$y \rightarrow ()$	40									
9	$\angle$	16	TEST TO DETERMINE IF TRAVERSE OR IF LAW OF SINES								
a	$x \angle y$	30									
b	9	11									
c	9	11									
d	IF $x=y$	50									
1	$\angle$	13	BRANCH IF LAW OF SINES								
1	1	01									
2	2	02									
3	↑	27									
4	↑	27									
5	STOP	41	SECONDS	MINUTES	DEGREES	ENTER BEARING ANGLE					
6	ROLL ↑	22									
7	$x \rightarrow ()$	23									
8	d	17									
9	6	06									
a	0	00									
b	÷	35									
c	↓	25	CONVERT TO DECIMAL DEGREES								
d	+	33									
2	6	06									
1	0	00									
2	÷	35									
3	d	17									
4	+	33									
5	2	02									
6	↑	27									
7	STOP	41	2	2	BEARING ANGLE	DISPLAY (ENTER QUADRANT CODE IN X)					
8	$x \angle y$	30									
9	IF $x=y$	50									
a	3	03									
b	6	06									
c	3	03									
d	IF $x=y$	50									

HEWLETT-PACKARD FROM 9-2

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD FROM 5-8, a-0 & a-c

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	3	03								
1	5	05									
2	SET FLAG	54									
3	1	01									
4	IF $x=y$	50									
5	CHG SIGN	32									
6	1	01									
7	ROLL $\uparrow$	22									
8	X	36									
9	9	11									
a	0	00									
b	IF FLAG	43									
c	+	33									
d	+	33									
4	0	-	34								
1	L	16									
2	$\uparrow$	27									
3	9	11									
4	6	06									
5	IF $x < y$	52									
6	5	05									
7	9	11									
8	3	03									
9	STOP	41	3	1	MACHINE ANGLE	DISPLAY (ENTER DISTANCE IN X IF TRAVERSE)					
a	$x \neq y$	30									
b	$\downarrow$	25									
c	TO RECT	66									
d	ACC +	60									
5	0	L	16								
1	$\uparrow$	27									
2	1	01									
3	+	33									
4	$\uparrow$	27									
5	RCL	61									
6	GOTO () ()	44									
7	1	01									
8	5	05									
9	9	11									
a	9	11									
b	IF $x=y$	50									
c	9	11									
d	3	03									

CONVERT TO MACHINE ANGLE

TEST COUNT TO DETERMINE
TRAVERSE OR LAW OF SINES

DISPLAY
(ENTER DISTANCE IN X
IF TRAVERSE)

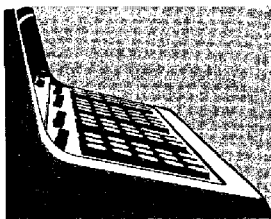
COMPLETE TRAVERSE

BRANCH TO NEW COURSE

Step	Key	Code	Display			Storage						
			x	y	z	r	s	t	u	v	w	x
6	0	b	14									
1	ROLL $\uparrow$	22										
2	—	34										
3	$\uparrow$	27										
4	RCL	61										
5	TO POLAR	62										
6	$x \rightarrow ()$	23										
7	f	15										
8	b	14										
9	$x \rightarrow y$	30										
0	—	34										
1	$\downarrow$	25										
2	—	34										
3	$x \rightarrow ()$	23										
7	0	b	14									
1	f	15										
2	ROLL $\downarrow$	31										
3	$\sin x$	70										
4	ROLL $\uparrow$	22										
5	$x \rightarrow y$	30										
6	$\times$	36										
7	ROLL $\downarrow$	31										
8	$x \rightarrow y$	30										
9	$\sin x$	70										
0	$\div$	35										
1	$y \rightarrow ()$	24										
2	b	14										
3	$x \rightarrow y$	30										
8	0	$\sin x$	70									
1	$\uparrow$	27										
2	f	15										
3	$\times$	36										
4	b	14										
5	CHG SIGN	32										
6	ROLL $\downarrow$	31										
7	$x \rightarrow y$	30										
8	$\div$	35										
9	$x \rightarrow y$	30										
0	CHG SIGN	32										
1	$x \rightarrow y$	30										
2	CLEAR $\times$	37										
3	STOP	41	0	2nd DISTANCE	1st DISTANCE	DISPLAY						

COMPLETE LAW OF SINES

Step	Key	Code	Display			Storage										
			s	y	z	f	e	d	c	b	a					
9	0	GO TO () ()	44													
1	0	00	BRANCH TO NEW PROBLEM													
2	0	00														
3	9	11														
4	7	07														
5	x→()	23														
6	C	16														
7	ROLL ↓	31														
8	y→()	40														
9	b	14														
a	↓	25	TEST FOR FIRST OR SECOND													
b	↓	25	COURSE OF LAW OF SINES													
c	GO TO () ()	44														
d	1	01														
a	0	5	05													
1	y→()	40														
2	C	16														
3	↓	25														
4	1	01														
5	STOP	41	ENDING E ENDING N 0			ENTER ENDING COORDINATES FOR LAW OF SINES										
6	ACC -	63														
7	9	11	CALL FOR FIRST BEARING ENTRY													
8	↑	27	OF LAW OF SINES													
9	↑	27														
a	GO TO () ()	44	BRANCH FOR FIRST BEARING ENTRY													
b	1	01	IN LAW OF SINES													
c	5	05														
d	END	46														
0																
1																
2																
3																
4																
5																
6																
7																
8																
9																
a																
b																
c																
d																



COORDINATE GEOMETRY AND ENCLOSED AREA

PART NO.
09100-74008

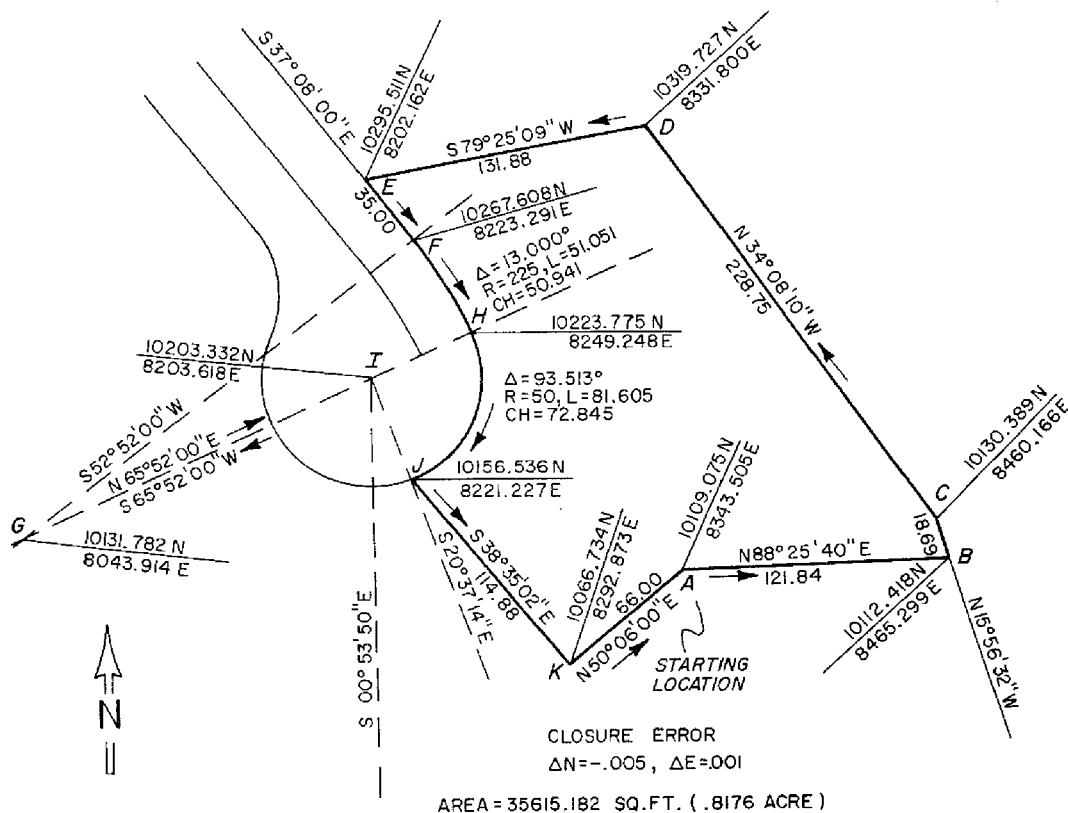
This program traverses by bearing and distance and calculates coordinates, enclosed area, and the following curve data:

1. Length
2. Chord
3. Central angle in decimal degrees
4. Coordinates of tangent points

This program is designed to traverse from point to point on a survey map indicating coordinates of successive points on the survey and also indicating the descriptive features of tangent curved portions. If direction of traverse is given in degrees and lengths in feet, then the area is given in square feet. The four quadrants are represented as follows: NE = 1, SE = 2, SW = 3, NW = 4.

QUADRANT CODE

4 = NW	1 = NE
3 = SW	2 = SE



USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

ENTER COORDINATES:

Northing → Y

Easting → X

PRESS: X → ()

PRESS: d

PRESS: Y → ()

PRESS: c

PRESS: CONTINUE

DISPLAY:

1 → Z

Northing → Y

Easting → X

ENTER BEARING ANGLE DATA: ←

Degrees → Z

Minutes → Y

Seconds → X

Note: Decimal Degrees, Decimal Minutes or Decimal Seconds may be entered provided they are entered in the proper register.

PRESS: CONTINUE

DISPLAY

Decimal Bearing → Z

2 → Y

2 → X

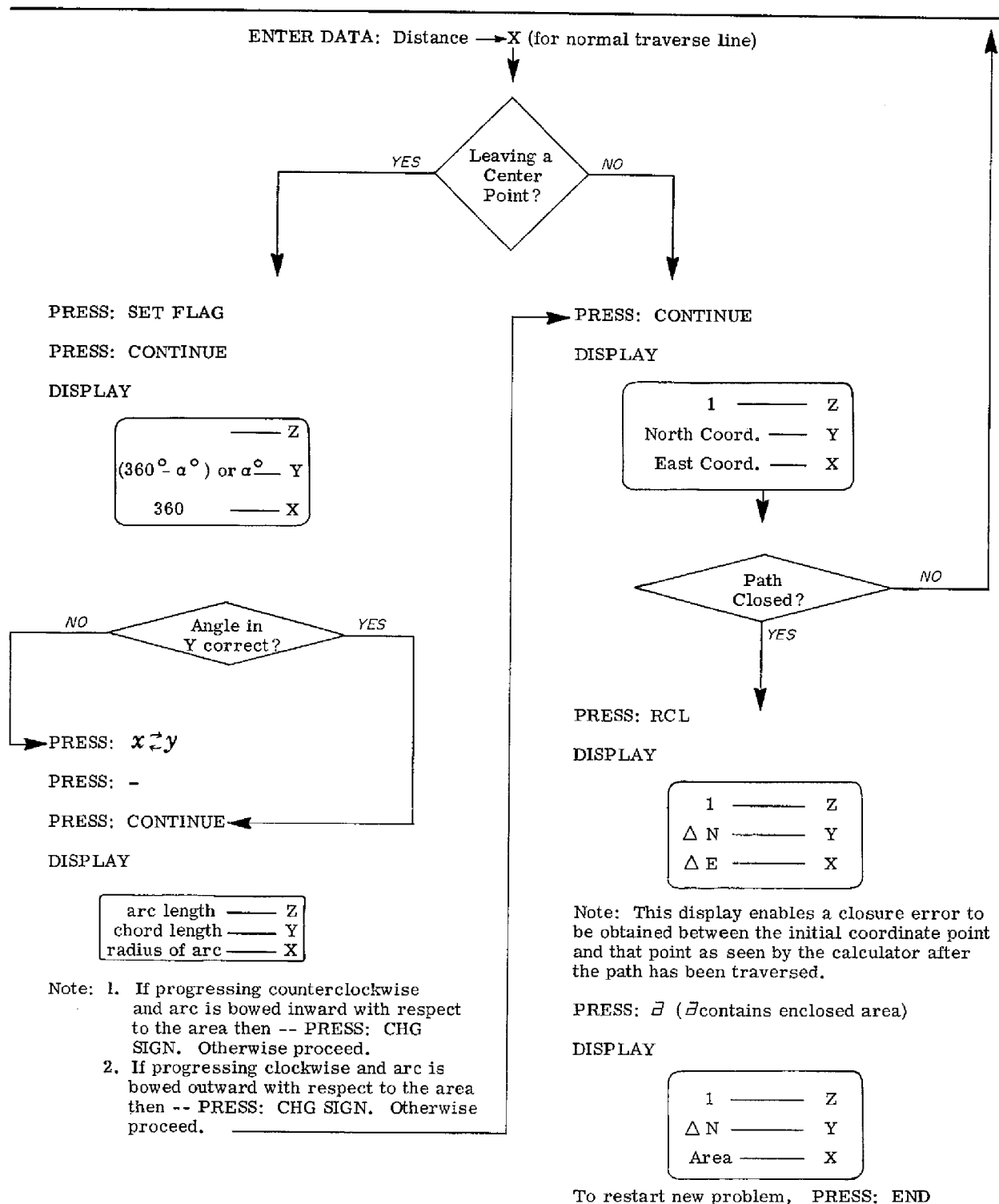
ENTER DATA: Quadrant Code (1 = NE, 2 = SE, 3 = SW, 4 = NW) in X register.

PRESS: CONTINUE

DISPLAY: Intermediate results

NO

USER INSTRUCTIONS (con't)



EXAMPLES

EXAMPLES (con't)

STARTING COORDINATES = Coordinates of A

Coordinates of A:

10109.075 Northing
8343.505 Easting
NE 88° 25' 40"
Distance 121.84'

Coordinates of B:

10112.418 Northing *
8465.299 Easting *
NW 15° 56' 32"
Distance 18.69'

Coordinates of C:

10130.389 Northing *
8460.166 Easting *
NW 34° 08' 10"
Distance 228.75'

Coordinates of D:

10319.727 Northing *
8331.800 Easting *
SW 79° 25' 09"
Distance 131.88'

Coordinates of E:

10295.511 Northing *
8202.162 Easting *
SE 37° 08' 00"
Distance 35.00'

Coordinates of F:

10267.608 Northing *
8223.291 Easting *

START OF CURVE:

SW 52° 52' 00"
Distance 225.00'

Coordinates of G:

10131.782 Northing *
8043.914 Easting *
NE 65° 52' 00"
Distance 225.00'

51.051 --- Arc Length *
50.941 --- Chord Length*
225.000 --- Radius *

Central Angle 13.000

Coordinates of H:

10223.775 Northing *
8249.248 Easting *
SW 65° 52' 00"
Distance 50.00'

Coordinates of I:

10203.332 Northing *
8203.618 Easting *
SE 20° 37' 14"
Distance 50.00'

81.605 --- Arc Length
72.845 --- Chord Length
50.00 --- Radius
Central Angle 93.513

Coordinates of J:

10156.536 Northing *
8221.227 Easting *
SE 38° 35' 02"
Distance 114.88'

Coordinates of K:

10066.734 Northing *
8292.873 Easting *
NE 50° 06' 00"
Distance 66.00'

Coordinates of A:

10109.070 Northing*
8343.506 Easting *

CLOSURE ERROR

N = -.005
E = +.001

ENCLOSED AREA:

35,615.182 sq. feet
.8176 acre

*Coordinate Answers

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20									
1	y→()	40									
2	a	13									
3	RCL	61									
4	⌈	16									
5	+	33									
6	f	15									
7	↑	27									
8	d	17									
9	+	33									
0	1	01									
1	ROLL ↓	31									
2	STOP	41									
3	ROLL ↑	22									
1	0 x→()	23									
1	b	14									
2	6	06									
3	0	00									
4	÷	35									
5	↓	25									
6	+	33									
7	6	06									
8	0	00									
9	÷	35									
0	b	14									
1	+	33									
2	2	02									
3	↑	27									
2	0 STOP	41									
1	x↔y	30									
2	IF x=y	50									
3	2	02									
4	d	17									
5	3	03									
6	IF x=y	50									
7	2	02									
8	⌈	16									
9	SET FLAG	54									
0	1	01									
1	IF x=y	50									
2	CHG SIGN	32									
3	1	01									

FROM 5-3

STORE AREA IN a

ADD COORDINATES OF STARTING POINT

SECONDS MINUTES DEGREES

ENTER BEARING

CONVERT BEARING TO DECIMAL DEGREES

QUAD. CODE

ENTER QUADRANT CODE

CONVERT BEARING TO MATHEMATICAL ANGLE.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	ROLL ↑	22								
1	X	36									
2	9	11									
3	0	00									
4	IF FLAG	43									
5	+	33									
6	+	33									
7	-	34									
8	STOP	41									
9	IF FLAG	43									
a	5	05									
b	4	04									
c	y→()	40									
d	9	11									
0	TO RECT	66									
1	ACC +	60									
2	↑	27									
3	E	12									
4	X	36									
5	f	15									
6	ROLL ↑	22									
7	X	36									
8	↓	25									
9	-	34									
a	CHG SIGN	32									
b	2	02									
c	÷	35									
d	a	13									
5	+	33									
1	GO TO () ()	44									
2	0	00									
3	1	01									
4	x→()	23									
5	b	14									
6	↓	25									
7	↑	27									
8	y→()	24									
9	9	11									
a	-	34									
b	1	01									
c	8	10									
d	0	00									

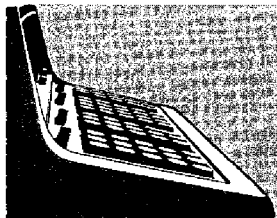
JUMP TO CIRCULAR
ARC ROUTINE

COMPUTE COMPONENTS
AND ACCUMULATE

COMPUTE AREA INCREMENT
AND ACCUMULATE

FROM 18 C

3-b



PART NO.
09100-74009

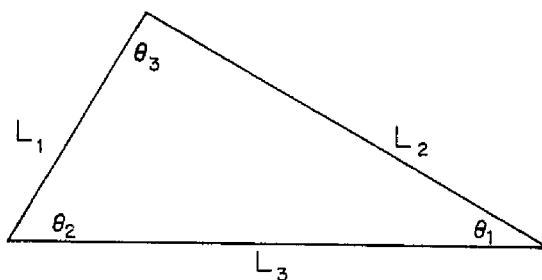
TRIANGLE SOLUTION - SIDES GIVEN

This program uses the law of cosines to solve for the three included angles and area of any triangle where the side lengths are given.

The equation (law of cosines) used is:

$$L_i^2 = L_j^2 + L_k^2 - 2L_jL_k \cos \theta_i \quad \text{where: } L_i, L_j, L_k \text{ and } \theta_i$$

correspond to the variables shown in the diagram below:



Rewriting the above equation, θ_1 becomes:

$$\theta_1 = \cos^{-1} \left(\frac{L_i^2 - (L_j^2 + L_k^2)}{2L_jL_k} \right)$$

The area is calculated by:

$$A = \frac{1}{2} L_i L_j \sin \theta_k$$

Reference: The Calculus
Barnes & Noble College Outline Series

USER INSTRUCTIONS

SET: DEGREES

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

(i is set to 1 internally)

ENTER DATA:

 L_1 _____ $\rightarrow$ Z L_2 _____ $\rightarrow$ Y L_3 _____ $\rightarrow$ X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
θ_1	_____	X

(decimal degrees)

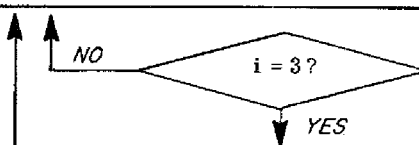
PRESS: CONTINUE

DISPLAY

θ_1 (degrees)	_____	Z
θ_1 (minutes)	_____	Y
θ_1 (seconds)	_____	X

Note: The first DISPLAY will be θ_1 . To display θ_2 press CONTINUE. θ_3 will be displayed after pressing CONTINUE again.

USER INSTRUCTIONS (con't)



PRESS: CONTINUE

DISPLAY

(1)

0	_____	Z
0	_____	Y
area	_____	X

To reset problem:

EXAMPLES

(A)

Data: $L_1 = 16$, $L_2 = 8$, $L_3 = 10$

Solution:

	Dec. Degrees	Degrees, Min., & Sec.
θ_1	125.10°	125° 05' 58.68"
θ_2	24.15°	24° 08' 48.65"
θ_3	30.75°	30° 45' 12.67"

A = 32.73

(B)

Data: $L_1 = 3$, $L_2 = 4$, $L_3 = 5$

Solution:

	Dec. Degrees	Degrees, Min., & Sec.
θ_1	36.87°	36° 52' 11.63"
θ_2	53.13°	53° 07' 48.37"
θ_3	90.00°	90° 00' 00"

A = 6.00

Step	Key	Code	Display			Storage					
			x	y	z	F	e	d	c	b	a
0	0	CLEAR	20								
	1	1	01								
	2	$x \rightarrow ()$	23								
	3	$\bar{a}$	13	INITIALIZE COUNTER							
	4	STOP	41	L_3	L_2	L_1	ENTER L_1, L_2, L_3				
	5	ACC +	60								
	6	ROLL $\downarrow$	31								
	7	$y \rightarrow ()$	40	STORE L_1, L_2, L_3							
	8	$\bar{d}$	17								
	9	RCL	61								
	$\bar{a}$	TO POLAR	62								
	$\bar{b}$	$\uparrow$	27								
	$\bar{c}$	$\times$	36								
	$\bar{d}$	$\bar{d}$	17								
1	0	$\uparrow$	27								
	1	$\times$	36								
	2	$\downarrow$	25								
	3	$x \leftrightarrow y$	30								
	4	$-$	34								
	5	2	02								
	6	$\div$	35								
	7	$\bar{e}$	12								
	8	$\div$	35	CALCULATE θ_1							
	9	$\bar{f}$	15								
	$\bar{a}$	$\div$	35								
	$\bar{b}$	$\downarrow$	25								
	$\bar{c}$	CHG SIGN	32								
	$\bar{d}$	arc ∇	72								
2	0	$\cos x$	73								
	1	$x \rightarrow ()$	23								
	2	$\bar{b}$	14								
	3	$\uparrow$	27								
	4	CLEAR x	37								
	5	$\uparrow$	27								
	6	ROLL $\uparrow$	22								
	7	STOP	41	θ_1	0	0	DISPLAY DECIMAL θ_1				
	8	$\uparrow$	27								
	9	int x	64								
	$\bar{a}$	$-$	34								
	$\bar{b}$	$x \rightarrow ()$	23								
	$\bar{c}$	$\bar{c}$	16								
	$\bar{d}$	6	06								

HEWLETT-PACKARD

HEWLETT-PACKARD FROM 5-3

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	00									
	1	X									
	2	x↔y									
	3	↑									
	4	Int x									
	5	—									
	6	ROLL ↓									
	7	X									
	8	⌊									
	9	ROLL ↓									
	▢	STOP	41	SECONDS	MINUTES	DEGREES	DISPLAY θ_i				
	b	a	13								
4	⌊	↑	27								
	d	1	01								
	0	+	33								
	1	y→()	40								
	2	▢	13								
	3	4	04								
	4	IF x=y	50								
	5	5	05								
	6	4	04								
	7	y↔()	24								
	8	d	17								
	9	y↔()	24								
5	a	f	15								
	b	y↔()	24								
	⌊	e	12								
	d	y→()	40								
	0	d	17								
	1	GO TO () ()	44								
	2	0	00								
	3	9	11								
	4	RCL	61								
	5	X	36								
	6	2	02								
	7	÷	35								
	8	b	14								
	9	sin x	70								
	▢	X	36								
	b	CLEAR X	37								
	⌊	↑	27								
	d	ROLL ↑	22								

CONVERT DECIMAL θ_i TO DEGREES, MINUTES AND SECONDS

INCREMENT COUNTER

BRANCH AFTER ALL ANGLES ARE CALCULATED

ROTATE LENGTH FOR CALCULATION OF NEXT θ_i

BRANCH TO CALCULATE NEXT θ_i

CALCULATE $A = \frac{1}{2} L_i L_j \sin \theta_k$

[illegible]

CIRCULAR SECTOR

PART NO.
09100-74010

This program calculates the arc length, chord length, and segment and sector areas of a circular sector given the radius and central angle (α) of the sector.

The following equations are used:

$$\text{Sector Area} = \frac{\pi r^2 \theta}{360}$$

$$\text{Segment Area} = \frac{\pi r^2 \theta}{360} - \frac{r^2 \sin \theta}{2}$$

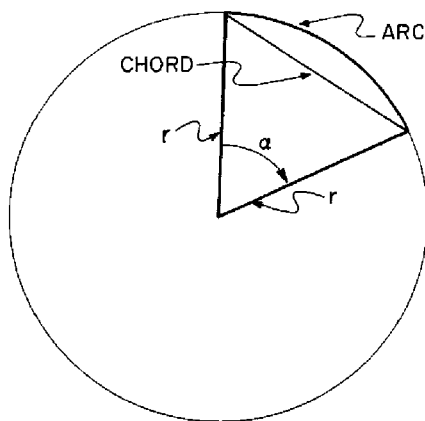
$$\text{Chord length} = 2r \sin (\theta/2)$$

$$\text{Arc length} = \frac{\pi r \theta}{180}$$

where r is the radius of the sector (any dimension of length), and θ is the angle (in degrees) subtended by the arc of the sector.

A chord, arc, segment, etc. are illustrated below.

Sector diagram:



The segment is the area enclosed by the arc and the chord.

Reference: Handbook of Chemistry & Physics
40th Edition (1958-1959)
Chemical Rubber Publishing Co.

USER INSTRUCTIONS

EXAMPLES

SET: DEGREES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or End]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

ENTER DATA: $\alpha^0 \rightarrow Z$, $\alpha' \rightarrow Y$, $\alpha'' \rightarrow X$.

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
2	_____	X

ENTER DATA: $r \rightarrow X$

PRESS: CONTINUE

DISPLAY

1	_____	Z
Sector area	_____	Y
Segment area	_____	X

PRESS: CONTINUE

DISPLAY

2	_____	Z
Chord length	_____	Y
Arc length	_____	X

To reset problem:

(A) Data: $\alpha = 180^\circ$ $r = 2$

Solution: Sector area = 6.2832

Segment area = 6.2832

Chord length = 4

Arc length = 6.2832

(B) Data: $\alpha = 20^\circ 15' 30''$ $r = 6$

Solution: Sector area = 6.3643

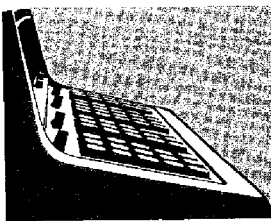
Segment area = .1318

Chord length = 2.1104

Arc length = 2.1214

[illegible]

[illegible]



PART NO.
09100-74011

TRAVERSE WITH COMPASS RULE ADJUSTMENT OPTION

This program traverses by bearing and distance, calculates coordinates, closure error, total traverse distance and the precision ratio. The precision ratio is the ratio of the total distance traversed to the closure error distance from a fixed point.

The program may then be used to distribute the closure error by the Compass Rule. The Compass Rule Assumes:

1. Course corrections are proportional to course lengths.
2. Angular measurement errors are equal to linear measurement errors.

The Compass Adjustment formulas used are:

$$\text{easting correction} = \left[\frac{\text{course distance}}{\text{total traverse distance}} \right] \times [\text{easting closure error}]$$

$$\text{northing correction} = \left[\frac{\text{course distance}}{\text{total traverse distance}} \right] \times [\text{northing closure error}]$$

QUADRANT CODE

4 = NW	1 = NE
3 = SW	2 = SE

If the traverse includes a curve, the curve is traversed using Program 1 in the same manner as in Program 09100-74001 by proceeding from the starting point of the curve to the center point of the curve, and then from the center point to the end point of the curve. When exiting the curve (i.e. when proceeding from the center point to the end point of the curve) the distance traversed must be entered in both the X and Y display registers (see "User Instructions"). The radius, arc length, chord length, and central angle of the curve will be displayed prior to the coordinates of the end point of the curve.

USER INSTRUCTIONS

ENTER PROGRAM # 1: (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER COORDINATES:

Northing → Y

Easting → X

PRESS: ACC+

ENTER BEARING ANGLE:

Degrees → Z

Minutes → Y

Seconds → X

PRESS: CONTINUE

DISPLAY: Bearing Angle

Decimal	_____	Z
Degrees	_____	
2	_____	Y
2	_____	X

ENTER DATA: Quadrant Code → X

(NE = 1, SE = 2, SW = 3, NW = 4)

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
3	_____	X

NO

Exit
from curve?

YES

ENTER DATA: Distance → Y, Distance → X

PRESS: CONTINUE

DISPLAY

Arc Length	_____	Z
Chord	_____	Y
Radius	_____	X

USER INSTRUCTIONS con't

PRESS: CONTINUE

DISPLAY: Central Angle

Degrees	_____	Z
Minutes	_____	Y
Seconds	_____	X

PRESS: CONTINUE

ENTER DATA: Distance → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
Northing	_____	Y
Easting	_____	X

NO

Is
traverse
complete?

YES

ENTER FIXED COORDINATES:

Northing → Y

Easting → X

PRESS: GO TO () ()

PRESS: 9

PRESS: 7

PRESS: CONTINUE

DISPLAY

Precision Ratio	_____	Z
Closure Error	_____	Y
Distance	_____	X
Traversed	_____	

ENTER PROGRAM #2: (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

USER INSTRUCTIONS (con't)

ENTER STARTING COORDINATES:

Northing → Y

Easting → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
2	_____	X

ENTER Bearing Angles:

Degrees → Z

Minutes → Y

Seconds → X

PRESS: CONTINUE

DISPLAY: Bearing Angle

Decimal	_____	Z
Degrees	_____	
2	_____	Y
2	_____	X

ENTER DATA: Quadrant Code → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
3	_____	X

ENTER DATA: Distance → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
Corrected	_____	Y
Distance	_____	
Quadrant	_____	X
Code	_____	

PRESS: CONTINUE

DISPLAY: Corrected Bearing Angle

Degrees	_____	Z
Minutes	_____	Y
Seconds	_____	X

USER INSTRUCTIONS (con't)

PRESS: CONTINUE

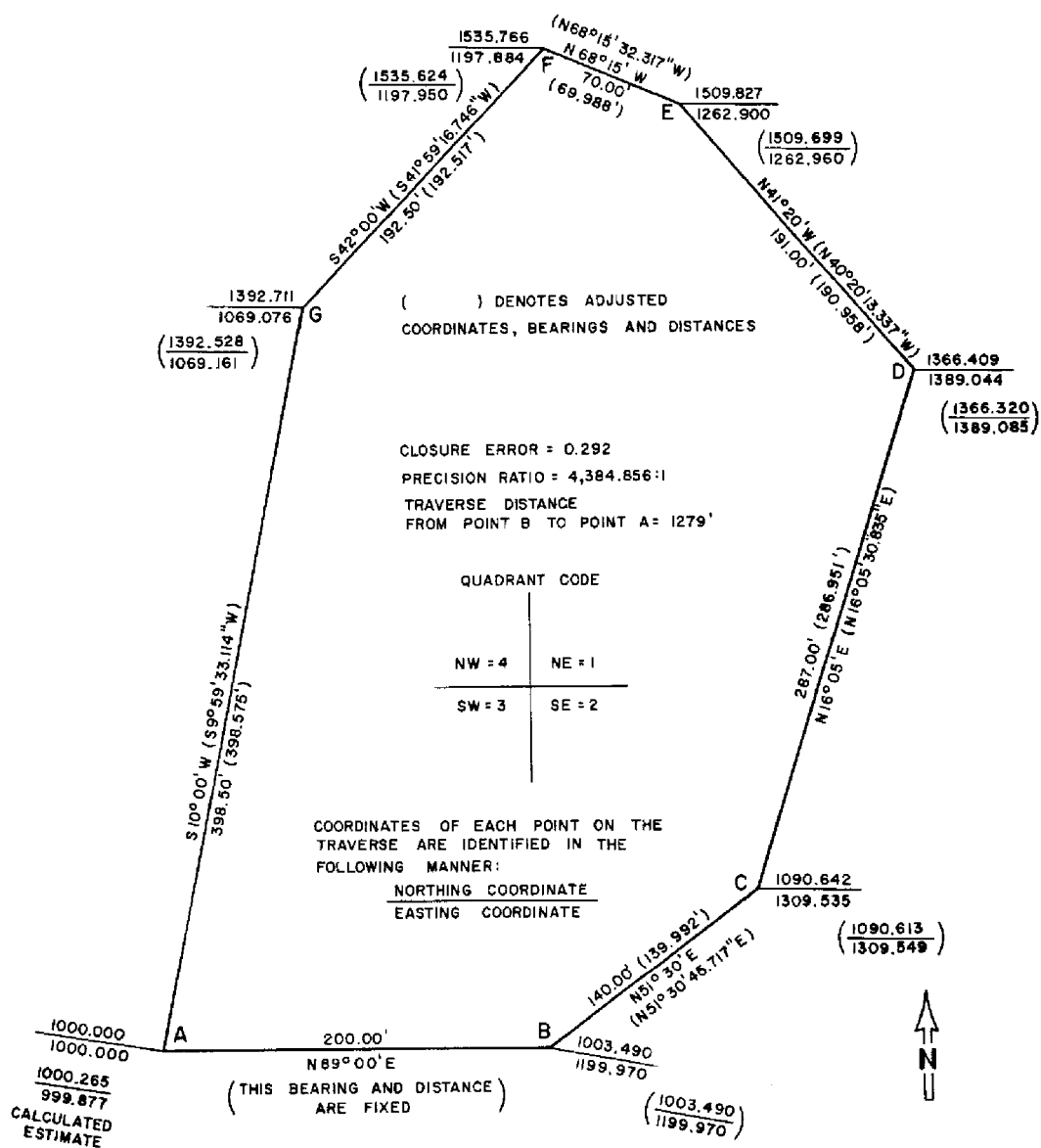
DISPLAY: CORRECTED COORDINATES

0	_____	Z
Northing	_____	Y
Easting	_____	X

To continue with corrected traverse.

To enter new traverse data return to beginning of USER INSTRUCTIONS, re-enter Program #1 and continue as before.

EXAMPLE



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	$x \rightarrow I$	23									
2	d	17	E _i	N _i	0						
3	STOP	41	SEC.	MIN.	DEG.						
4	ROLL $\uparrow$	22									
5	$x \rightarrow I$	23									
6	L	16									
7	6	06									
8	0	00									
9	$\div$	35									
a	$\downarrow$	25									
b	33	+	CONVERT DEGREES, MINUTES, AND SECONDS TO DECIMAL DEGREES								
c	6	06									
d	0	00									
1	0	$\div$	35								
1	L	16									
2	+	33									
3	2	02									
4	$\uparrow$	27									
5	STOP	41	QUAD. CODE	0	0						
6	$x \rightarrow y$	30									
7	IF $x=y$	50									
8	2	02									
9	4	04									
a	3	03									
b	IF $x=y$	50									
c	2	02									
d	3	03									
2	0	SET FLAG	54								
1	1	01									
2	IF $x=y$	50									
3	CHG SIGN	32									
4	1	01	CALCULATE MACHINE ANGLE								
5	ROLL $\uparrow$	22									
6	X	36									
7	9	11									
8	0	00									
9	IF FLAG	43									
a	+	33									
b	+	33									
c	-	34									
d	CLEAR X	37									

ENTER STARTING
COORDINATES
NORTHING $\rightarrow$ Y, EASTING $\rightarrow$ X
PRESS ACC +
ENTER BEARING ANGLE
DEGREES $\rightarrow$ Z, MINUTES $\rightarrow$ Y
SECONDS $\rightarrow$ X

ENTER QUADRANT
CODE $\rightarrow$ X

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	$\square$	16								
1	$\div$	35									
2	π	56									
3	CHG SIGN	32									
4	$\times$	36									
5	b	14									
6	$\times$	36									
7	$y \rightarrow ()$	24									
8	d	17									
9	-	34									
	$\square$	16									
	b	$\uparrow$	27								
	$\square$	2	02								
	d	$\div$	35								
7	0	$x \rightarrow y$	30								
1	$\sin x$	70									
2	$\times$	36									
3	b	14									
4	$\times$	36									
5	ROLL $\downarrow$	31									
6	+	33									
7	$y \rightarrow ()$	24									
8	d	17									
9	ROLL $\uparrow$	22									
	$\square$	STOP	41								
	b	$\square$	16								
	$\square$	$\uparrow$	27								
	d	int x	64								
8	0	-	34								
1	$x \rightarrow ()$	23									
2	$\square$	16									
3	6	06									
4	0	00									
5	$\times$	36									
6	$x \rightarrow y$	30									
7	$\uparrow$	27									
8	int x	64									
9	-	34									
	$\square$	ROLL $\downarrow$	31								
	b	$\times$	36								
	$\square$	$\square$	16								
	d	ROLL $\downarrow$	31								

CALCULATE AND STORE ARC LENGTH

CALCULATE Σ DISTANCE $_{i-1}$

CALCULATE CHORD

CALCULATE AND STORE
 Σ DISTANCE $_i = \Sigma$ DISTANCE $_{i-1} + C_i$

RADIUS CHORD ARC LENGTH DISPLAY

CONVERT CENTRAL ANGLE TO
DEGREES, MINUTES, AND SECONDS

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	RCL	61									
	1	↑	27									
	2	d	17									
	3	÷	35									
	4	ROLL ↑	22									
	5	x↔y	30									
	6	÷	35	CALCULATE $\frac{\Delta E}{\Sigma D_i}$ AND $\frac{\Delta N}{\Sigma D_i}$								
	7	ROLL ↓	31									
	8	y→()	40									
	9	d	17									
	a	x→()	23									
	b	C	16									
	c	CLEAR	20									
	d	1	01									
	1	0	STOP	41	EASTING	NORTHING	0	ENTER STARTING COORDINATES				
1		ACC +	60	STORE STARTING COORDINATES								
2		↓	25									
3		2	02									
4		STOP	41	SECONDS	MINUTES	DEGREES	ENTER BEARING					
5		ROLL ↑	22									
6		x→()	23									
7		b	14									
8		6	06									
9		0	00									
a		÷	35									
b		↓	25									
c		+	33	CONVERT TO DECIMAL DEGREES								
d		6	06									
2		0	0	00								
	1	÷	35									
	2	b	14									
	3	+	33									
	4	2	02									
	5	↑	27									
	6	STOP	41	2	2	DEC. DEGREES	DISPLAY					
	7	x↔y	30									
	8	IF x=y	50									
	9	3	03									
	a	5	05									
	b	3	03									
	c	IF x=y	50									
	d	3	03									

FROM a-8

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	4	04								
	1	SET FLAG	54								
	2	1	01								
	3	IF X = Y	50								
	4	CHG SIGN	32								
	5	1	01								
	6	ROLL ↑	22								
	7	X	36								
	8	9	11								
	9	0	00								
3	a	IF FLAG	43								
	b	+	33								
	c	+	33								
	d	-	34								
4	0	CLEAR X	37								
	1	y → ()	40								
	2	b	14								
	3	↑	27								
	4	↑	27								
	5	3	03								
	6	STOP	41	DISTANCE	0	0					ENTER DISTANCE
	7	↑	27								
	8	ROLL ↑	22								
	9	c	16								
	a	X	36								
	b	d	17								
	c	ROLL ↑	22								
	d	X	36								
5	0	y → ()	24								
	1	b	14								
	2	TO RECT	66								
	3	ROLL ↓	31								
	4	+	33								
	5	b	14								
	6	ROLL ↑	22								
	7	+	33								
	8	ROLL ↓	31								
	9	ACC +	60								
	a	TO POLAR	62								
	b	x → ()	23								
	c	b	14								
	d	CLEAR X	37								

FROM 2-a

CONVERT TO MACHINE ANGLE

DISTANCE 0 0 ENTER DISTANCE

CALCULATE NORTHING AND EASTING CORRECTION

CALCULATE CORRECTED COORDINATES

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	IF $x < y$	52								
	1	7	07								
	2	6	06								
	3	y	55								
	4	9	11								
	5	0	00								
	6	IF $x > y$	53								
	7	7	07								
	8	0	00								
	9	—	34								
	a	3	03								
	b	GOTO () ()	44								
	c	8	10								
	d	5	05								
7	0	$x \neq y$	30								
	1	—	34								
	2	2	02								
	3	GOTO () ()	44								
	4	8	10								
	5	5	05								
	6	9	11								
	7	0	00								
	8	IF $x > y$	53								
	9	8	10								
	a	2	02								
	b	—	34								
	c	4	04								
	d	GOTO () ()	44								
8	0	8	10								
	1	5	05								
	2	$x \neq y$	30								
	3	—	34								
	4	1	01								
	5	ROLL $\uparrow$	22								
	6	CLEAR $\mathcal{X}$	37								
	7	ROLL $\downarrow$	31								
	8	$y \neq ()$	24								
	9	b	14								
	a	STOP	41								
	b	b	14								
	c	$\uparrow$	27								
	d	int x	64								
			QUAD. CODE	DISTANCE	0	DISPLAY CORRECTED DISTANCE AND QUADRANT CODE					

CONVERT CORRECTED MACHINE ANGLE TO BEARING ANGLE AND QUADRANT CODE

DISPLAY CORRECTED DISTANCE AND QUADRANT CODE

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	—	34								
	1	x→()	23								
	2	b	14								
	3	6	06								
	4	0	00								
	5	x	36								
	6	x↔y	30								
	7	↑	27								
	8	int x	64								
	9	—	34								
	a	ROLL ↓	31								
	b	x	36								
	c	b	14								
	d	ROLL ↓	31								
a	0	STOP	41	SECONDS	MINUTES	DEGREES	DISPLAY CORRECTED BEARING				
	1	CLEAR x	37								
	2	ROLL ↓	31								
	3	RCL	61								
	4	STOP	41	EASTING	NORTHING	0	DISPLAY CORRECTED COORDINATES				
	5	↓	25								
	6	GO TO () ()	44								
	7	1	01								
	8	3	03								
	9	END	46								
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

CONVERT CORRECTED BEARING ANGLE
TO DEGREES, MINUTES, AND SECONDS

DISPLAY CORRECTED
BEARING

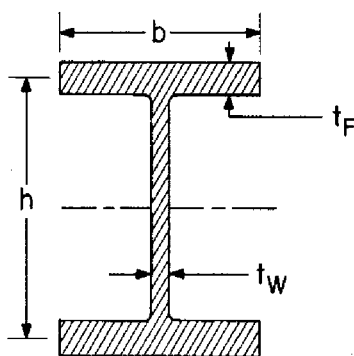
DISPLAY CORRECTED
COORDINATES

SHEAR COEFFICIENT - THIN WALLED I-SECTION

This program computes the shear coefficient for a thin-walled I-section as given by:

$$K = \frac{10(1+\nu)(1+3m)^2}{(12 + 72m + 150m^2 + 90m^3) + \nu(11 + 66m + 135m^2 + 90m^3) + 30n^2(m+m^2) + 5\nu n^2(8m+9m^2)}$$

where $m = 2bt_F/ht_W$, $n = b/h$



where: ν is Poisson's ratio.

The neutral axis is dotted line.

Reference: The Shear Coefficient in Timoshenko's Beam Theory
by G.R. Cowper

Journal of Applied Mechanics June 1966

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER: $b \rightarrow Z$, $h \rightarrow Y$, $t_F \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER: $t_W \rightarrow Y$, $\nu \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
K	—	X

Let $b = 6$, $h = 12$, $t_F = 1$

$t_W = .75$, $\nu = 3$

$K = .4222$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	STOP	41	t_F	h	b	ENTER b,h,t _F					
3	ROLL ↓	31									
4	ACC +	60									
5	÷	35									
6	$y \rightarrow ()$	24									
7	E	12									
8	2	02	CALCULATE n								
9	X	36									
a	↓	25									
b	X	36									
c	$y \rightarrow ()$	40									
d	d	17									
1	0	CLEAR x	37								
1	↑	27									
2	↑	27									
3	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
4	STOP	41	v	t_w	0	ENTER t _w ,v					
5	↑	27									
6	$y \rightarrow ()$	24									
7	d	17									
8	f	15									
9	ROLL ↑	22	CALCULATE m								
a	X	36									
b	↓	25									
c	÷	35									
d	$y \rightarrow ()$	40									
2	0	f	15								
1	9	11									
2	0	00									
3	↑	27									
4	f	15									
5	X	36									
6	1	01									
7	5	05									
8	0	00									
9	+	33	CALCULATE $(12 + 72m + 150m^2 + 90m^3)$								
a	f	15									
b	X	36									
c	7	07									
d	2	02									

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	+	33								
	1	f	15								
	2	x	36								
	3	1	01								
	4	2	02								
	5	+	33								
	6	9	11								
	7	0	00								
	8	↑	27								
	9	f	15								
	a	x	36								
	b	1	01								
	c	3	03								
	d	5	05								
4	0	+	33								
	1	f	15								
	2	x	36								
	3	6	06								
	4	6	06								
	5	+	33								
	6	f	15								
	7	x	36								
	8	1	01								
	9	1	01								
	a	+	33								
	b	d	17								
	c	x	36								
	d	↓	25								
5	0	+	33								
	1	f	15								
	2	↑	27								
	3	x	36								
	4	+	33								
	5	E	12								
	6	x	36								
	7	x	36								
	8	3	03								
	9	0	00								
	a	x	36								
	b	↓	25								
	c	+	33								
	d	y20	24								

CALCULATE $v(11 + 66m + 135m^2 + 90m^3)$

CALCULATE $30n^2(m + m^2)$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	C	16								
	1	9	11								
	2	↑	27								
	3	f	15								
	4	x	36								
	5	x	36								
	6	↑	27								
	7	8	10								
	8	x	36								
	9	↓	25								
	a	+	33								
	b	E	12								
	c	x	36								
	d	x	36								
7	0	d	17								
	1	x	36								
	2	5	05								
	3	x	36								
	4	C	16								
	5	+	33								
	6	yz(1)	24								
	7	f	15								
	8	3	03								
	9	x	36								
	a	1	01								
	b	+	33								
	c	d	17								
	d	↑	27								
8	0	1	01								
	1	+	33								
	2	1	01								
	3	0	00								
	4	x	36								
	5	↓	25								
	6	xzy	30								
	7	x	36								
	8	x	36								
	9	f	15								
	a	÷	35								
	b	CLEAR x	37								
	c	↑	27								
	d	ROLL ↑	22								

CALCULATE $5\nu n^2 (8m + 9m^2)$

CALCULATE $10(1+\nu)(1+3m)^2$

$$K_1 = \frac{10(1+\nu)(1+3m)^2}{(12+72m+150m^2+90m^3)+\nu(11+66m+135m^2+90m^3)}$$

A diagram of a rectangular cross-section. The width is labeled t and the height is labeled h . The rectangle is shaded with diagonal lines. A dashed horizontal line passes through the center of the rectangle.

$$K_2 = \frac{10(1+\nu)(1+3m)^2}{(12+72m+150m^2+90m^3) + \nu(11+66m+135m^2+90m^3) + 10n^2[(3+\nu)m+3m^2]}$$

Journal of Applied Mechanics June 1966

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0-0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

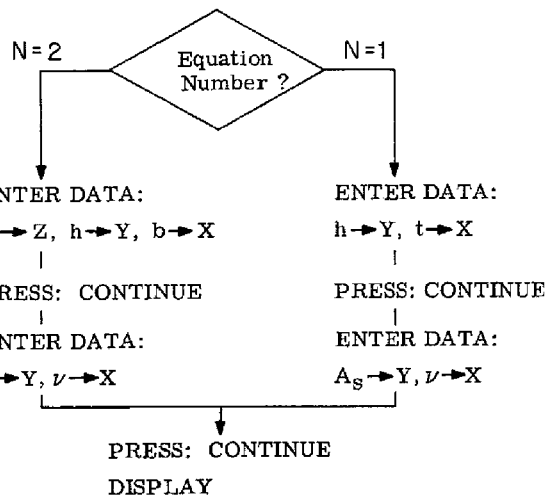
ENTER DATA: (Equation Number) = $N \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
N	—	X

(verifies equation number)



0	—	Z
0	—	Y
K_N	—	X

Equation 1 ($N = 1$)

Let $t = .5$, $h = 12$, $A_s = 2$, $\nu = 3$

$K_1 = 0.6225$

Equation 2 ($N = 2$)

Let $b = 8$, $h = 12$, $\nu = 3$, $t_1 = .75$, $t = .5$

$K_2 = .5039$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	CLEAR	20									
1	STOP	41	N	0	0	ENTER EQUATION NUMBER (1 OR 2)					
2	$x \rightarrow ()$	23									
3	C	16									
4	↑	27									
5	2	02									
6	IF $x=y$	50									
7	7	07									
8	5	05	BRANCH TO PROPER ROUTINE. RETURN TO 0-0 IF EQUATION NUMBER ENTERED IS NOT 1 OR 2								
9	1	01									
a	IF $x=y$	50									
b	1	01									
c	2	02									
d	GOTO ()	44									
1	0	00									
1	0	00									
2	↓	25	DISPLAY IS 1 (VERIFIES EQUATION NO. 1)								
3	STOP	41	t	h	0	ENTER h AND t					
4	X	36									
5	$y \rightarrow ()$	40									
6	f	15									
7	↓	25									
8	↓	25									
9	STOP	41	v	A _s	0	ENTER A _s AND v					
a	$x \rightarrow ()$	23									
b	d	17									
c	2	02									
d	X	36									
2	0	f	15								
1	÷	35									
2	$y \rightarrow ()$	40									
3	f	15									
4	9	11									
5	0	00									
6	X	36									
7	1	01									
8	5	05									
9	0	00									
a	+	33									
b	f	15									
c	X	36	CALCULATE $12 + 72m + 150m^2 + 90m^3$								
d	7	07									

FROM 9-3

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	2	02								
	1	+	33								
	2	F	15								
	3	X	36								
	4	1	01								
	5	2	02								
	6	+	33								
	7	9	11								
	8	0	00								
	9	↑	27								
	a	F	15								
	b	X	36								
	c	1	01								
	d	3	03								
4	0	5	05								
	1	+	33								
	2	F	15								
	3	X	36								
	4	6	06								
	5	6	06								
	6	+	33								
	7	F	15								
	8	X	36								
	9	1	01								
	a	1	01								
	b	+	33								
	c	d	17								
	d	X	36								
5	0	↓	25								
	1	+	33								
	2	y ² (1)	24								
	3	c	16								
	4	1	01								
	5	IF x=y	50								
	6	9	11								
	7	4	04								
	8	3	03								
	9	↑	27								
	a	d	17								
	b	+	33								
	c	F	15								
	d	X	36								

CALCULATE $v(11 + 66m + 135m^2 + 90m^3)$

HEWLETT-PACKARD

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	↑	27								
	1	X	36								
	2	3	03								
	3	X	36								
	4	↓	25								
	5	+	33								
	6	E	12								
	7	X	36								
	8	X	36								
	9	1	01								
	a	0	00								
	b	X	36								
	c	C	16								
	d	+	33								
7	0	y→()	40								
	1	C	16								
	2	GO TO () ()	44								
	3	9	11								
	4	4	04								
	5	↓	25								
	6	STOP	41	b	h	t ₁	ENTER t ₁ , h, b				
	7	x↔y	30								
	8	ACC +	60								
	9	÷	35								
	a	y↔()	24								
	b	E	12								
	c	ROLL ↓	31								
	d	X	36								
8	0	y↔()	24								
	1	b	14								
	2	CLEAR x	37								
	3	↑	27								
	4	↑	27								
	5	STOP	41	v	t	0	ENTER t, v				
	6	x→()	23								
	7	d	17								
	8	f	15								
	9	X	36								
	a	b	14								
	b	x↔y	30								
	c	÷	35								
	d	y→()	40								

CALCULATE $10n^2 [(3+v)m+3m^2]$

DISPLAY 2 (VERIFIES EQUATION NO. 2)

ENTER t₁, h, b

ENTER t, v

FROM 5-7

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	F	15								
1	GO TO () ()	44									
2	2	02									
3	3	03									
4	d	17									
5	↑	27									
6	1	01									
7	+	33									
8	1	01									
9	0	00									
a	x	36									
b	F	15									
c	↑	27									
d	3	03									
a	0	x	36								
1	1	01									
2	+	33									
3	↓	25									
4	x	36									
5	x	36									
6	c	16									
7	÷	35									
8	CLEAR x	37									
9	↑	27									
a	ROLL ↑	22									
b	END	46	K _N	0	0	DISPLAY					
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

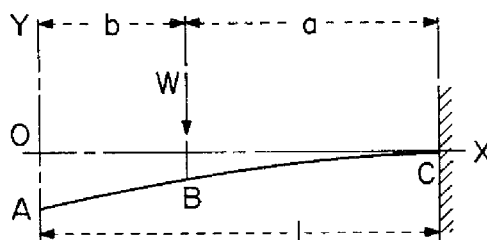
CALCULATE $10(1+\nu)(1+3m)^2$

CANTILEVER BEAM INTERMEDIATE LOAD

PART NO.
09100-74203

This program computes the shear, moment, and deflection reactions for a cantilever beam with a concentrated intermediate load as given by:

CANTILEVER, INTERMEDIATE LOAD



Reaction R_2 and Vertical Shear V	Bending Moment M and max bending moment	Deflection y , maximum deflection, and end slope θ
$R_2 = +W$	(A to B) $M = 0$	(A to B) $y = -\frac{1}{6} \frac{W}{EI} (-a^3 + 3a^2b - 3a^2x)$
(A to B) $V = 0$	(B to C) $M = -W(x-b)$	(B to C) $y = -\frac{1}{6} \frac{W}{EI} [(x-b)^3 - 3a^2(x-b) + 2a^3]$
(B to C) $V = -W$	Max $M = -Wa$ at C	Max $y = -\frac{1}{6} \frac{W}{EI} (3a^2b - a^3)$ $\theta = +\frac{1}{2} \frac{Wa^2}{EI}$ (A to B)

NOTATION:

W = Load (lb)

M = Positive when clockwise

V = Positive when upward

Y = Positive when upward

θ = Radians = $\tan \theta$

All forces are in pounds, all moments in inch-pounds, all deflections and dimensions in inches.

Reference: Formula for Stress and Strain
by R. J. Roark

McGraw-Hill Book Company 1965

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER: 1 → Z, a → Y, b → X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER: E → Z, I → Y, W → X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
3	—	X

ENTER: x → X

PRESS: CONTINUE

DISPLAY

R_2	—	Z
V_{AB}	—	Y
V_{BC}	—	X

PRESS: CONTINUE

DISPLAY

M_{AB}	—	Z
M_{BC}	—	Y
M_{MAX}	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
Y_{AB}	—	Y
Y_{BC}	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
Y_{MAX}	—	Y
θ	—	X

EXAMPLES

LET 1 = 100
 a = 60
 b = 40
 E = 10^6
 I = 20
 W = 1000
 x = 24

THEN R_2 = 1000
 V_{AB} = 0
 V_{BC} = -1000
 M_{AB} = 0
 M_{BC} = 16000
 M_{MAX} = -60000
 Y_{AB} = -5.040
 Y_{BC} = -5.006
 Y_{MAX} = -7.200
 θ = .090

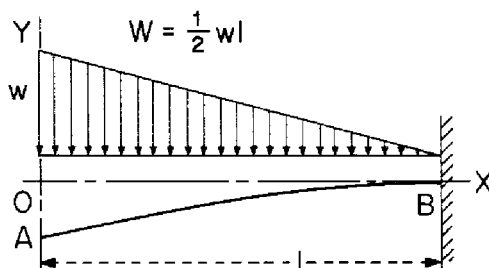
Step	Key	Code	Display			Storage					
			$\approx$	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	STOP	41	b	a	I	ENTER I, a, b					
3	ACC +	60									
4	CLEAR X	37									
5	ROLL ↓	31									
6	$y \rightarrow ()$	40									
7	d	17									
8	↓	25									
9	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
a	STOP	41	W	I	E	ENTER E, I, W					
b	$x \rightarrow ()$	23									
c	C	16									
d	ROLL ↓	31									
1	0	X	36								
1	CLEAR X	37									
2	ROLL ↓	31									
3	÷	35									
4	$y \rightarrow ()$	40									
5	b	14									
6	↓	25									
7	3	03	DISPLAY 3 TO INDICATE THIRD ENTRY								
8	STOP	41	X	O	O	ENTER X					
9	$x \rightarrow ()$	23									
a	a	13									
b	C	16									
c	↑	27	CALCULATE R_2, V								
d	CLEAR X	37									
2	0	↑	27								
1	C	16									
2	CHG SIGN	32									
3	STOP	41	V_{BC}	V_{AB}	R_2	DISPLAY					
4	a	13									
5	↑	27									
6	f	15									
7	—	34									
8	C	16									
9	CHG SIGN	32	CALCULATE M_{AB}, M_{BC}, M_{MAX}								
a	X	36									
b	↑	27									
c	e	12									
d	X	36									

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	CLEAR x	37								
	1	ROLL ↓	31								
	2	STOP	41	M _{MAX}	M _{BC}	M	DISPLAY				
	3	E	12								
	4	↑	27								
	5	X	36								
	6	X	36								
	7	↑	27								
	8	X	36								
	9	3	03								
	a	X	36								
	b	d	17								
	c	X	36								
	d	↓	25								
4	0	xzy	30								
	1	—	34								
	2	E	12								
	3	↑	27								
	4	X	36								
	5	a	13								
	6	X	36								
	7	3	03								
	8	X	36								
	9	↓	25								
	a	—	34								
	b	b	14								
	c	X	36								
	d	6	06								
5	0	CHG SIGN	32	CALCULATE Y_{AB}, Y_{BC}							
	1	÷	35								
	2	y ² ()	24								
	3	a	13								
	4	f	15								
	5	—	34								
	6	E	12								
	7	↑	27								
	8	X	36								
	9	3	03								
	a	CHG SIGN	32								
	b	X	36								
	c	↓	25								
	d	xzy	30								

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	X	36								
	1	↑	27								
	2	X	36								
	3	X	36								
	4	↓	25								
	5	+	33								
	6	E	12								
	7	↑	27								
	8	X	36								
	9	X	36								
	a	2	02								
	b	X	36								
	c	↓	25								
	d	+	33								
7	0	b	14								
	1	X	36								
	2	6	06								
	3	CHG SIGN	32								
	4	÷	35								
	5	CLEAR X	37								
	6	ROLL ↓	31								
	7	y ₂ (1)	24								
	8	a	13								
	9	STOP	41	Y _{BC}	Y _{AB}	0	DISPLAY				
	a	E	12								
	b	↑	27								
	c	X	36								
	d	3	03								
8	0	X	36								
	1	d	17								
	2	X	36								
	3	E	12								
	4	↑	27								
	5	X	36								
	6	X	36								
	7	↓	25								
	8	-	34								
	9	b	14								
	a	X	36								
	b	6	06								
	c	CHG SIGN	32								
	d	÷	35								

CALCULATE Y_{MAX}

CANTILEVER, TRIANGULAR LOAD



Reaction R_2 and Vertical Shear V	Bending Moment M and Maximum Bending Moment	Deflection y , maximum deflection and end slope θ
$R_2 = +W$	$M = -\frac{1}{3} \frac{W}{l^2} (3lx^2 - x^3)$	$y = -\frac{1}{60} \frac{W}{EI} l^2 (-x^5 - 15l^4x + 5lx^4 + 11l^5)$
$V = -W \left(\frac{2lx - x^2}{l^2} \right)$	Max $M = -\frac{2}{3} Wl$ at B	Max $y = -\frac{11}{60} \frac{Wl^3}{EI}$ at A $\theta = +\frac{1}{4} \frac{W}{EI} l^2$ at A

$$\theta = \text{Radians} = \tan \theta$$

All forces are in pounds, all moments in inch-pounds, all deflections and dimensions in inches.

Reference: Formula for Stress and Strain
by R. J. Roark

McGraw-Hill Book Company 1965

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: W → Z, l → Y, x → X

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: E → Y, I → X

PRESS: CONTINUE

DISPLAY

0	—	Z
R ₂	—	Y
V	—	X

PRESS: CONTINUE

DISPLAY

0	—	Z
M	—	Y
M _{MAX}	—	X

PRESS: CONTINUE

DISPLAY

Y	—	Z
Y _{MAX}	—	Y
θ	—	X

LET W = 1000

l = 100

x = 24

E = 10⁶

I = 20

THEN R₂ = 1000

V = -422.4

M = -5299.2

M_{MAX} = -66666.6

Y = -6.180

Y_{MAX} = -9.167

θ = .125

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
2	STOP	41	X	I	W	ENTER W, I, X					
3	ACC +	60									
4	CLEAR X	37									
5	ROLL ↓	31									
6	y→()	40									
7	d	17									
8	↓	25									
9	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
a	STOP	41	I	E	O	ENTER E, I					
b	X	36									
c	d	17									
d	x↔y	30									
1	0	÷	35								
1	y→()	40									
2	c	16									
3	E	12									
4	↑	27									
5	2	02									
6	X	36									
7	f	15									
8	X	36									
9	↑	27									
a	X	36									
b	↓	25									
c	—	34									
d	E	12									
2	0	↑	27	CALCULATE R ₂ , V							
1	X	36									
2	↓	25									
3	÷	35									
4	d	17									
5	CHG SIGN	32									
6	X	36									
7	d	17									
8	x↔y	30									
9	↑	27									
a	CLEAR X	37									
b	ROLL ↓	31									
c	STOP	41	V	R ₂	O	DISPLAY					
d	E	12									

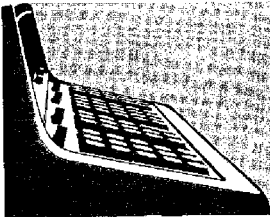
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	↑	27								
	1	3	03								
	2	X	36								
	3	f	15								
	4	X	36								
	5	X	36								
	6	↑	27								
	7	X	36								
	8	X	36								
	9	↓	25								
	a	-	34								
	b	d	17								
	c	X	36								
	d	3	03								
4	0	÷	35	CALCULATE M, M _{MAX}							
	1	E	12								
	2	↑	27								
	3	X	36								
	4	↓	25								
	5	CHG SIGN	32								
	6	÷	35								
	7	d	17								
	8	↑	27								
	9	E	12								
	a	X	36								
	b	2	02								
	c	X	36								
	d	3	03								
5	0	CHG SIGN	32								
	1	÷	35								
	2	CLEAR X	37								
	3	ROLL ↓	31								
	4	STOP	41	M _{MAX}	M	O	DISPLAY				
	5	f	15								
	6	↑	27								
	7	X	36								
	8	X	36								
	9	X	36								
	a	X	36								
	b	↑	27								
	c	1	01								
	d	5	05								

6
↓
7
↓
8
↓

X	36
E	12
X	36
X	36
X	36
X	36
↓	25
+	33
y→()	40
b	14
f	15
↑	27
X	36
X	36
X	36
E	12
X	36
5	05
X	36
E	12
↑	27
X	36
X	36
X	36
X	36
1	01
1	01
X	36
↓	25
+	33
b	14
-	34
c	16
X	36
6	06
0	00
CHG SIGN	32
÷	35
E	12
÷	35
÷	35
y→()	40

CALCULATE Y

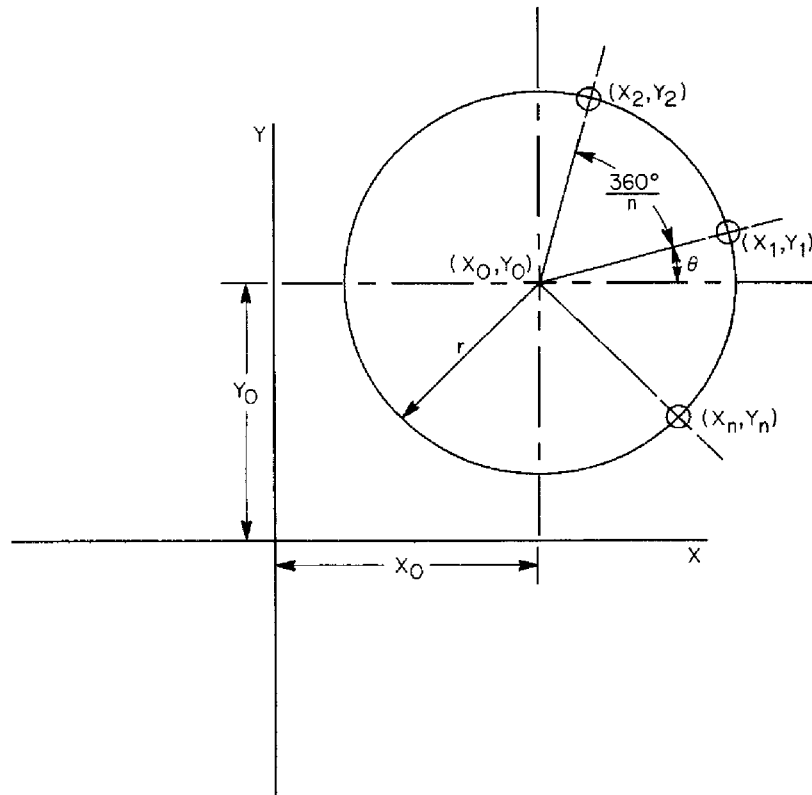
[illegible]



COORDINATES OF EQUALLY SPACED POINTS ON A CIRCLE

PART NO.
09100-74205

This program computes the coordinates (X_i, Y_i) $i = 1, \dots, n$ of equally spaced points on a circle of radius r . The user specifies the number of points n , and offset θ , and coordinates of the center of the circle X_0 and Y_0 . See the figure below.



The equations used are:

$$X_i = r \cos \left((i-1) \frac{360^\circ}{n} + \theta \right) + X_0$$

$i = 1, \dots, n$

$$Y_i = r \sin \left((i-1) \frac{360^\circ}{n} + \theta \right) + Y_0$$

θ - offset angle in degrees

USER INSTRUCTIONS

ENTER PROGRAM (Starting address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE
DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $Y_0 \rightarrow Y$, $X_0 \rightarrow X$ PRESS: CONTINUE
DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $\theta \rightarrow Z$, $n \rightarrow Y$, $r \rightarrow X$ PRESS: CONTINUE
DISPLAY

i	—	Z
Y_i	—	Y
X_i	—	X

PRESS CONTINUE AFTER i REACHES n TO
RESTART ANOTHER SOLUTION

EXAMPLES

$X_0 = 2 \text{ in.}$

$Y_0 = 1 \text{ in.}$

$r = 2 \text{ in.}$

$n = 10$

$\theta = 0^\circ$

i	X_i	Y_i
1	3.618033989	2.175570505
2	2.618033989	2.902113033
3	1.381966011	2.902113033
4	0.381966011	2.175570505
5	0.000000000	1.000000000
6	0.381966011	- 0.175570505
7	1.381966011	- .902113033
8	2.618033989	- .902113033
9	3.618033989	- .175570505
10	4.000000000	1.000000000

[illegible]

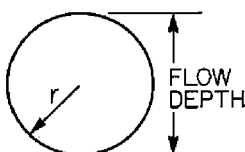
The basic equation for open channel flow with any designated flow depth in a container (pipe, etc.) with any cross-sectional area is the Chezy-Manning equation given below:

$$(1) \quad Q = \frac{1.49 AR^{2/3} S^{1/2}}{n}$$

n = Roughness coefficient (dimensionless)

This program is specialized for open-channel flow in a circular pipe with flow depth designated at full.

Situation:



$$\text{Then } R = \text{hydraulic radius} = \frac{\text{area of flow cross-section}}{\text{wetted perimeter}} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{D}{4} \quad (D = \text{diameter of container})$$

substituting in equation (1) gives:

$$Q = 1.49 \left(\frac{\pi D^2}{4} \right) \left(\frac{D}{4} \right)^{2/3} \frac{S^{1/2}}{n}$$

$$= \frac{(1.49) \left(\frac{\pi}{4} \right)}{(4)^{2/3}} \frac{D^{8/3} S^{1/2}}{n} = \frac{.46441 D^{8/3} S^{1/2}}{n} \quad (\text{equation to be used})$$

Variables to be entered for flow calculation are D, S, n.

John Wiley & Sons, Inc.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address 0 - 0)

PRESS: GO TO (0) (0) [or END]

→ PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
0	—	X

ENTER DATA: $n \rightarrow Z$, $D \rightarrow Y$, $S \rightarrow X$

PRESS: CONTINUE

DISPLAY

Q	—	Z
0	—	Y
0	—	X

EXAMPLE

Find Q_{FULL} in a circular pipe of diameter 18 in.,
if the slope is .001 feet/ft. and $n = .015$

Input: $n = .015$

$D = 1.5 \left(\frac{18''}{12''} = 1.5' \right)$

$S = .001 \text{ ft./ft.}$

Answer: $Q = 2.8866 \text{ ft.}^3/\text{sec.}$

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	1	STOP	41	S	D	n	ENTER n,D,S				
2	2	$\sqrt{x}$	76								
3	3	ROLL $\downarrow$	31								
4	4	$y \rightarrow ()$	40								
5	5	f	15								
6	6	$\ln x$	65								
7	7	$x \rightarrow y$	30								
8	8	8	10								
9	9	x	36								
	$\equiv$	3	03								
	$\div$	35									
	$\downarrow$	25									
	e^x	74	CALCULATE Q								
1	0	x	36								
1	1	f	15								
2	2	$\div$	35								
3	3	.	21								
4	4	4	04								
5	5	6	06								
6	6	4	04								
7	7	4	04								
8	8	1	01								
9	9	x	36								
	$\equiv$	CLEAR x	37								
	$\uparrow$	27									
	c	END	46	0	0	Q	DISPLAY				
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	$\equiv$										
	$\div$										
	$\downarrow$										
	e^x										
	$\equiv$										
	$\div$										
	$\downarrow$										
	e^x										
	$\equiv$										

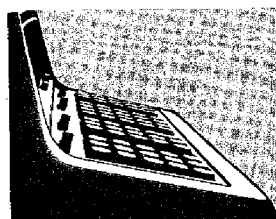
HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD

HEWLETT-PACKARD



PART NO.
09100-75002

Calculation of Flow Correction (Δ) in a System of Pipes Hardy-Cross Method

This method is based on the fact that the sum of the head losses in the pipes in a given circuit is equal to zero.

The head loss in a pipe is proportional to some function of the flow in the pipe and is expressed as follows:

$$h_L = k Q^x$$

According to the Hazen-Williams formula h_L can be expressed as follows:

$$h_L = k Q^{1.85}$$

A flow, Q , is assumed to flow in a pipe. The actual flow in the pipe is then seen to be:

$$Q_{\text{Actual}} = Q_{\text{Assumed}} + \Delta_{\text{Flow correction}}$$

then since $h_L = kQ^x$

$$h_L = k (Q + \Delta)^x = k [Q^x + xQ^{(x-1)} \Delta + \dots]$$

Terms beyond the second in the expansion are considered negligible; therefore, $h_L \cong kQ^x \cong kQ^x + kxQ^{(x-1)}(\Delta)$

Since $\sum h_L = 0$ in a circuit, then $\sum kQ^x = 0 = \sum kQ^x + \sum kxQ^{(x-1)} \Delta$

$$\text{or } \Delta = - \frac{\sum kQ^x}{\sum kxQ^{(x-1)}}$$

$$\text{Also } \frac{h_L}{Q} = \frac{kQ^x}{Q} = kQ^{(x-1)}$$

$$\text{Then } kQ^x = h_L \text{ and } kQ^{(x-1)} = \frac{h_L}{Q}$$

$$\text{Therefore: } \Delta = \frac{\sum h_L}{1.85 \cdot \sum \frac{h_L}{Q}} \quad \text{is the equation to be used.}$$

The assumed flow is corrected by Δ and the process is repeated until Δ becomes negligible. In sanitary engineering when Δ becomes 50 gpm or less the network is said to be determined.

In practice h_L is determined by a nomograph that relates Q , h_L and D where Q is in gpm, h_L = ft/1000 ft. of pipe and D is the diameter of the pipe in inches.

Dimensions:

Head loss = h_L , given in feet/1000 ft. of pipe)
Flow = Q , given in gallons per minute (gpm)
Length of pipe = L , given in thousands of feet.
Flow correction = Δ , given in gpm.

Diameter of pipe = D , given in inches, (D is used as data for the nomograph to determine h_L).

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: END

→ PRESS: CONTINUE

DISPLAY

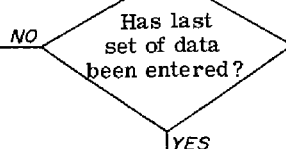
0	—	Z
0	—	Y
0	—	X

→ ENTER DATA: $Q \rightarrow Z$, $h_L \rightarrow Y$, $L \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
(h_L/Q)	—	Y
0	—	X



PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

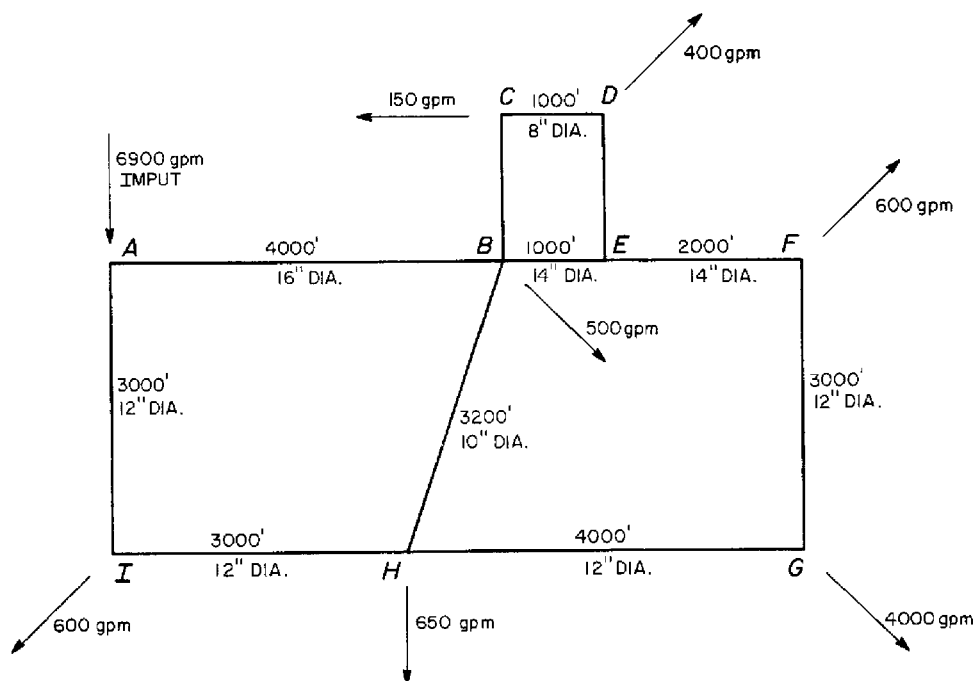
0	—	Z
0	—	Y
Δ	—	X

→ To reset problem:

Note (1): The flows and the head losses in a circuit are considered positive in a clockwise direction and negative in a counter clockwise direction. These values when inserted in the calculator must have the correct algebraic sign.

Note (2): After 2nd display the cumulative h_L (Total) may be displayed in the X register by pressing f.

EXAMPLE



Line	Diameter	Length in 1000	Assumed Q in gpm	From Nomo- graph h_L in ft. per 1000 ft.	$kQ^x = h_L$ Total in Feet	$kQ^{(x-1)} =$ h_L/Q
AB	16"	4	4800	20	80	.017
BE	14"	1	3200	17	17	.005
EF	14"	2	2950	15	30	.010
FG	12"	3	2350	20	60	.026
AI	12"	3	-2100	-16.5	-49.5	.024
IH	12"	3	-1500	-9.0	-27.0	.018
HG	12"	4	-1650	-10.5	-42.0	.025
					$\sum kQ^x = 68.5$	$\sum kQ^{(x-1)} = .12471$

Answer: $\Delta = -\frac{\sum kQ^x}{1.85 (\sum kQ^{(x-1)})} = -296.913 \text{ g.p.m.}$



PART NO.
09100-75003

RECTANGULAR WEIR

This program calculates the rate of fluid flow over a rectangular weir.

The following equations are used:

$$Q = \frac{2}{3} cb \sqrt{2g} \left[\left(H + \frac{V^2}{2g} \right)^{3/2} - \left(\frac{V^2}{2g} \right)^{3/2} \right]$$

where: Q = rate of fluid flow (ft.³/sec.)
 b = length of weir crest (ft.)
 H = head on weir (ft.)
 V = average velocity of fluid approach (ft./sec.)
 c = correction factor

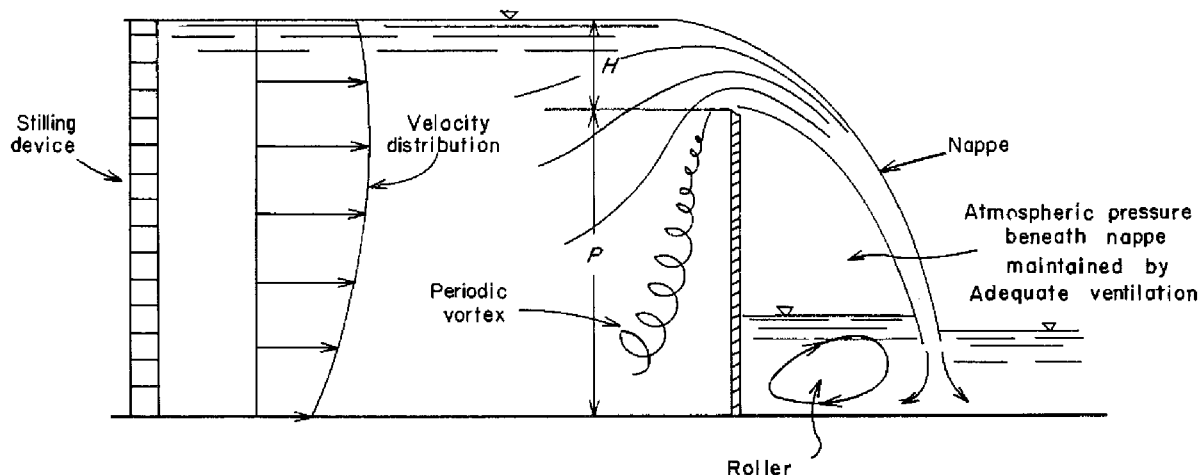
The coefficient (c) includes the effects of various phenomena, such as viscosity, turbulence, surface tension, non-uniform velocity, etc.

The program includes the ability to enter c as data, or to calculate c using Rehbock's equation, given below:

$$c = .605 + .08 H/p + \frac{1}{305H}$$

where: p = the weir height

Diagram of a standard rectangular weir:



Reference: Elementary Fluid Mechanics - 3rd Edition
 John K. Vennard
 John Wiley & Sons, Inc.

USER INSTRUCTIONS

EXAMPLES

ENTER PROGRAM: (Starting Address is (0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $V \rightarrow Z$, $b \rightarrow Y$, $H \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

YES NO

Wish to
calculate
c?

ENTER DATA: $p \rightarrow X$

ENTER DATA: $c \rightarrow X$

PRESS: SET FLAG

PRESS: CONTINUE

PRESS: CONTINUE

DISPLAY

0	—	Z
2	—	Y
Q	—	X

(2 indicates that c
was calculated)

DISPLAY

0	—	Z
1	—	Y
Q	—	X

(1 indicates that c
was entered as data)

TO RESET PROBLEM:

(A)

Data: $H = 1$ ft.
 $V = 1$ ft./sec.
 $b = 3$ ft.
 $c = .6$

(c entered as data)

Solution: $Q = 9.8321$ ft.³/sec.

(B)

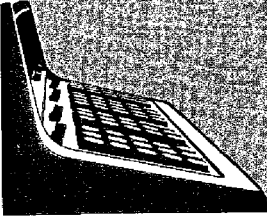
Data: $H = 2$ ft.
 $V = 1$ ft./sec.
 $b = 6$ ft.
 $p = 6.85$ ft.

(c to be calculated)

Solution: $Q = 57.8007$ ft.³/sec.

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	E	12								
	1	X	36								
	2	y→()	40								
	3	d	17	STORE Q _p							
	4	CLEAR	20								
	5	2	02								
	6	STOP	41	C or P			ENTER DATA, C or P				
	7	IF FLAG	43								
	8	4	04	BRANCH TO CALCULATE C IF P IS ENTERED AS DATA							
	9	6	06								
	a	↑	27	CALCULATE Q FOR DATA ENTRY OF C							
	b	d	17								
	c	X	36								
	d	CLEAR X	37								
4	0	↑	27								
	1	1	01								
	2	ROLL ↑	22								
	3	GO TO () ()	44								
	4	6	06	BRANCH TO DISPLAY Q							
	5	6	06								
	6	↑	27								
	7	3	03								
	8	0	00								
	9	5	05								
	a	↑	27								
	b	c	16								
	c	X	36								
	d	ROLL ↑	22								
5	0	÷	35	CALCULATE C IF P IS ENTERED AS DATA							
	1	.	21								
	2	0	00								
	3	8	10								
	4	X	36								
	5	1	01								
	6	ROLL ↑	22								
	7	÷	35								
	8	.	21								
	9	6	06								
	a	0	00								
	b	5	05								
	c	+	33								
	d	CLEAR X	37								

[illegible]



WATER FLOW IN PIPE

PART NO.
09100-75004

Given the roughness coefficient (ϵ), the diameter (d) of a pipe in inches, the rate of flow (Q) of water in gal./min. into the pipe, this program calculates the friction factor (f) and the head loss (h_f) in feet.

The equations used are the Colebrook equation

$$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{2.51}{R_e \sqrt{f}} + \frac{12 \epsilon}{3.7 d} \right)$$

used to calculate f , and the Darcy-Weisback equation

$$h_f = f \left(\frac{L}{d} \right) \left(\frac{6 V^2}{g} \right)$$

where L = length of pipe in feet
and V = velocity in ft./sec.

R_e is Reynolds number where $R_e = \frac{Vd}{12\nu} = \frac{77 Q}{720 \pi \nu d}$

For water, $\nu = 1.40 \times 10^{-5}$ ft.²/sec.

Therefore, $R_e = \frac{77 \times 10^5}{1008 \pi} \times \frac{Q}{d}$

Reference: Marks Standard Handbook for Mechanical Engineers
Seventh Edition
McGraw-Hill Book Company
1967

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

ENTER DATA: Roughness Coefficient $\rightarrow$ Y,
Diameter $\rightarrow$ X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
2	_____	X

ENTER DATA: Length $\rightarrow$ Y, Rate of Flow $\rightarrow$ X

PRESS: CONTINUE

DISPLAY

d	_____	Z
Q	_____	Y
f	_____	X

PRESS: CONTINUE

DISPLAY

d	_____	Z
Q	_____	Y
h_f	_____	X

—To enter new data

Data:

d = 10 in.
 ϵ = .00085
 Q = 2000 gpm.
 L = 500 ft.

Results:

f = .02035
 h_f = 12.65377 ft.

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
1	3	03	STORE 3, CLEAR AND DISPLAY 1 TO INDICATE FIRST ENTRY									
2	x→()	23										
3	ε	13										
4	1	01										
5	STOP	41	d	ε	0	ENTER ROUGHNESS COEFFICIENT AND DIAMETER						
6	÷	35										
7	x→()	23										
8	b	14	CALCULATE AND STORE RELATIVE ROUGHNESS (ε/d)									
9	y→()	40										
a	c	16										
b	CLEAR	20	CLEAR AND DISPLAY 2 TO INDICATE SECOND ENTRY									
c	2	02										
d	STOP	41										
			Q	L	0	ENTER LENGTH AND RATE OF FLOW						
1	0	ACC +	60									
1	↑	27	STORE Q AND L									
2	7	07										
3	7	07										
4	ENTER EXP	26										
5	6	06										
6	X	36										
7	1	01	CALCULATE Re									
8	0	00										
9	0	00										
a	8	10										
b	÷	35										
c	π	56										
d	÷	35										
2	0	b										14
1	÷	35										
2	y→()	40										
3	d	17										
4	2	02										
5	.	21										
6	5	05										
7	1	01										
8	↑	27										
9	d	17										
a	÷	35										
b	a	13										
c	X	36										
d	c	16	CALCULATE Δ = 2 Log (2.51 / Re * 1 / √f + 12 / 3.7 * ε / d) 1 / √f									

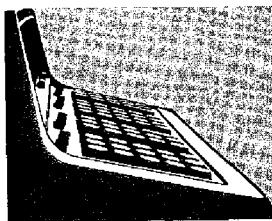
FROM 5-4

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	↑	27								
	1	1	01								
	2	2	02								
	3	x	36								
	4	3	03								
	5	.	21								
	6	7	07								
	7	÷	35								
	8	↓	25								
	9	+	33								
	a	↓	25								
	b	log x	75								
	c	↑	27								
	d	y	55								
4	0	2	02								
	1	x	36								
	2	a	13								
	3	-	34								
	4	2	02								
	5	÷	35								
	6	ENTER EXP	26								
	7	3	03								
	8	CHG SIGN	32								
	9	IF x > y	53								
	a	5	05								
	b	5	05								
	c	a	13								
	d	+	33								
5	0	y → ()	40								
	1	a	13								
	2	GO TO ()	44								
	3	2	02								
	4	4	04								
	5	1	01								
	6	↑	27								
	7	a	13								
	8	÷	35								
	9	↓	25								
	a	↑	27								
	b	x	36								
	c	y → ()	40								
	d	a	13								

CALCULATE $\frac{\Delta}{2}$ ENTER TOLERANCE, 10^{-3} BRANCH WHEN $\frac{\Delta}{2} < \text{TOLERANCE}$ ADD $\left(\frac{1}{\sqrt{f}}\right)_i + \frac{0_i}{2}$ AND STORE AS NEW ESTIMATE $\left(\frac{1}{\sqrt{f}}\right)_{i+1}$ BRANCH FOR $\frac{\Delta_{i+1}}{2}$ CALCULATION

CALCULATE f

[illegible]



PART NO.
09100-75201

RADIOACTIVE DECAY

Given a number of activity readings at various times from a Geiger-Mueller counter or similar radioactivity-measuring device, this program calculates the decay constant (λ), the half-life (τ), and, if desired, a set of M/M_0 values versus time. M_0 is the original mass of the sample and M is the mass remaining after a time t .

The equation for activity is:

$$1) A = \frac{-dN}{dt} = \lambda N_0 e^{-\lambda t}$$

Taking the natural logarithm of both sides of equation (1), the following equation results.

$$2) \ln A = \ln \lambda N_0 - \lambda t$$

Since equation (2) is a linear function of t , a linear regression (method of least squares) is performed on the set of $\ln A$ and t to obtain the slope ($-\lambda$) of the $\ln A$ versus t line.

The following equation is used to solve for λ (see Program 09100-70811).

$$\lambda = \frac{- \left[n \cdot \sum_{i=1}^n (\ln A_i) (t_i) - \left(\sum_{i=1}^n t_i \right) \left(\sum_{i=1}^n \ln A_i \right) \right]}{n \cdot \sum_{i=1}^n (t_i)^2 - \left(\sum_{i=1}^n t_i \right)^2}$$

Given λ , the half-life τ is calculated from the equation:

$$\tau = \ln 2 / \lambda$$

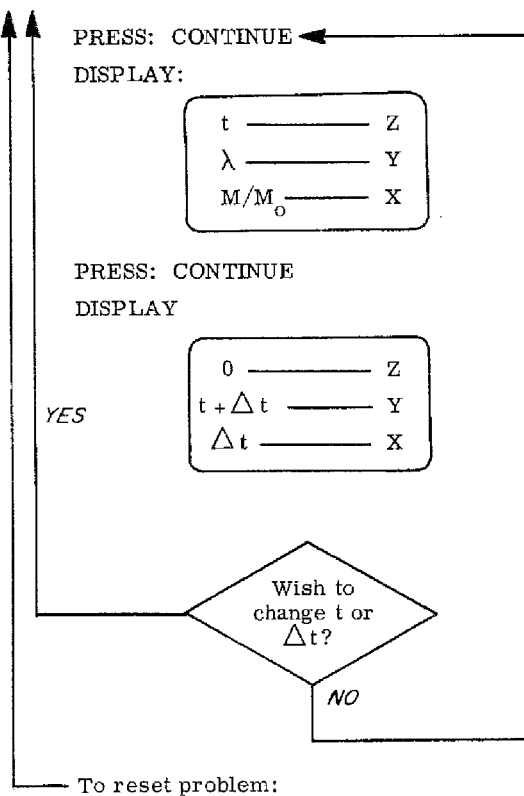
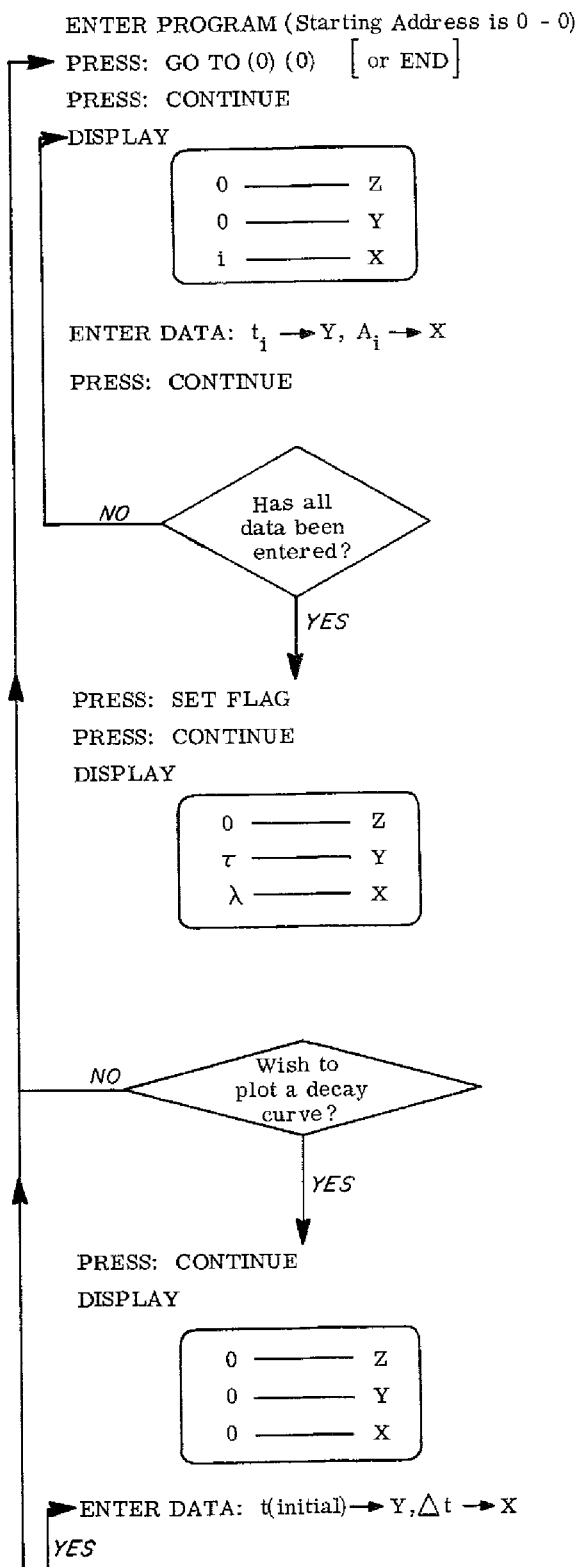
The fraction of mass remaining at time t is:

$$\frac{M}{M_0} = e^{-\lambda t}$$

The fraction of mass at any time t is easily obtained by entering the desired t in the Y register at the correct display during program execution (see "User Instructions"). M/M_0 is calculated for the value of time appearing in the Y register before incrementing that time by the amount entered in the X register for the next calculation. A decay curve (M/M_0 versus t) may also be obtained for any initial time and any increment (Δt).

USER INSTRUCTIONS

USER INSTRUCTIONS (con't)



EXAMPLES

- A) Calculate λ , τ and the value of M/M_0 at $t = \tau$ for following set of data. (M/M_0 should be equal to .5 at $t = \tau$)

Data:

i	t_i (minutes)	A_i (counts/minute)
1	.1	5.6×10^7
2	.3	5.01×10^7
3	.5	4.44×10^7
4	1	3.29×10^7
5	10	1.48×10^5

Solution: $\tau = 1.15491$

$$\lambda = .60018$$

$$M/M_0 \text{ (for } t = 1.15491) = .50000$$

- B) Calculate λ , τ and a set of M/M_0 values for t (initial) = 0, $\Delta t = .2$, using the following data.

Data:

i	t_i (minutes)	A_i (counts/min.)
1	1	4.01×10^5
2	1.5	3.80×10^5
3	4	2.61×10^4
4	4.5	2.11×10^4

Solution: $\tau = .75422$

$$\lambda = .91903$$

Δt	t	M/M_0
.2	0	1.00000
.2	.2	.83210
.2	.4	.69239
.2	.6	.57613
.2	.8	.47940
.2	1.0	.39891



Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	$x \rightarrow ()$	23									
2	C	16									
3	$x \rightarrow ()$	23									
4	b	14									
5	1	01									
6	$x \rightarrow ()$	23									
7	a	13									
8	STOP	41	A_i	t_i	0	ENTER DATA					
9	IF FLAG	43									
10	2	02									
11	9	11									
12	$\ln x$	65									
13	ACC +	60									
1	0	$x \leftrightarrow y$	30								
1	X	36									
2	$\uparrow$	27									
3	X	36									
4	b	14									
5	+	33									
6	$y \rightarrow ()$	40									
7	b	14									
8	C	16									
9	ROLL $\uparrow$	22									
10	+	33									
11	$y \rightarrow ()$	40									
12	C	16									
13	CLEAR x	37									
2	0	$\uparrow$	27								
1	a	13									
2	$\uparrow$	27									
3	1	01									
4	+	33									
5	$\downarrow$	25									
6	GO TO ()	44									
7	0	00									
8	6	06									
9	a	13									
10	$\uparrow$	27									
11	1	01									
12	-	34									
13	$y \leftrightarrow ()$	24									

CLEAR STORAGE AND
DISPLAY REGISTERS

INITIALIZE COUNTER

CALCULATE $\sum \ln (A_i)$ AND $\sum t_i$

CALCULATE $\sum (t_i)^2$

CALCULATE $\sum t_i \cdot \ln (A_i)$

INCREMENT COUNTER

BRANCH TO ENTER NEXT DATA SET

DECREMENT n

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	$\bar{C}$	16								
	1	$\bar{C}$	16								
	2	X	36								
	3	$\uparrow$	27								
	4	RCL	61								
	5	$x \leftrightarrow y$	30								
	6	X	36								
	7	ROLL $\downarrow$	31								
	8	—	34								
	9	$y \leftrightarrow ()$	24								
	a	b	14								
	b	$\bar{C}$	16								
	c	X	36								
4	d	$\downarrow$	25								
	0	ROLL $\downarrow$	31								
	1	X	36								
	2	$\downarrow$	25								
	3	—	34								
	4	b	14								
	5	$x \leftrightarrow y$	30								
	6	$\div$	35								
	7	y	55								
	8	2	02								
	9	$\ln x$	65								
	a	$x \leftrightarrow y$	30								
	b	$\div$	35								
5	c	$\uparrow$	27								
	d	CLEAR X	37								
	0	$y \rightarrow ()$	40								
	1	a	13								
	2	ROLL $\downarrow$	31								
	3	STOP	41	λ	τ	0	DISPLAY				
	4	CLEAR	20								
	5	STOP	41	Δt	t(INITIAL)	0	ENTER DATA: t(INITIAL) $\rightarrow$ Y, $\Delta t \rightarrow$ X				
	6	$\uparrow$	27								
	7	$\downarrow$	25								
	8	$x \rightarrow ()$	23								
	9	$\bar{C}$	16								
	a	a	13								
	b	CHG SIGN	32								
	c	X	36								
	d	$\downarrow$	25								

CALCULATE λ CALCULATE τ STORE λ CALCULATE M/M_0

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	e^x 74									
1	↑	27									
2	$\bar{a}$	13	RECALL AND POSITION λ AND $\dagger$								
3	$x \leftrightarrow y$	30									
4	STOP	41	M/M_0	λ	$\dagger$	DISPLAY					
5	CLEAR x	37									
6	ROLL ↓	31	INCREMENT $\dagger$								
7	$\bar{c}$	16									
8	+	33									
9	GOTO () ()	44									
a	5	05	BRANCH TO DISPLAY $\dagger$ AND Δ FOR NEXT								
b	5	05	M/M_0 CALCULATION.								
c	END	46									
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

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ELEMENTAL PERCENTAGE AND MOLECULAR WEIGHT

PART NO.
09100-75501

This program calculates relative elemental percentages of up to and including 4 elements. The atomic weight of the elements are programmed into the calculator. The total molecular weight of the compound is also calculated.

USER INSTRUCTIONS

NOTE

N_1 , N_2 , N_3 and N_4 indicate the number of atoms to be used i.e., if carbon is the first element and 10 atoms are to be used then $N_1 = 10$.

ENTER PROGRAM (Starting Address is 0-0)

N_1 { PRESS: GO TO (0) (4)
SET: PROGRAM
ENTER PROGRAM STEPS TO ENTER
ATOMIC WEIGHT OF N_1 . A MAXI-
MUM OF 6 STEPS IS ALLOWED.
SET: RUN

N_2 { PRESS: GO TO (1) (4)
SET: PROGRAM
ENTER ATOMIC WEIGHT OF N_2 AS
BEFORE.
SET: RUN

N_3 { PRESS: GO TO (2) (4)
SET: PROGRAM
ENTER ATOMIC WEIGHT OF N_3 AS
BEFORE
SET: RUN

N_4 { PRESS: GO TO (3) (4)
SET: PROGRAM
ENTER ATOMIC WEIGHT OF N_4 AS
BEFORE
SET: RUN

(Note the atomic weights could have been manually entered with the program steps and stored on a magnetic card for subsequent use. When using the card in this case skip all above instructions except ENTER PROGRAM.)

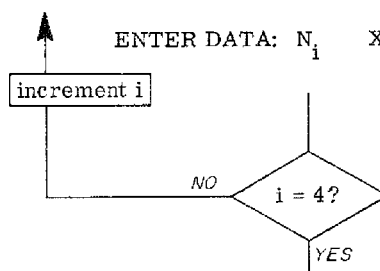
PRESS: GO TO (0) (0) or END

PRESS: CONTINUE

DISPLAY

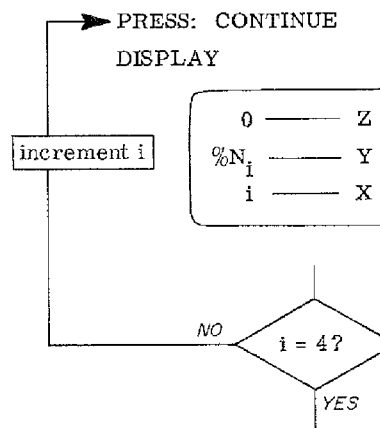
0 — Z
0 — Y
i — X

ENTER DATA: N_1 X N_i = the no. of atoms of each element of the compound



PRESS: CONTINUE
DISPLAY

0 — Z
% N_1 — Y
i — X



PRESS: CONTINUE
DISPLAY

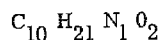
0 — Z
0 — Y
M.W. — X

To reuse with same atomic weights
PRESS: CONTINUE

EXAMPLES

Atomic Weights:

C - 12.010 atomic units (N_1)
H - 1.008 atomic units (N_2)
N - 14.010 atomic units (N_3)
O - 16.000 atomic units (N_4)



EXAMPLES (Cont'd)

 $\%C = 64.129$ $\%H = 11.303$ $\%N = 7.481$ $\%O = 17.087$ $M.W. = 187.278$

Atomic Weights:

 $C - 12.010 \text{ atomic units } (N_1)$ $H - 1.008 \text{ atomic units } (N_2)$ $S - 32.07 \text{ atomic units } (N_3)$ $C_{10} H_{22} S$ $\%C = 68.886$ $\%H = 12.720$ $\%S = 18.394$ $M.W. = 174.346$

NOTE: The number of atoms of N_4
must be entered as 0.



Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	1	01	DISPLAY 1 TO INDICATE FIRST ENTRY								
	2	STOP	41	N ₁	0	0	ENTER N ₁					
	3	↑	27									
	4	CONTINUE	47									
	5	CONTINUE	47									
	6	CONTINUE	47	BLANK AREA FOR INSERTING ATOMIC WEIGHT OF N ₁								
	7	CONTINUE	47									
	8	CONTINUE	47									
	9	CONTINUE	47									
	a	X	36									
	b	ACC +	60	CALCULATE PARTIAL MOLECULAR WEIGHT								
	c	y→()	40									
d	a	13										
1	0	↓	25									
	1	2	02	DISPLAY 2 TO INDICATE SECOND ENTRY								
	2	STOP	41	N ₂	0	0	ENTER N ₂					
	3	↑	27									
	4	CONTINUE	47									
	5	CONTINUE	47									
	6	CONTINUE	47	BLANK AREA FOR INSERTING ATOMIC WEIGHT OF N ₂								
	7	CONTINUE	47									
	8	CONTINUE	47									
	9	CONTINUE	47									
	a	X	36									
	b	ACC +	60	CALCULATE PARTIAL MOLECULAR WEIGHT								
	c	y→()	40									
d	b	14										
2	0	↓	25									
	1	3	03	DISPLAY 3 TO INDICATE THIRD ENTRY								
	2	STOP	41	N ₃	0	0	ENTER N ₃					
	3	↑	27									
	4	CONTINUE	47									
	5	CONTINUE	47									
	6	CONTINUE	47	BLANK AREA FOR INSERTING ATOMIC WEIGHT OF N ₃								
	7	CONTINUE	47									
	8	CONTINUE	47									
	9	CONTINUE	47									
	a	X	36									
	b	ACC +	60	CALCULATE PARTIAL MOLECULAR WEIGHT								
	c	y→()	40									
d	c	16										

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	03	DISPLAY 3 TO INDICATE % N ₃								
1	STOP	41	3	%N ₃	0	DISPLAY					
2	y ₂ ()	24	RECALL %N ₄ AND POSITION DISPLAY								
3	C	16									
4	4	04	DISPLAY 4 TO INDICATE % N ₄								
5	STOP	41	4	%N ₄	0	DISPLAY					
6	y ₂ ()	24	RECALL MOLECULAR WEIGHT AND POSITION DISPLAY								
7	E	12									
8	↓	25									
9	END	46	M.W.	0	0	DISPLAY					
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

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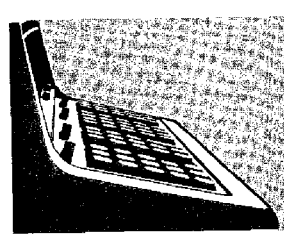
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ELEMENTAL PERCENTAGE AND MOLECULAR WEIGHT 6 ELEMENT

PART NO.
09100-75502

This program calculates relative elemental percentages of up to and including 6 elements. The atomic weight of the elements are programmed into the calculator. The total molecular weight of the compound is also calculated.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

N_1 { PRESS: GO TO (0) (4)
SET: PROGRAM
Enter program steps for atomic weight of N_1 ;
maximum of 6 steps is allowed.
SET: RUN

N_2 { PRESS: GO TO (1) (4)
SET: PROGRAM
Enter program steps for atomic weight of N_2
as before.
SET: RUN

N_3 { PRESS: GO TO (2) (4)
SET: PROGRAM
Enter atomic weight of N_3 as before.
SET: RUN

N_4 { PRESS: GO TO (3) (4)
SET: PROGRAM
Enter atomic weight of N_4 as before.
SET: RUN

N_5 { PRESS: GO TO (4) (4)
SET: PROGRAM
Enter atomic weight of N_5 as before.
SET: RUN

N_6 { PRESS: GO TO (5) (4)
SET: PROGRAM
Enter atomic weight of N_6 as before.
SET: RUN

PRESS: GO TO (0) (0) [or End]

PRESS: CONTINUE

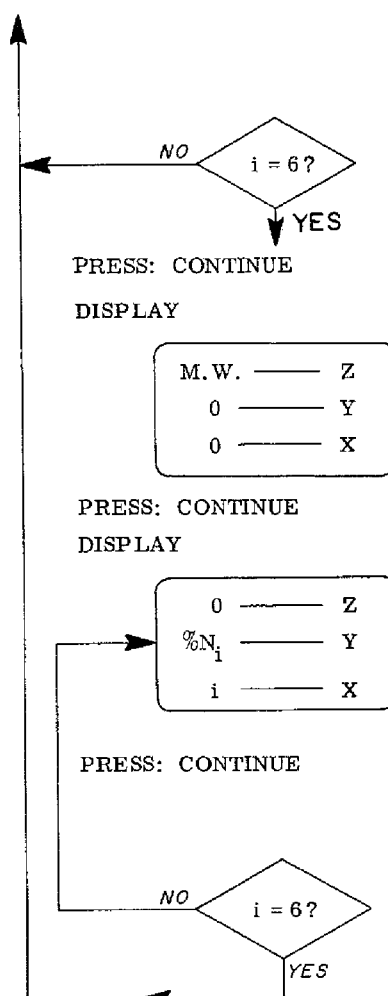
DISPLAY

0	—	Z
0	—	Y
i	—	X

(i indicates number of element to be entered)

ENTER DATA: $N_i \rightarrow X$ (N_i = the number of atoms of each element.)

USER INSTRUCTIONS con't



Note: To reset problem with different elements, repeat user instructions; otherwise, enter new number of atoms of each element when initial display appears after completion of last problem.

EXAMPLE

Elements:	N ₁ (C)	N ₂ (H)	N ₃ (S)	N ₄ (N)	N ₅ (O)	N ₆ (Si)
At. Wt.:	12.01	1.008	32.07	14.01	16.00	28.09
# of Atoms	6	2	8	1	2	3

Solution:

$$\% \text{ C} = 15.63\%$$

$$\% \text{ H} = .44\%$$

$$\% \text{ S} = 55.66\%$$

$$\% \text{ N} = 3.04\%$$

$$\% \text{ O} = 6.94\%$$

$$\% \text{ Si} = 18.28\%$$

$$\text{Molecular Weight} = 460.92$$



Step	Key	Code	Display							
			x	y	z	f	c	d	e	b
0	CLEAR	20								
1	1	01								
2	STOP	41	N ₁	0	0	ENTER N ₁				
3	↑	27								
4	CONTINUE	47								
5										
6										
7										
8										
9	CONTINUE	47								
a	X	36								
b	ACC +	60								
c	y→()	40								
d	B	13								
1	↓	25								
1	2	02								
2	STOP	41	N ₂	0	0	ENTER N ₂				
3	↑	27								
4	CONTINUE	47								
5										
6										
7										
8										
9	CONTINUE	47								
a	X	36								
b	ACC +	60								
c	y→()	40								
d	B	14								
2	↓	25								
1	3	03								
2	STOP	41	N ₃	0	0	ENTER N ₃				
3	↑	27								
4	CONTINUE	47								
5										
6										
7										
8										
9	CONTINUE	47								
a	X	36								
b	ACC +	60								
c	y→()	40								
d	C	16								

AREA FOR INSERTING
ATOMIC WEIGHT OF N₁

CALCULATE PARTIAL MOLECULAR WEIGHT

STORE X₁

AREA FOR INSERTING
ATOMIC WEIGHT OF N₂

CALCULATE PARTIAL MOLECULAR WEIGHT

STORE X₂

AREA FOR INSERTING
ATOMIC WEIGHT OF N₃

CALCULATE PARTIAL MOLECULAR WEIGHT

STORE X₃

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
3	0	↓	25									
1	4	04										
2	STOP	41	N ₄	0	0	ENTER N ₄						
3	↑	27										
4	CONTINUE	47										
5												
6												
7												
8												
9	CONTINUE	47										
a	X	36										
b	ACC +	60										
c	y→()	40										
d	d	17										
4	0	↓	25									
1	5	05										
2	STOP	41	N ₅	0	0	ENTER N ₅						
3	↑	27										
4	CONTINUE	47										
5												
6												
7												
8												
9	CONTINUE	47										
a	X	36										
b	ACC +	60										
c	y→()	40										
d	f	15										
5	0	↓	25									
1	6	06										
2	STOP	41	N ₆	0	0	ENTER N ₆						
3	↑	27										
4	CONTINUE	47										
5												
6												
7												
8												
9	CONTINUE	47										
a	X	36										
b	E	12										
c	xzy	30										
d	+	33										

AREA FOR INSERTING
ATOMIC WEIGHT OF N₄

CALCULATE PARTIAL-MOLECULAR-WEIGHT

STORE X₄

AREA FOR INSERTING
ATOMIC WEIGHT OF N₅

CALCULATE PARTIAL-MOLECULAR-WEIGHT

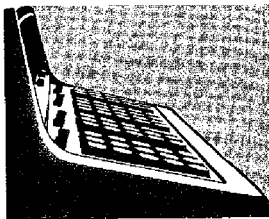
STORE X₅

AREA FOR INSERTING
ATOMIC WEIGHT OF N₆

CALCULATE AND STORE
TOTAL MOLECULAR WEIGHT

Step	Key	Code	Display			Storage					
			x	y	z	f	a	d	c	b	a
6	0	$x \leftrightarrow y$	30								
	1	$x \rightarrow ()$	23								
	2	E	12								
	3	$\uparrow$	27								
	4	ENTER EXP	26	CALCULATE MOLECULAR WEIGHT							
	5	2	02								
	6	$\div$	35								
	7	$\downarrow$	25	CALCULATE %N ₆							
	8	$\div$	35								
	9	$y \leftrightarrow ()$	24								
7	a	a	13	CALCULATE %N ₁							
	b	$\div$	35								
	c	$y \leftrightarrow ()$	24								
	d	b	14	CALCULATE %N ₂							
	0	$\div$	35								
	1	$y \leftrightarrow ()$	24								
	2	c	16	CALCULATE %N ₃							
	3	$\div$	35								
	4	$y \leftrightarrow ()$	24								
	5	d	17	CALCULATE %N ₄							
8	6	$\div$	35								
	7	$y \leftrightarrow ()$	24								
	8	f	15	CALCULATE %N ₅							
	9	$\div$	35								
	a	CLEAR X	37								
	b	$y \leftrightarrow ()$	24								
	c	E	12	RECALL AND POSITION MOLECULAR WEIGHT							
	d	$\uparrow$	27								
	0	STOP	41	0	0	M.W.	DISPLAY MOLECULAR WEIGHT				
	1	b	14								
9	2	$\uparrow$	27								
	3	1	01								
	4	STOP	41	1	%N ₁	0	DISPLAY %N ₁				
	5	$y \leftrightarrow ()$	24								
	6	c	16								
	7	2	02								
	8	STOP	41	2	%N ₂	0	DISPLAY %N ₂				
	9	$y \leftrightarrow ()$	24								
	a	d	17								
	b	3	03								
10	c	STOP	41	3	%N ₃	0	DISPLAY %N ₃				
	d	$y \leftrightarrow ()$	24								

[illegible]



CHN ANALYSIS - K VALUES

PART NO.
09100-75503

This program calculates the K values (K_C , K_H , and K_N), for compounds containing carbon (C), hydrogen (H), and nitrogen (N), from blank values (B_C , B_H , and B_N), percentages of C, H, and N from a known standard ($\%C_s$, $\%H_s$, and $\%N_s$), and measured quantities of C, H, and N of the known standard (C_{s_1} , H_{s_1} , and N_{s_1}).

Two sets of measurements of C-H-N quantities of the standard are normally taken, although one set of measurements is sufficient for operation of the program.

The following equations are used:

$$K_C = \frac{\%C_s}{\overline{C}_s - B_C}$$

$$K_H = \frac{\%H_s}{\overline{H}_s - B_H}$$

$$K_N = \frac{\%N_s}{\overline{N}_s - B_N}$$

where $\overline{M}_s$ [$M = C, H, \text{ or } N$] is the average of M_{s_1} and M_{s_2} .

If only one set of C-H-N quantities of the standard are used, then:

$$\overline{M}_s [M = C, H, \text{ or } N] = M_{s_1}$$

$$K_C = \frac{\%C_s}{C_1 - B_C}, \text{ etc.}$$

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (3) (1)

SET: ENTER: Program steps for the constant - %N_s
(five spaces available).SET:

PRESS: GO TO (4) (3)

SET: ENTER: Program steps for the constant - %C_s
(five spaces available).SET:

PRESS: GO TO (5) (3)

SET: ENTER: Program steps for the constant - %H_s
(five spaces available).SET:

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: B_N → Z, B_H → Y, B_C → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

ENTER DATA: N_{s1} → Z, H_{s1} → Y, C_{s1} → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
2	_____	X

ENTER DATA: N_{s2} → Z, H_{s2} → Y, C_{s2} → X

USER INSTRUCTIONS (con't)

PRESS: CONTINUE

DISPLAY

K _N	_____	Z
K _H	_____	Y
K _C	_____	X

Note: If only one set of standard values is to be used, N_{s2}, H_{s2}, and C_{s2} must be set to zero. Do not press "clear" at any time during program operation.

To reset program for a different standard, repeat user instructions.

EXAMPLES

(A) Only 1 set of standard values is available

Given: %C_s = 51.79, %H_s = 5.07, %N_s = 20.14
 B_C = 1.6, B_H = 30, B_N = 1.0
 C_{s1} = 125.0, H_{s1} = 119.5, N_{s1} = 88.0

Note: Since only 1 set of standards is available, the 2nd set of standards must be set to zero at the appropriate data input of the program. Do not press "CLEAR" to zero the 2nd set of standards.

Solution: K_C = .420, K_H = .057, K_N = .231(B) Given: %C_s = 51.79, %H_s = 5.07, %N_s = 20.14

B_C = 1.6, B_H = 30, B_N = 1.0
 C_{s1} = 121.0, H_{s1} = 121.5, N_{s1} = 79.5
 C_{s2} = 120.5, H_{s2} = 115.5, N_{s2} = 79.5

Solution: K_C = .435, K_H = .057, K_N = .257

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	—	34								
	1	CONTINUE	47								
	2	CONTINUE	47								
	3	.	21								
	4	CONTINUE	47								
	5	CONTINUE	47								
	6	$x \div y$	30								
	7	$\div$	35								
	8	$y \rightarrow ()$	40								
	9	d	17								
	a	f	15								
	b	ROLL $\uparrow$	22								
	c	$\div$	35								
	d	$x \div y$	30								
4	0	$\uparrow$	27								
	1	a	13								
	2	—	34								
	3	CONTINUE	47								
	4	CONTINUE	47								
	5	.	21								
	6	CONTINUE	47								
	7	CONTINUE	47								
	8	$x \div y$	30								
	9	$\div$	35								
	a	$y \rightarrow ()$	40								
	b	f	15								
	c	e	12								
	d	ROLL $\uparrow$	22								
5	0	$\div$	35								
	1	b	14								
	2	—	34								
	3	CONTINUE	47								
	4	CONTINUE	47								
	5	.	21								
	6	CONTINUE	47								
	7	CONTINUE	47								
	8	$x \div y$	30								
	9	$\div$	35								
	a	$y \rightarrow ()$	40								
	b	e	12								
	c	d	17								
	d	$x \div y$	30								

CALCULATE AND STORE K_N

STEPS 3-1 THROUGH 3-5 ARE
THE BLANK SPACES FOR
ENTERING % N_s

CALCULATE AND STORE K_C

STEPS 4-3 THROUGH 4-7 ARE
THE BLANK SPACES FOR
ENTERING % C_s

CALCULATE AND STORE K_H

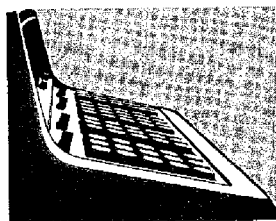
STEPS 5-3 THROUGH 5-7 ARE
THE BLANK SPACES FOR
ENTERING % H_s

RECALL AND POSITION K_C , K_H
AND K_N FOR DISPLAY

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	ROLL ↑	22								
	1	END	46	K _C	K _H	K _N	DISPLAY				
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

HEWLETT-PACKARD HEWLETT-PACKARD HEWLETT-PACKARD HEWLETT-PACKARD HEWLETT-PACKARD

[illegible]



PART NO.
09100-75504

CHN PERCENTAGES

Percentages of carbon (C), hydrogen (H), and nitrogen (N) in an unknown substance are calculated from measured quantities of C, H, and N, blank values (B_C , B_H , and B_N), and K values (K_C , K_H , K_N) which may be calculated with the K value program (09100-75503). K and B values must be stored prior to program operation either manually by the operator, or automatically by the use of the K value program.

The following equations are used:

$$\% C_1 = K_C (C_1 - B_C)$$

$$\% C_2 = K_C (C_2 - B_C)$$

or, in general:

$$\% M_1 [M = C, H, \text{ or } N] = K_M (M_1 - B_M)$$

$$\% M_2 [M = C, H, \text{ or } N] = K_M (M_2 - B_M)$$

The percentage evaluation is considered successful if M_1 and M_2 differ by .3% or less.

If only one set of CHN measurements are available, then C_2 , H_2 , and N_2 may be made any value at the corresponding data input. In this case only $\% C_1$, $\% H_1$, and $\% N_1$ are useful information; disregard answers for $\% C_2$, $\% H_2$, and $\% N_2$.

USER INSTRUCTIONS

USER INSTRUCTIONS (con't)

ENTER PROGRAM [(Starting Address is 0 - 0)]

YES

Have K and B
values been stored by
use of the K-Values program?

NO

ENTER DATA: $K_N \rightarrow Z$, $K_H \rightarrow Y$, $K_C \rightarrow X$

PRESS: $\begin{cases} x \rightarrow \\ f \rightarrow \\ y \rightarrow \\ e \rightarrow \\ R \downarrow \\ y \rightarrow \\ d \end{cases}$

ENTER DATA: $B_N \rightarrow Z$, $B_H \rightarrow Y$, $B_C \rightarrow X$

PRESS: $\begin{cases} x \rightarrow \\ a \rightarrow \\ y \rightarrow \\ b \rightarrow \\ R \downarrow \\ y \rightarrow \\ c \end{cases}$

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $N_1 \rightarrow Z$, $H_1 \rightarrow Y$, $C_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
2	—	X

ENTER DATA: $N_2 \rightarrow Z$, $H_2 \rightarrow Y$, $C_2 \rightarrow X$

Note: If only one C-H-N set is available, N_2 , H_2 , and C_2 may be set to zero or any other value—Simply disregard the solutions for $\% C_2$, $\% H_2$, and $\% N_2$.

PRESS: CONTINUE

DISPLAY

$\% C_2$	—	Z
$\% C_1$	—	Y
1	—	X

PRESS: CONTINUE

DISPLAY

$\% H_2$	—	Z
$\% H_1$	—	Y
2	—	X

PRESS: CONTINUE

DISPLAY

$\% N_2$	—	Z
$\% N_1$	—	Y
3	—	X

To reset problem for different C, H, and N samples.

To reset program for different sets of K and B, repeat user instructions.

EXAMPLES

(A)

Example (A) of the K-value program (09100-75503) has previously been run, and the K and B values have already been stored.

Data: $C_1 = 118.3$, $H_1 = 75.0$, $N_1 = 49.1$
 $C_2 = 128.6$, $H_2 = 69.7$, $N_2 = 53.4$

Solution: $\%C_1 = 48.98$, $\%C_2 = 53.30$
 $\%H_1 = 2.55$, $\%H_2 = 2.25$
 $\%N_1 = 11.13$, $\%N_2 = 12.13$

(B)

The K-value program (09100-75503) has not been run; K and B values must therefore be stored manually. (see "user instructions").

Data: $B_C = 2.1$, $B_H = 28$, $B_N = 3$
 $K_C = .520$, $K_H = .102$, $K_N = .235$
 $C_1 = 132.1$, $H_1 = 92.0$, $N_1 = 57.9$

Solution: $\%C_1 = 67.6$
 $\%H_1 = 6.53$
 $\%N_1 = 12.90$

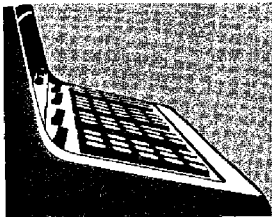
Note: Disregard answers for $\%C_2$, $\%H_2$, and $\%N_2$ since a second set of C-H-N was not available.



Step	Key	Code	Display			Storage			
			x	y	z	f	e	d	c
0	0	CLEAR x	37						
1	↑	27							
2	↑	27							
3	1	01							
4	STOP	41							
5	x→()	23	C ₁	H ₁	N ₁	ENTER 1st SET OF C			
6	9	11							
7	y→()	40							
8	8	10							
9	ROLL ↓	31							
a	y→()	40							
b	7	07							
c	CLEAR x	37							
d	↑	27							
1	0	↑	27						
1	2	02							
2	STOP	41							
3	x→()	23	C ₂	H ₂	N ₂	ENTER 2nd SET OF C, H,			
4	6	06							
5	b	14							
6	-	34							
7	B	12							
8	X	36							
9	y→()	24							
a	8	10							
b	b	14							
c	-	34							
d	B	12							
2	0	X	36						
1	y→()	24							
2	9	11							
3	B	13							
4	-	34							
5	f	15							
6	X	36							
7	y→()	24							
8	6	06							
9	B	13							
a	-	34							
b	f	15							
c	X	36							
d	y→()	24							

STORE C₁, H₁ AND N₁STORE C₂CALCULATE AND STORE % H₂ AND % H₁CALCULATE AND STORE % C₁ AND % C₂

[illegible]



MOLECULAR WEIGHT BY VPO

PART NO.
09100-75505

Data obtained from the vapor pressure osmometer (VPO) is used to calculate either the depression constant (K_d) for a substance with standard molecular weight, or the molecular weight (MW) of an unknown substance. In normal application, VPO readings (V) for various concentrations (C) of a substance with known molecular weight are taken, and K_d is determined. The molecular weight of an unknown substance may then be determined from VPO readings obtained from various concentrations of the unknown, and from the previously determined K_d .

The same procedure is used to calculate either K_d or MW. In both cases, a linear regression is performed with V/C and C as the dependent and independent variables respectively. The regression is similar to that of the regression program (09100-70803) for equations of the form $Y = mx + b$; in this case the defining equation is $V/C = mc + b$, where m is the slope of the V/C versus C curve. The V/C versus C curve is then extrapolated to infinite dilution ($C = 0$) to obtain the $Y = V/C$ intercept (b); i.e. $\lim_{C \rightarrow 0} V/C = b$.

K_d is then calculated using the equation:

$$K_d = b(MW) \text{ where MW, in this case, is the molecular weight of a known substance.}$$

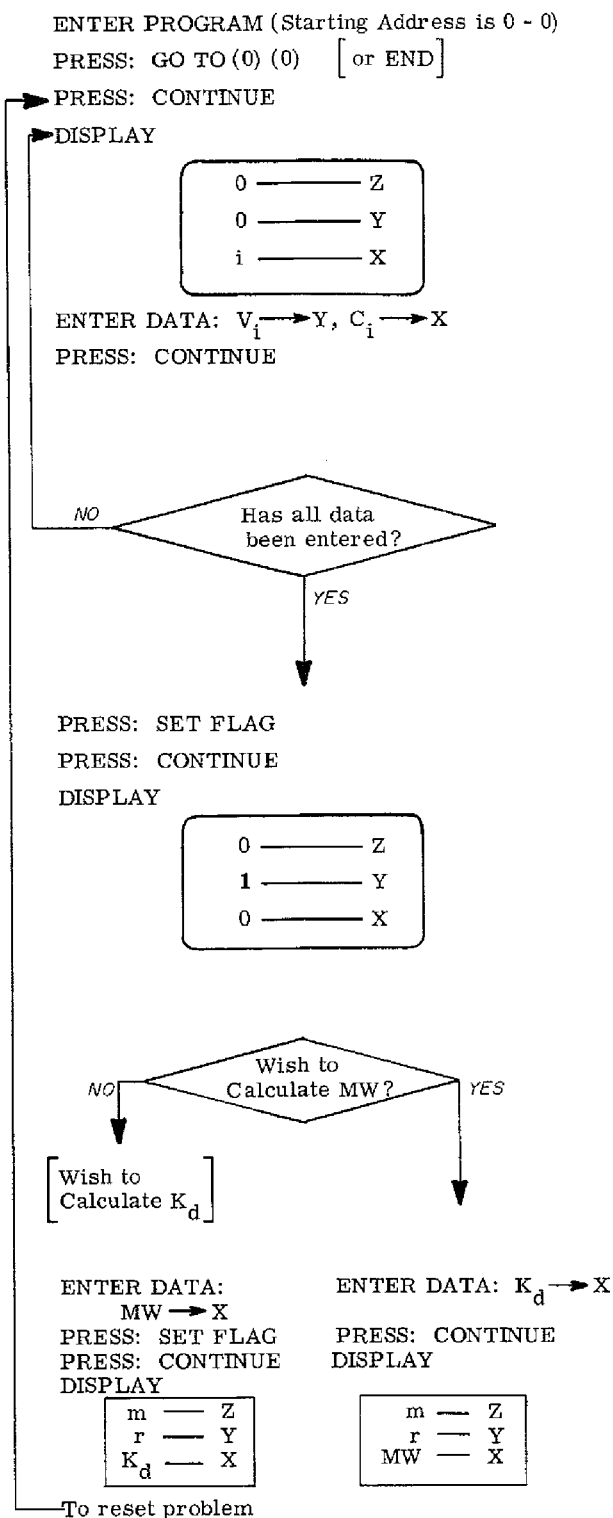
Likewise, MW may be calculated by the equation:

$$MW = \frac{K_d}{b} \text{ where now MW is the molecular weight (of an unknown substance) which is to be determined.}$$

A correlation coefficient (r) is also calculated. r is a measure of reproducibility and also how ideal the system is.

USER INSTRUCTIONS

EXAMPLES



- (A) Calculate K_d for the following standard molecular weight, and set of VPO and C readings.

Data: MW = 1500

i	V_i	C_i
1	500	34
2	330	24
3	205	16
4	125	8

Solution: $m = -.017$
 $r = -.156$
 $K_d = 21858.377$

- (B) Calculate MW for the following data:

Data: $K_d = 337.576$

i	V_i	C_i
1	56.10	121.95
2	23.85	57.32
3	11.45	27.85
4	5.68	13.72

Solution: $m = .0005$
 $r = .9419$
 MW = 843.5813

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0 CLEAR	20	CLEAR DISPLAY AND STORAGE REGISTERS.								
1	x→()	23									
2	d	17									
3	x→()	23									
4	c	16									
5	x→()	23	INITIALIZE COUNTER								
6	b	14									
7	1	01									
8	x→()	23	ENTER DATA								
9	a	13									
a	STOP	41									
b	IF FLAG	43									
c	3	03									
d	5	05	CALCULATE $\Sigma X = \Sigma C$ AND $\Sigma Y = \Sigma V$								
1	0 ÷	35									
1	ACC +	60									
2	↑	27									
3	x	36									
4	x↔y	30	CALCULATE ΣX^2								
5	y↔()	24									
6	d	17									
7	+	33									
8	y↔()	24									
9	d	17	CALCULATE ΣXY								
a	↓	25									
b	x	36									
c	b	14									
d	+	33									
2	0 y→()	40	CALCULATE ΣY^2								
1	b	14									
2	ROLL ↑	22									
3	↑	27									
4	x	36									
5	c	16	INCREMENT COUNTER								
6	+	33									
7	y→()	40									
8	c	16									
9	a	13									
a	↑	27	INCREMENT COUNTER								
b	1	01									
c	+	33									
d	CLEAR x	37									

FROM 3-4

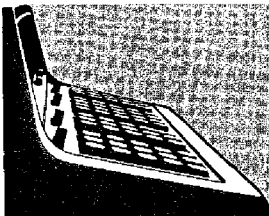
Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	↑	27								
	1	ROLL ↑	22								
	2	GOTO () ()	44								
	3	0	00								
	4	8	10								
	5	B	13								
	6	↑	27								
	7	1	01								
	8	—	34								
	9	E	12								
	a	x↔y	30								
	b	÷	35								
	c	y↔()	24								
4	d	f	15								
	0	÷	35								
	1	x→()	23								
	2	B	13								
	3	y→()	40								
	4	E	12								
	5	X	36								
	6	E	12								
	7	X	36								
	8	d	17								
	9	x↔y	30								
	a	—	34								
	b	y↔()	24								
5	c	c	16								
	d	f	15								
	0	↑	27								
	1	X	36								
	2	B	13								
	3	X	36								
	4	↓	25								
	5	—	34								
	6	y↔()	24								
	7	b	14								
	8	↑	27								
	9	RCL	61								
	a	X	36								
	b	B	13								
	c	X	36								
	d	↓	25								

BRANCH TO ENTER NEXT SET OF DATA

DECREMENT COUNTER

CALCULATE $\bar{y}$ CALCULATE $\bar{x}$ STORE $\bar{x}$ AND nCALCULATE $\sum (x - \bar{x})^2$ CALCULATE $\sum (y - \bar{y})^2$

[illegible]



MEMBRANE OSMOMETER

PART NO.
09100-75506

The membrane osmometer is used to obtain data for calculation of either the constant RT (R = gas constant, T = absolute temperature), or the number average molecular weight ($\bar{M}_n$). In normal application, osmotic pressure (P) measurements are taken for various concentrations (C) of a substance with known $\bar{M}_n$, and RT is subsequently calculated. The number average molecular weight of an unknown substance may then be determined from membrane osmometer measurements of P obtained from various concentrations of the unknown, and from the previously determined RT .

The same procedure is used to calculate either RT or $\bar{M}_n$. In both cases, a linear regression is performed with $(P/C)^{1/2}$ and C as the dependent and independent variables respectively. The regression is similar to that of the regression program (09100-70803) for equations of the form $y = mx + b$; in this case the defining equation is $P/C = mc + \frac{RT}{\bar{M}_n}$, where m is the slope of the (P/C) versus C curve. The $(P/C)^{1/2}$ versus C curve is then extrapolated to infinite dilution ($c=0$) to obtain the $Y = P/C$ intercept (b), i.e. $\lim_{C \rightarrow 0} P/C = b$. $(P/C)^{1/2}$ rather than P/C is used in the regression to avoid extrapolation error when the P/C and C data results in a P/C versus C plot with pronounced curvature. In many cases where the first power plot has pronounced curvature, the square-root plot will produce a straight line suitable for extrapolation. The desired intercept (b) of the P/C versus C curve is then the square of the $(P/C)^{1/2}$ versus C intercept.

RT is calculated using the equations:

$$RT = \bar{M}_n (b) \quad \text{where } \bar{M}_n \text{ is a known number average molecular weight.}$$

Likewise, $\bar{M}_n$ may be calculated by the equation:

$$\bar{M}_n = \frac{RT}{b} \quad \text{where now } \bar{M}_n \text{ is the number average molecular weight (of an unknown substance) which is to be determined.}$$

A correlation coefficient (r) is also calculated. r is a measure of reproducibility and also how ideal the system is.

USER INSTRUCTION

EXAMPLES

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: END

PRESS: CONTINUE

DISPLAY

0	—	Z
0	—	Y
1	—	X

ENTER DATA: $P_i \rightarrow Y$, $C_i \rightarrow X$

PRESS: CONTINUE

NO

Has all
data been en-
tered?

YES

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	—	Z
1	—	Y
0	—	X

YES

Wish to
calculate $\bar{M}_n$?

[Wish to calculate RT]

ENTER DATA:
 $RT \rightarrow X$ ENTER DATA: $\bar{M}_n \rightarrow X$

PRESS: SET FLAG PRESS: CONTINUE

PRESS: CONTINUE

DISPLAY

DISPLAY

m	—	Z
r	—	Y
$\bar{M}_n$	—	X

m	—	Z
r	—	Y
RT	—	X

To reset problem:

- (A) Determine RT for a substance with known number average molecular weight ($\bar{M}_n$) using the following data:

Data: $\bar{M}_n = 1.2 \times 10^5$

i	P_i	C_i
1	.58	2
2	1.75	5
3	4.45	10
4	12.64	20

Solution: $m = .014$
 $r = .998$
 $RT = 32,185.017$

- (B) Calculate $\bar{M}_n$ for an unknown substance using the following data:

Data: $RT = 3.65 \times 10^4$

i	P_i	C_i
1	.67	2.2
2	1.50	4.3
3	3.72	8.4
4	10.41	18.6

Solution: $m = .012$
 $r = .977$
 $\bar{M}_n = 124,403.599$

Step	Key	Code	Display	Notes
0	0 CLEAR	20		
1	$x \rightarrow ()$	23		
2	d	17		
3	$x \rightarrow ()$	23		CLEAR DISPLAY AND STORAGE REGISTERS.
4	c	16		
5	$x \rightarrow ()$	23		
6	b	14		
7	1	01		
8	$x \rightarrow ()$	23		INITIALIZE COUNTER
9	a	13		
10	STOP	41	C P O	ENTER DATA
11	IF FLAG	43		
12	3	03		BRANCH IF ALL DATA HAS BEEN ENTERED
13	8	10		
14	$\div$	35		
15	ROLL $\downarrow$	31		CALCULATE $(P/C)^{1/2}$
16	$\sqrt{x}$	76		
17	ROLL $\uparrow$	22		
18	ACC $+$	60		CALCULATE $\sum C = \sum X$ AND $\sum (P/C)^{1/2} = \sum Y$
19	$\uparrow$	27		
20	$\times$	36		
21	$x \leftrightarrow y$	30		
22	$y \leftrightarrow ()$	24		CALCULATE $\sum X^2$
23	d	17		
24	$+$	33		
25	$y \leftrightarrow ()$	24		
26	d	17		
27	$\downarrow$	25		
28	$\times$	36		
29	b	14		CALCULATE $\sum XY$
30	$+$	33		
31	$y \leftrightarrow ()$	40		
32	b	14		
33	ROLL $\uparrow$	22		
34	$\uparrow$	27		
35	$\times$	36		CALCULATE $\sum Y^2$
36	c	16		
37	$+$	33		
38	$y \leftrightarrow ()$	40		
39	c	16		
40	a	13		
41	$\uparrow$	27		INCREMENT COUNTER

FROM 3-7

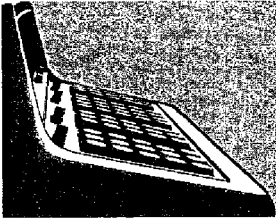
Step	Key	Code	Display			Storage					
			X	Y	Z	F	E	D	C	B	A
3	0	1	01								
	1	+	33								
	2	CLEAR X	37								
	3	↑	27								
	4	ROLL ↑	22								
	5	GOTO ()	44								
	6	0	00								
	7	8	10								
	8	θ	13								
	9	↑	27								
4	0	1	01								
	1	-	34								
	2	y→()	40								
	3	θ	13								
	4	E	12								
	5	xzy	30								
	6	÷	35								
	7	y→()	24								
	8	f	15								
	9	÷	35								
5	0	y→()	40								
	1	E	12								
	2	X	36								
	3	E	12								
	4	X	36								
	5	d	17								
	6	xzy	30								
	7	-	34								
	8	y→()	24								
	9	f	15								
	0	↑	27								
	1	X	36								
	2	θ	13								
	3	X	36								
	4	↓	25								
	5	-	34								
	6	y→()	24								
	7	b	14								
	8	↑	27								
	9	RCL	61								
	0	X	36								

BRANCH TO ENTER NEXT SET OF DATA.

DECREMENT AND STORE COUNTER.

CALCULATE $\bar{Y}$ CALCULATE AND STORE $\bar{X}$ CALCULATE AND STORE $\Sigma (X - \bar{X})^2$ CALCULATE AND STORE $\Sigma (Y - \bar{Y})^2$

[illegible]

PART NO.
09100-75801

TIME-KEEPER

This program keeps time in the same manner as a watch or clock. Any initial time (in hours, minutes, and seconds) may be entered, and the time thereafter is presented in an intermittently flashing display. Hours run from 0 through 24, and thereafter revert to 1, corresponding to military standards. Adjustments are available for calibration of a particular calculator. Speed of execution is varied by insertion of several non-functional program instructions (instructions which merely use time and do not affect the mathematical operation of the program). The user adjusts accuracy by inputting a number, b , (0 to 30 should be sufficient) which represents the number of times per count the nonfunctional steps are executed. Varying b by ± 1 results in approximately a 17 millisecond variation per count (i.e., 1 second variation in a minute).

USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address is 0 - 0)

→ PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: $b \rightarrow x$

b is the calibration variable for
adjustment of accuracy. $0 \leq b \leq 30$

PRESS: $X \rightarrow ()$

PRESS: d

ENTER DATA: Hours $\rightarrow Z$, minutes $\rightarrow Y$, seconds $\rightarrow X$

PRESS: CONTINUE

DISPLAY

hours	_____	Z
minutes	_____	Y
seconds	_____	X

To halt program execution, PRESS: STOP

To reset problem:

→ PRESS: STOP

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
0	0	CLEAR	20								
1	x→()	23									
2	C	16									
3	STOP	41	SEC.	MIN.	HRS.	ENTER DATA					
4	ROLL ↓	31									
5	y→()	40									
6	B	13									
7	ROLL ↓	31	INCREMENT SECONDS								
8	1	01									
9	+	33									
10	6	06									
11	0	00									
12	IF x=y	50	BRANCH TO INCREMENT MINUTES IF SEC. = 60								
13	3	03									
14	0	00									
15	ROLL ↓	31									
16	ACC +	60									
17	ROLL ↑	22									
18	ROLL ↓	31									
19	C	16									
20	↑	27									
21	d	17									
22	IF x=y	50									
23	2	02									
24	4	04									
25	1	01	NON-FUNCTIONAL STEPS FOR PROGRAM CALIBRATION								
26	+	33									
27	y→()	40									
28	0	16									
29	GO TO ()	44									
30	1	01									
31	3	03									
32	CLEAR x	37									
33	x→()	23									
34	C	16									
35	B	13									
36	ROLL ↓	31	CLEAR STORAGE REGISTERS AND RECALL TIME FOR DISPLAY								
37	RCL	61									
38	ACC -	63									
39	GO TO ()	44									
40	9	11	BRANCH TO DISPLAY CURRENT TIME								
41	0	00									

FROM 9-8

1

2

41

[illegible]

Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
6	0	↑	27	INCREMENT HOURS								
	1	1	01									
	2	+	33									
	3	2	02	BRANCH TO RESET HOURS TO 1 IF HOURS > 24								
	4	4	04									
	5	IF x < y	52									
	6	8	10									
	7	9	11									
	8	ROLL ↑	22									
	9	ROLL ↓	31									
a	C	16										
b	↑	27										
c	d	17										
d	IF x = y	50										
7	0	7										07
	1	a	13									
	2	1	01									
	3	+	33									
	4	y → ()	40									
	5	C	16									
	6	↓	25									
	7	GOTO () ()	44									
	8	6	06									
	9	8	10									
a	↓	25										
b	CLEAR x	37										
c	x → ()	23										
d	C	16										
8	0	↑										27
	1	ACC +	60									
	2	ACC -	63									
	3	RCL	61									
	4	π	56									
	5	CLEAR x	37									
	6	GOTO () ()	44	BRANCH TO DISPLAY CURRENT TIME								
	7	9	11									
	8	0	00									
	9	1	01	RESET HRS. TO 1								
a	x ≥ y	30										
b	GOTO () ()	44										
c	7	07										
d	b	14										

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
9	0	PAUSE 57									
1											
2											
3											
4											
5											
6	GO TO () ()	44									
7	0	00									
8	4	04									
9	END	46									
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
a											
b											
c											
d											

DISPLAY CURRENT TIME
AND ADJUST EXECUTION SPEED

BRANCH TO INCREMENT SECONDS

FROM 2-8, 5-CB 8-8-2

PRIME NUMBER PROGRAM

PART NO.
09100-75802

This program displays all prime numbers between specified upper and lower limits and the total number of prime numbers found between the limits.

A prime number n is an integer, not a unit (± 1), that is divisible by only $\pm n$ and ± 1 .

Reference:

Elementary Theory of Numbers
Harriet Griffin
1954

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: Upper limit → X

PRESS: CONTINUE

DISPLAY

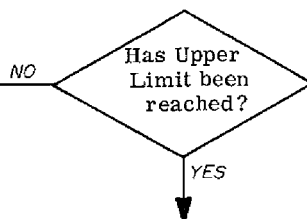
0	_____	Z
UL	_____	Y
0	_____	X

ENTER DATA: Lower Limit → X

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
Prime Number	_____	X



PRESS: CONTINUE

DISPLAY

Upper Limit	_____	Z
Lower Limit	_____	Y
Number of Primes	_____	X

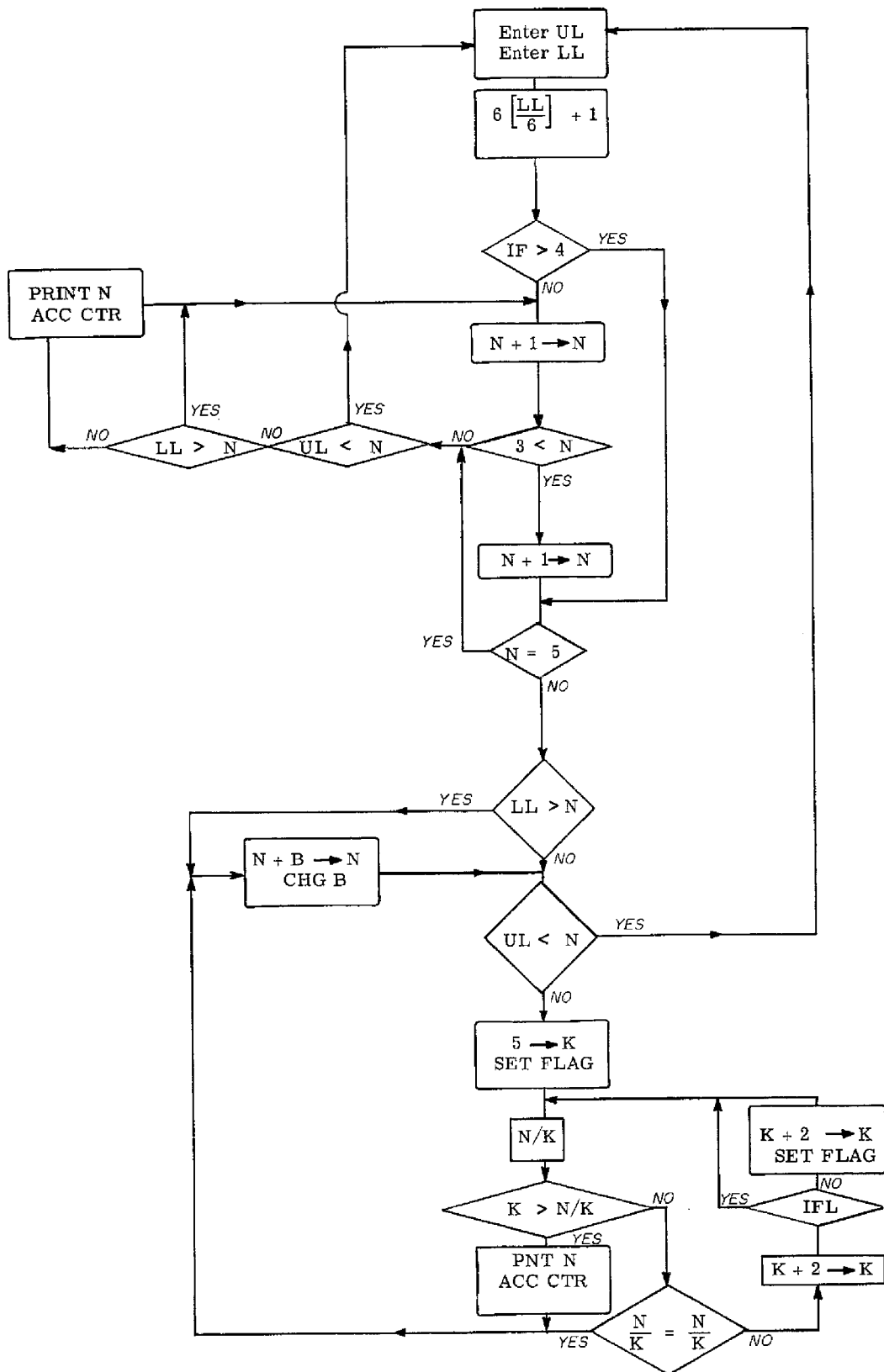
To enter new limits:

Upper Limit = 100

Lower Limit = 0

Primes = 1, 2, 3, 5, 7, 11, 13, 17, 19, 23, 29,
31, 37, 41, 43, 47, 53, 59, 61, 67, 71,
73, 79, 83, 89, 97

Number of Primes = 26





Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
0	0	CLEAR	20									
	1	STOP	41	U.L.	0	0	ENTER UPPER LIMIT					
	2	y→()	40									
	3	a	13									
	4	x↔y	30									
	5	STOP	41	L.L.	0	0	ENTER LOWER LIMIT					
	6	x→()	23	STORE LIMITS								
	7	d	17									
	8	y→()	40									
	9	c	16									
	a	x↔y	30									
	b	6	06									
	c	÷	35									
	d	x↔y	30									
1	0	int x	64									
	1	x	36									
	2	1	01									
	3	+	33									
	4	4	04									
	5	x→()	23									
	6	b	14									
	7	IF x<y	52									
	8	4	04									
	9	2	02									
	a	CLEAR	20									
	b	1	01									
	c	+	33									
	d	3	03									
	2	0	IF x<y	52								
		1	3	03								
		2	a	13								
		3	c	16								
		4	IF x<y	52								
		5	8	10								
6		4	04									
7		d	17									
8		IF x>y	53									
9		1	01									
a		b	14									
b		↓	25									
c		STOP	41	PRIME NO.	0	0	DISPLAY					
d		ROLL ↓	31									

FROM 3-9

FROM 4-1

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
3	0	y2()	24								
	1	B	13								
	2	1	01								
	3	+	33								
	4	y2()	24								
	5	B	13								
	6	ROLL ↑	22								
	7	GO TO ()	44								
	8	1	01								
	9	C	16								
	a	1	01								
	b	+	33								
	c	5	05								
	d	IF x=y	50								
4	0	2	02								
	1	3	03								
	2	ACC +	60								
	3	d	17								
	4	IF x>y	53								
	5	7	07								
	6	4	04								
	7	C	16								
	8	IF x<y	52								
	9	8	10								
	a	4	04								
	b	5	05								
	c	x→()	23								
	d	f	15								
5	0	SET FLAG	54								
	1	RCL	61								
	2	÷	35								
	3	IF x>y	53								
	4	6	06								
	5	9	11								
	6	↓	25								
	7	↑	27								
	8	int x	64								
	9	IF x=y	50								
	a	7	07								
	b	4	04								
	c	↓	25								
	d	2	02								

FROM 2-2

FROM 1-9

FROM 8-3

FROM 6-3 & 6-8

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
6	0	ACC +	60								
	1	IF FLAG	43								
	2	5	05								
	3	1	01								
	4	ACC +	60								
	5	SET FLAG	54								
	6	GO TO (1)	44								
	7	5	05								
	8	1	01								
	9	↓	25								
	a	E	12								
	b	STOP	41	PRIME NUMBER	0	0	DISPLAY				
	c	y ₂ ()	24								
	d	B	13								
7	0	1	01								
	1	+	33								
	2	y ₂ ()	24								
	3	B	13								
	4	y ₂ ()	24								
	5	b	14								
	6	ACC +	60								
	7	2	02								
	8	IF x=y	50								
	9	+	33								
	a	+	33								
	b	-	34								
	c	y ₂ ()	40								
	d	b	14								
8	0	RCL	61								
	1	GO TO () ()	44								
	2	4	04								
	3	7	07								
	4	C	16								
	5	↑	27								
	6	d	17								
	7	↑	27								
	8	B	13								
	9	END	46	NUMBER OF PRIMES	LOWER LIMIT	UPPER LIMIT	DISPLAY				
	a										
	b										
	c										
	d										

FROM 5-5

FROM 4-6 8 5-b

FROM 4-a-8 2-6

No data entry is necessary for program operation. To run the program:

SET:

FIXED

PRESS:



0	arc ▽	72
	hyper ▽	67
	SET FLAG	54
	CLEAR	20
	3	03
	.	21
	1	01
	4	04
	1	01
	5	05
	9	11
	2	02
	6	06
	5	05
1	3	03
	6	06
	0	00
	↑	27
	π	56
	IF x=y	50
	1	01
	9	11
	STOP	41
	√x	76
	y→()	40
	E	12
	ROLL ↓	31
	√x	76
2	ROLL ↑	22
	x	36
	E	12
	CHG SIGN	32
	+	33
	ENTER EXP	26
	CHG SIGN	32
	9	11
	y	55
	IF x>y	53
	2	02
	d	17
	STOP	41
	x≠y	30

CLEAR CLEARS arc ▽, hyper ▽ & SET FLAG

TEST DIGIT AND π ENTRY

STOP FOR ERROR OF DIGIT ENTRY, π, IF x=y, ↑, or .

COMPARE (√π)² TO π

STOP FOR ERROR OF

|y|, CHG SIGN, ENTER EXP, x, ROLL ↑, ROLL ↓, √x, y→(), IF x>y, E, or +

Step	Key	Code	Display			Storage					
			x	y	z	f	e	e'	e''	b	a
3	0	IF $x < y$	52								
	1	3	03								
	2	4	04								
	3	STOP	41	STOP FOR ERROR OF $x \neq y$ or IF $x < y$							
	4	.	21								
	5	7	07								
	6	8	10								
	7	↑	27								
	8	7	07	COMPARE .78 AND 78×10^{-1} ENTRIES							
	9	8	10								
	a	ENTER EXP	26								
	b	CHG SIGN	32								
4	c	1	01								
	d	—	34								
	0	IF $x > y$	53								
	1	CLEAR x	37								
	2	ROLL ↑	22								
	3	IF $x = y$	50								
	4	STOP	41	STOP FOR ERROR OF DIGIT ENTRY, — or CLEAR x							
	5	STOP	41								
	6	IF $x < y$	52								
	7	STOP	41	STOP FOR ERROR OF IF $x < y$							
	8	STOP	41								
	9	↓	25								
5	a	IF $x > y$	53								
	b	STOP	41	STOP FOR ERROR OF ↓							
	c	STOP	41								
	d	IF FLAG	43								
	0	STOP	41	STOP: CLEAR (STEP 0-3) FAILED TO RESET FLAG OR							
	1	STOP	41	ERROR OF IF FLAG							
	2	SET FLAG	54								
	3	π	56								
	4	int x	64								
	5	↑	27								
	6	$y \neq ()$	24								
	7	E	12								
	8	↓	25								
	9	int x	64								
	a	↑	27								
	b	CLEAR x	37								
	c	E	12								
	d	IF $x = y$	50								

6	π	56
	$x \leftrightarrow y$	30
	$\div$	35
	$\downarrow$	25
	$\uparrow$	27
	$\sin x$	70
	$x \rightarrow ()$	23
	e	12
	$\text{arc } \nabla$	72
	$\sin x$	70
	$\cos x$	73
	$x \rightarrow ()$	23
	f	15
	$\text{arc } \nabla$	72
	$\cos x$	73
	$\tan x$	71
	$\text{arc } \nabla$	72
	$\tan x$	71
	$-$	34
	$ y $	55
	$x \leftrightarrow y$	30
	$\uparrow$	27
	ENTER EXP	26
	CHG SIGN	32
	9	11
	IF $x < y$	52

THESE STEPS CHECK

 $\sin x$, $\cos x$, $\tan x$, $\text{arc } \nabla$, $\sin x$, $\text{arc } \nabla$, $\cos x$,
AND $\text{arc } \nabla$, $\tan x$ FOR $x = \pi/3$ RADIANS.

STOP 41

STOP FOR ERROR OF

 SET FLAG , $\text{int } x$, $y \leftrightarrow ()$, $\text{arc } \nabla$, $\sin x$, $\cos x$,
 $\tan x$, $\div$, or f

8	3	03
	$x \leftrightarrow y$	30
	3	03
	e^x	74
	$\ln x$	65
	$-$	34
	ENTER EXP	26
	CHG SIGN	32
	9	11
	$ y $	55
	IF $x < y$	52

THESE STEPS CHECK

 e^x AND $\ln x$

STOP 41

STOP FOR ERROR OF

 e^x or $\ln x$

STOP 41

3 03

9	hyper ▾	67
	sin x	70
	arc ▾	72
	hyper ▾	67
	sin x	70
	hyper ▾	67
	cos x	73
	arc ▾	72
	hyper ▾	67
	cos x	73
	hyper ▾	67
	tan x	71
	arc ▾	72
	hyper ▾	67
a	tan x	71
	log x	75
	x↔y	30
	1	01
	0	00
	ln x	65
	x	36
	↓	25
	e ^x	74
	↑	27
	3	03
	—	34
	y	55
	ENTER EXP	26
b	CHG SIGN	32
	9	11
	x↔y	30
	IF x>y	53
	STOP	41
	STOP	41
	RCL	61
	TO POLAR	62
	ROLL ↓	31
	—	34
	y	55
	ENTER EXP	26
	CHG SIGN	32
	9	11

THESE STEPS CHECK

hyper ▾ sin x, hyper ▾ cos x, hyper ▾ tan x,
 arc ▾ hyper ▾ sin x, arc ▾ hyper ▾ cos x,
 AND arc ▾ hyper ▾ tan x FOR X = 3.

THESE STEPS CHECK

log x

STOP FOR ERROR OF

hyper ▾

or

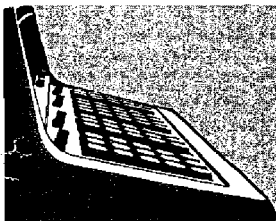
log x

IF $x < y$ 52
 STOP 41 STOP FOR ERROR OF TO POLAR or RCL
 STOP 41
 π 56
 $x \leftrightarrow y$ 30
 3 03
 $\div$ 35
 $\downarrow$ 25
 $x \leftrightarrow y$ 30
 TO RECT 66
 ACC - 63
 + 33
 $\downarrow$ 25
 int x 64
 $\uparrow$ 27
 2 02
 ACC + 60
 $x \leftrightarrow y$ 30
 RCL 61
 $\uparrow$ 27
 3 03
 PAUSE 57
 PAUSE 57 DOES NOT DISPLAY
 PAUSE 57
 GO TO () () 44
 0 00
 0 00
 END 46

1.
 2.0000
 3.

; ERROR OF ACC + , ACC - ,
 PAUSE or TO RECT

[illegible]



POUNDS ↔ DOLLARS CONVERSION

The British monetary system has primarily three divisions — pounds, shillings, and pence. The relationships among these three are:

1 pound (L) = 20 shillings (S)
1 shilling = 12 pence (P)
So: 1 pound = 240 pence

Let x = a conversion factor such that x dollars = 1 pound

To convert pounds to dollars

x · pounds	=	A
x/20 · shillings	=	B
x/240 · pence	=	C

Therefore: $A + B + C = \text{Dollars}$

To convert dollars to pounds:

$$\frac{\text{Dollars}}{x} = \bar{L} \quad (\text{decimal pounds})$$

Integer ($\bar{L}$) = L pounds

$$\text{Dollars} - L \cdot x = R_1$$

$$\frac{20 R_1}{x} = S \text{ (decimal shillings)}$$

Integer ($\bar{S}$) = S shillings

$$R_1 - \frac{S \cdot x}{20} = R_2$$

$$\frac{240 R_2}{x} = \bar{P} \text{ (decimal pence)}$$

Integer ($\bar{P}$) = P pence

Reference: None

USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address is (0) (0))

ENTER:: Conversion factor (x) → X register

PRESS: X →

PRESS: d

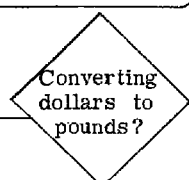
PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
[Conversion	_____	X
factor]		

(Converting
pounds to
dollars)



YES

NO

ENTER DATA: Pounds → Z
Shillings → Y
Pence → X

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

dollars	_____	Z
0	_____	Y
0	_____	X

ENTER DATA: Dollars (decimal quantity) → X

PRESS: CONTINUE

DISPLAY

pounds	_____	Z
shillings	_____	Y
pence	_____	X

: TO RESET PROBLEM

NOTE: The current conversion factor (x) is
2.4 (2.4 dollars = 1 pound)

EXAMPLES

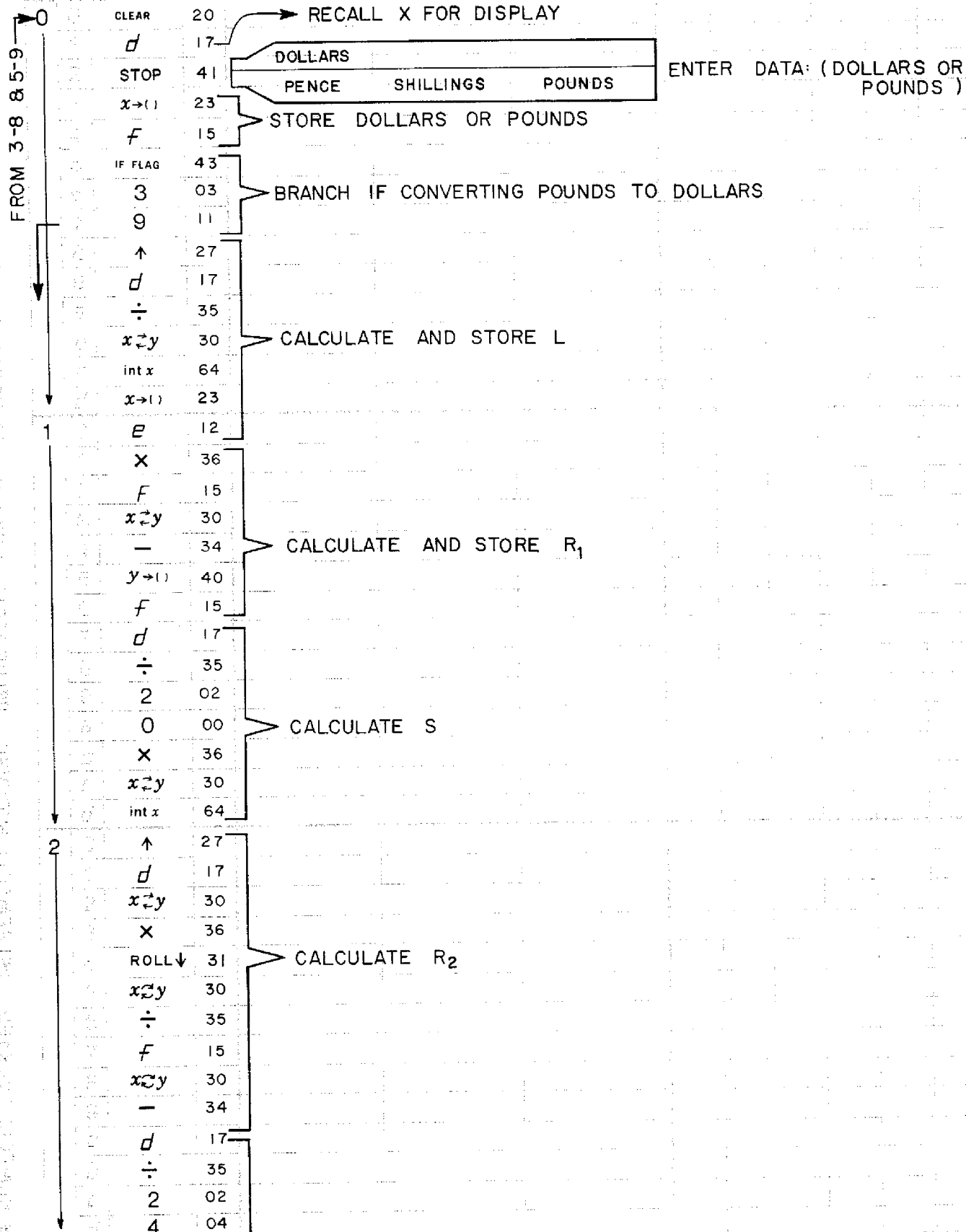
Conversion factor (x) = 2.4

(A) Convert 4 lbs., 10 shillings, 2 pence
to dollars.

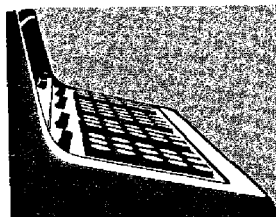
Solution: dollars = 10.82 (or 10 dollars
and 82 cents)

(B) Convert 1000 dollars to pounds.

Solution: pounds = 416 pounds, 13 shillings
and 4 pence



Line	Key	Code	Display	Storage
3	0	00		
	X	36		
	E	12		
	ROLL ↓	31		
	int x	64		
	STOP	41	PENCE SHILLING POUNDS	DISPLAY IN POUNDS FOR
	GO TO (1)	44		DOLLARS → POUNDS CONVERSION
	0	00		
	0	00		
	y → ()	40		
	E	12		
	↓	25		
	d	17		
	X	36		
4	y → ()	24		
	E	12		
	X	36		
	2	02		
	0	00		
	÷	35		
	y → ()	24		
	f	15		
	d	17		
	X	36		
	2	02		
	4	04		
	0	00		
	÷	35		
5	CLEAR X	37		
	ACC +	60		
	RCL	61		
	+	33		
	CLEAR X	37		
	↑	27		
	STOP	41	0 0 DOLLARS	DISPLAY IN DOLLARS FOR
	GO TO (1)	44		POUNDS → DOLLARS CONVERSION
	0	00		
	0	00		
	END	46		



PART NO.
09100-76003

NAVIGATIONAL COURSE CALCULATION

This program is designed for the navigator concerned with courses consisting of several adjoining legs, each leg being relatively short (500 miles or less). Although there is no theoretical limit to the leg length, only one heading from source to destination is given. Long legs should therefore be subdivided to improve calculated results.

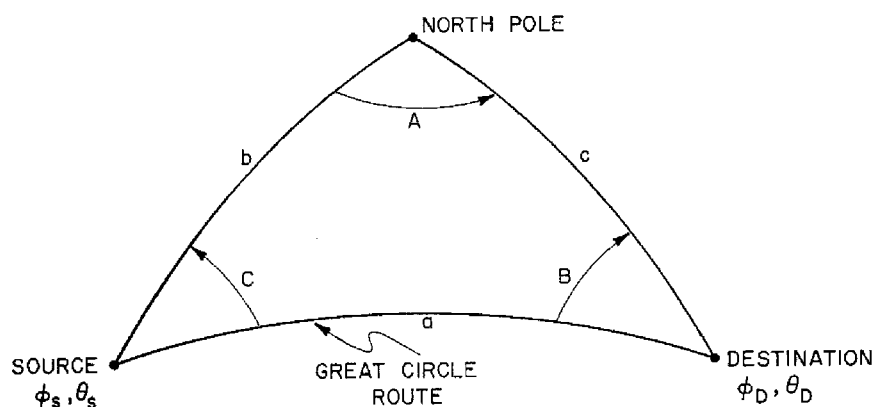
All headings lie between 0° and 360° with either 0° or 360° being a true north course; true west is 90° . Leg lengths are given in nautical miles (one nautical mile equals 6,080 feet). All legs are portions of great circles and all calculations are performed in spherical coordinates.

Referring to the diagram below, the angles A, B, and C are found from the coordinates of the source (ϕ_s, θ_s) and destination (ϕ_D, θ_D). The great circle route a is found from the equation:

$$a = \cos^{-1} [\cos b \cos c + \sin b \sin c \cos A]$$

The heading (c) is then:

$$c = \cos^{-1} \left[\frac{\cos c - \cos a \cos b}{\sin a \sin b} \right]$$



Notes:

- (1) Coordinates are entered in degrees, minutes and decimal fractions of minutes. The decimal point is used to separate degrees and minutes. Example: 30.173 means 30 degrees, 17.3 minutes. 45 degrees, 5 minutes, 30 seconds would be written $\underbrace{45}_{\text{degrees}}.\underbrace{0550}_{\text{minutes (i.e. 5.5 min.)}}$
- (2) Headings and magnetic variations are entered in decimal degrees (i.e. $17.5^\circ = 17$ degrees, 30 minutes)
- (3) Northern hemisphere latitudes and western hemisphere longitude are indicated as positive number, southern and eastern coordinates are indicated as negative numbers.
- (4) The program is operable over all coordinates except for legs starting or stopping at either the north or south pole, routes going directly over a pole, or a single leg which includes points which are diametrically opposite each other.

USER INSTRUCTIONS

The following notation is used:

T. H. = True heading
 M. H. = Magnetic heading
 L = Distance of each leg
 $\sum D$ = Total distance traversed over more than one leg
 ϕ = Latitude coordinate
 θ = Longitude coordinate
 ϕ_s, θ_s = Coordinates of the source of each leg
 ϕ_D, θ_D = Coordinates of the endpoint of each leg
 M. V. = Magnetic Variation
 N. M. = Nautical miles

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0 ——— Z
 0 ——— Y
 1 ——— X

ENTER DATA: ϕ_s (1) $\rightarrow$ Y, θ_s (1) $\rightarrow$ X

PRESS: CONTINUE

DISPLAY

0 ——— Z
 0 ——— Y
 1 ——— X

ENTER DATA: ϕ_D (n) $\rightarrow$ Y, θ_D (n) $\rightarrow$ X
 (n indicates the number of the leg under consideration)

PRESS: CONTINUE

DISPLAY

T. H. ——— Z
 L ——— Y
 2 ——— X

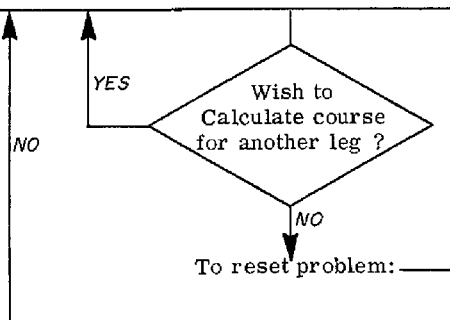
ENTER DATA: M. V. $\rightarrow$ X (do not alter the Y and Z register contents)

PRESS: CONTINUE

DISPLAY

M. H. ——— Z
 $\sum D$ ——— Y
 1 ——— X

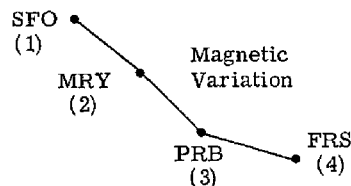
USER INSTRUCTIONS (con't)



Note: The beginning (source) coordinates and end coordinates are both entered for the first leg only; for additional legs the end coordinates of the previous leg are retained as the source coordinates of the next leg. Therefore, after the first leg only endpoint coordinates are entered as data.

EXAMPLE

A flight from San Francisco, California, to Monterey, to Paso Robles, to Fresno is to be charted.



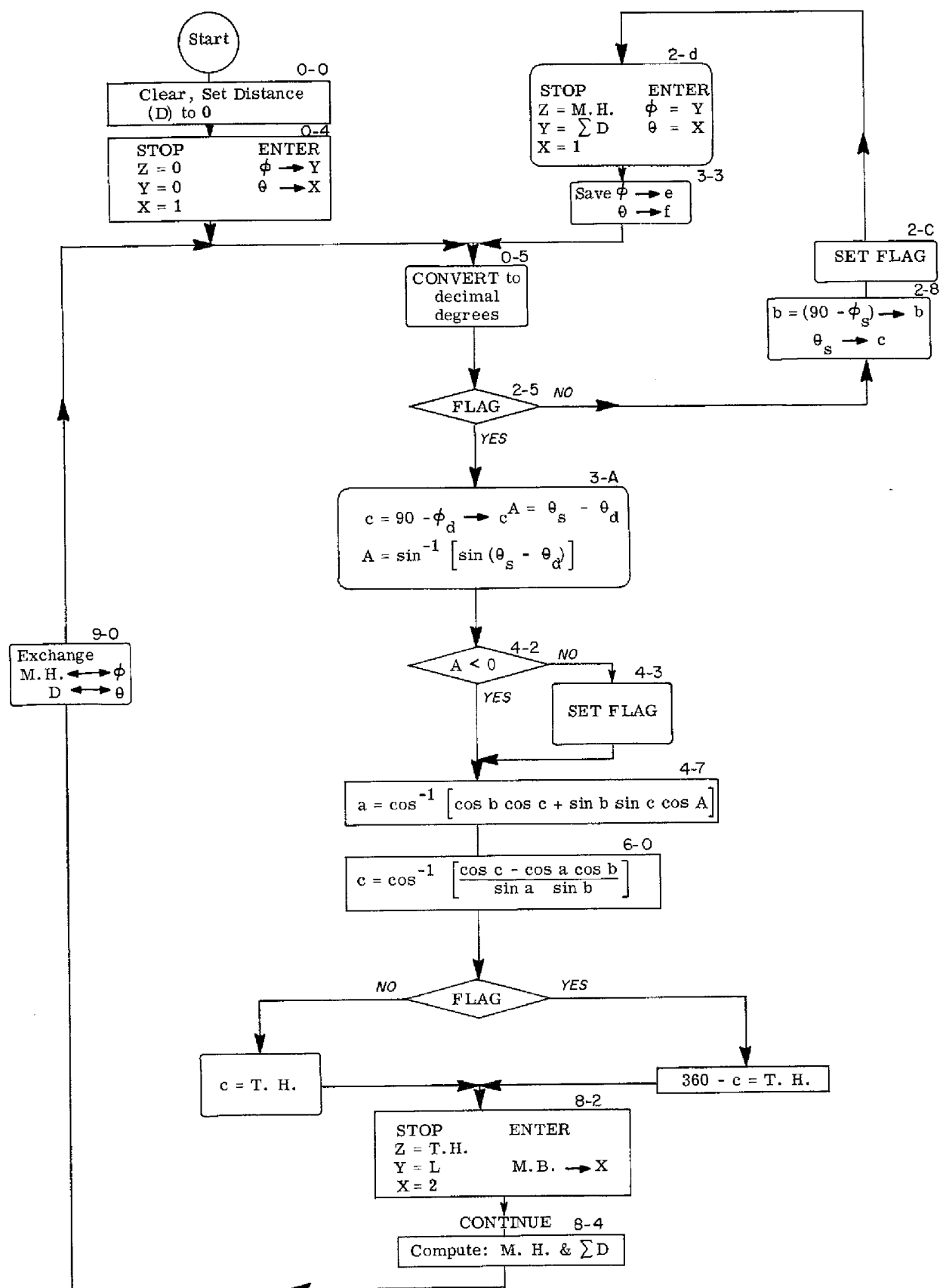
Data:

Points	ϕ	θ	M. V.
(1)	N37.37°	W122.23°	
(2)	N36.35°	W121.51°	17°E
(3)	N35.40°	W120.38°	16.5°E
(4)	N36.44°	W119.49°	16.3°E

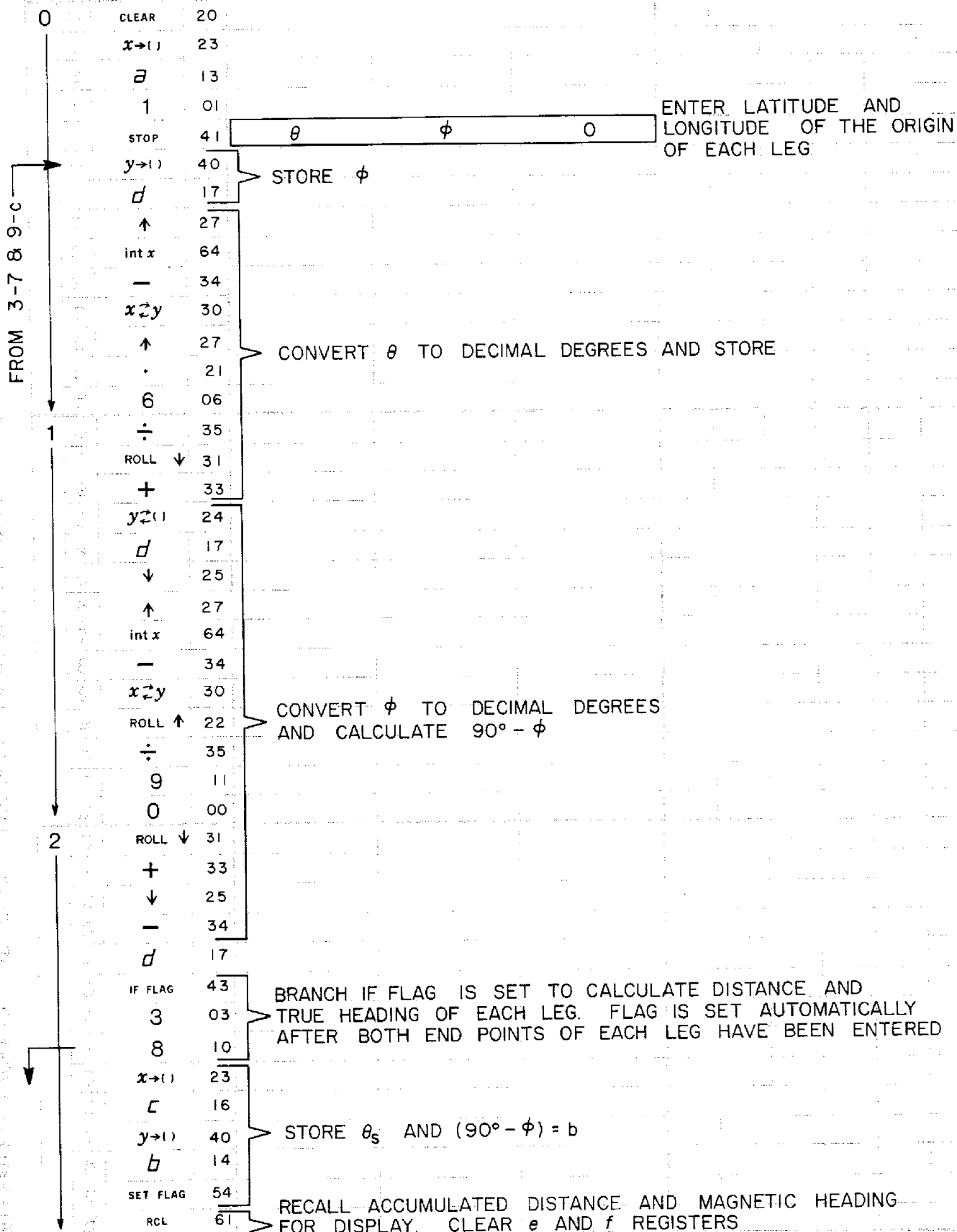
Magnetic variation will be input as a negative number due to the easterly coordinate.

Solution:

LEG	T. H.	M. H.	L(N. M.)	$\sum D(N. M.)$
First leg	157.46°	140.46°	67.05	67.05
Second leg	132.65°	116.15°	80.63	147.68
Third leg	31.47°	15.17°	75.23	222.91







Step	Key	Code	Display			Storage						
			x	y	z	f	e	d	c	b	a	
3	0	ACC -	63									
1	↑		27									
2	1		01									
3	STOP		41	θ	ϕ	0						ENTER LATITUDE AND LONGITUDE OF ENDPOINT OF EACH LEG
4	ACC +		60									STORE COORDINATES OF ENDPOINTS OF EACH LEG
5	GO TO ()		44									
6	0		00									BRANCH TO CONVERT ENDPOINT COORDINATES TO DECIMAL DEGREES
7	5		05									
8	$y \rightarrow z$		24									
9	C		16									
10	-		34									
11	0		00									
12	$x \rightarrow y$		30									
13	↑		27									
4	0	sin x	70									
1	ROLL ↑		22									
2	IF $x < y$		52									
3	SET FLAG		54									SET THE FLAG IF $\sin(\theta_s - \theta_D) > 0$
4	SET FLAG		54									
5	ROLL ↑		22									
6	COS x		73									
7	↑		27									
8	b		14									
9	sin x		70									CALCULATE DISTANCE (a) OF EACH LEG
10	X		36									
11	C		16									
12	sin x		70									
13	X		36									
5	0	C	16									
1	COS x		73									
2	↑		27									
3	b		14									
4	COS x		73									
5	X		36									
6	↓		25									
7	+		33									
8	↓		25									
9	arc v		72									
10	COS x		73									
11	$x \rightarrow ()$		23									
12	d		17									
13	COS x		73									

FROM 2-7

Step	Key	Code	Display	Remarks
6	0	↑	27	
	b		14	
2	cos x		73	
3	x		36	
4	c		16	
5	cos x		73	
6	-		34	
7	d		17	
8	sin x		70	
9	÷		35	CALCULATE TRUE HEADING (c) OF EACH LEG
0	b		14	
1	sin x		70	
2	÷		35	
3	3		03	
7	0	6	06	
1	0		00	
2	x↔y		30	
3	CHG SIGN		32	
4	arc		72	
5	cos x		73	
6	IF FLAG		43	
7	↑		27	
8	0		00	CALCULATE TRUE HEADING = (360-c) IF $\sin(\theta_s - \theta_p) < 0$; OTHERWISE (c) IS THE TRUE HEADING.
9	-		34	
0	d		17	
1	↑		27	
2	6		06	
3	0		00	
8	0	x	36	
1	2		02	
2	STOP		41	2 D T.H.
3	ROLL ↑		22	CALCULATE MAGNETIC VARIATION (M.V.) PLUS TRUE HEADING (T.H.)
4	+		33	
5	3		03	
6	6		06	
7	0		00	
8	IF x < y		52	ADD 360° IF (M.V. + T.H.) < 360°
9	+		33	RESULT: MAGNETIC HEADING (M.H.) = (M.V. + T.H.) + 360°
0	CONTINUE		47	
1	IF x < y		52	SUBTRACT 360° IF (M.V. + T.H.) > 360°
2	-		34	RESULT: M.H. = (M.V. + T.H.) - 360°
3	CONTINUE		47	

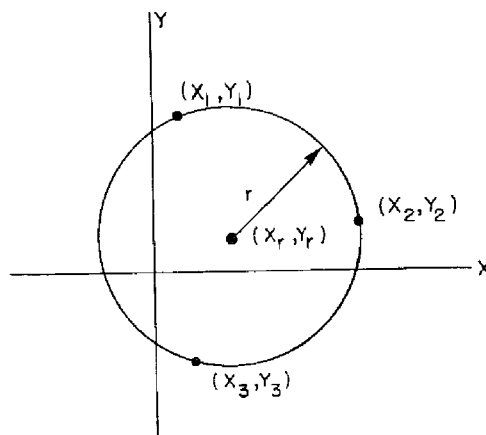
Star	Key	Code	Display			Storage						
			X	Y	Z	T	E	D	L	B	C	
9	$y \rightarrow ()$	24	STORE M.H. FOR RECALL AND FUTURE DISPLAY; RECALL ϕ_D .									
	θ	12										
	θ	13	SUM THE DISTANCES TRAVERSED BY EACH LEG (ΣD)									
	ROLL $\uparrow$	22										
	$+$	33										
	$y \rightarrow ()$	40										
	θ	13	STORE ΣD FOR RECALL AND FUTURE DISPLAY; RECALL θ_D .									
	$y \rightarrow ()$	24										
	f	15	BRANCH TO DISPLAY ΣD AND M.H. AND ENTER NEW ENDPOINT COORDINATES FOR NEXT LEG.									
	$\downarrow$	25										
	GO TO () ()	44										
	0	00										
	5	05										
	END	46										
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PART NO.
09100-76004

CIRCLE DETERMINED BY THREE POINTS

This program solves for the radius and center point of a circle which is determined by three given points in rectangular coordinates; i.e. (X_i, Y_i) , $(i = 1, 2, \text{ or } 3)$

Consider the following representative diagram:



The following equations are used to solve for X_r , Y_r and r .

$$1) (X_1 - X_r)^2 + (Y_1 - Y_r)^2 = r^2$$

$$2) (X_2 - X_r)^2 + (Y_2 - Y_r)^2 = r^2$$

$$3) (X_3 - X_r)^2 + (Y_3 - Y_r)^2 = r^2$$

Combining Equations 1 and 2:

$$4) X_2^2 - 2X_2X_r + X_r^2 + Y_2^2 - 2Y_2Y_r + Y_r^2 = X_1^2 - 2X_1X_r + X_r^2 + Y_1^2 - 2Y_1Y_r + Y_r^2$$

Rearranging:

$$5) \underbrace{(X_2 - X_1)}_A \underbrace{(X_2 + X_1)}_B + \underbrace{(Y_2 - Y_1)}_C \underbrace{(Y_2 + Y_1)}_D = 2X_r(X_2 - X_1) + 2Y_r(Y_2 - Y_1)$$

Substituting the variables indicated in equation (5) we have:

$$6) AB + CD = 2AX_r + 2CY_r$$

Rearranging:

$$7) X_r = \underbrace{\frac{AB + CD}{2A}}_{K_1} - \underbrace{\frac{C}{A}}_{N_1} Y_r$$

From equation (7) we then have:

$$8) X_r = K_1 - N_1 Y_r$$

Combining equations 1 & 3 we obtain:

$$\underbrace{(X_3^3 - X_1)}_a \underbrace{(X_3 + X_1)}_b + \underbrace{(Y_3 - Y_1)}_c \underbrace{(Y_3 + Y_1)}_d = 2 X_r (X_3 - X_1) + 2 Y_r (Y_3 - Y_1)$$

OR

$$9) X_r = \underbrace{\frac{ab + cd}{2a}}_{K_2} - \underbrace{\frac{c}{a}}_{N_2} Y_r$$

Therefore:

$$10) X_r = K_2 - N_2 Y_r$$

Combining equations (8) and (10):

$$11) Y_r = \frac{K_2 - K_1}{N_2 - N_1}$$

Equations (10) and (11) are used to solve for X_r and Y_r .

The radius (r) is found from equation (1):

$$r = \sqrt{(X_1 - X_r)^2 + (Y_1 - Y_r)^2}$$

USER INSTRUCTIONS

EXAMPLE

ENTER PROGRAM: (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
1	_____	X

ENTER DATA: $Y_1 \rightarrow Y$, $X_1 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
2	_____	X

ENTER DATA: $Y_2 \rightarrow Y$, $X_2 \rightarrow X$

PRESS: CONTINUE

DISPLAY

0	_____	Z
0	_____	Y
3	_____	X

ENTER DATA: $Y_3 \rightarrow Y$, $X_3 \rightarrow X$

PRESS: CONTINUE

DISPLAY

R	_____	Z
Y_R	_____	Y
X_R	_____	X

To enter new data points:

$$X_1 = 2$$

$$Y_1 = 1$$

$$X_2 = 2.5$$

$$Y_2 = .9$$

$$X_3 = 1$$

$$Y_3 = -3$$

$$R = 2.092$$

$$Y_R = -1.086$$

$$X_R = 1.843$$



[illegible]

			Display				Storage				
Step	Key	Code	x	y	z	f	e	d	c	b	a
3	0 ÷	35									
1	↓	25									
2	x↔y	30									
3	IF FLAG	43									
4	4	04									
5	2	02									
6	ACC -	63									
7	CLEAR x	37									
8	↑	27									
9	↑	27									
a	3	03									
b	STOP	41	X ₃ Y ₃ 0			ENTER DATA					
c	SET FLAG	54									
d	GOTO ()	44									
4	0	00									
1	a	13									
2	ACC +	60									
3	y→()	40									
4	c	16									
5	RCL	61									
6	÷	35									
7	↓	25									
8	x	36									
9	ROLL ↓	31									
a	y←()	24									
b	c	16									
c	-	34									
d	b	14									
5	0 ROLL ↑	22									
1	x→()	23									
2	d	17									
3	-	34									
4	a	13									
5	ROLL ↑	22									
6	-	34									
7	ROLL ↓	31									
8	TO POLAR	62									
9	ROLL ↓	31									
a	d	17									
b	x↔y	30									
c	END	46	X _r Y _r r			DISPLAY					

PART NO.
09100-76005

AREA OF A POLYGON

This program calculates the area of a polygon of n sides, where $n \geq 3$. The endpoint coordinates of each side of the polygon must be in rectangular form.

The equation used to calculate the area sums the area of trapezoids and is given below:

$$A = \frac{(X_1 + X_2)(Y_1 - Y_2) + (X_2 + X_3)(Y_2 - Y_3) + \dots + (X_n + X_1)(Y_n - Y_1)}{2}$$

Reference: Analytic Geometry
C. E. Love and E. D. Rainville
MacMillan Co., 5th Edition

USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address is 0 - 0)

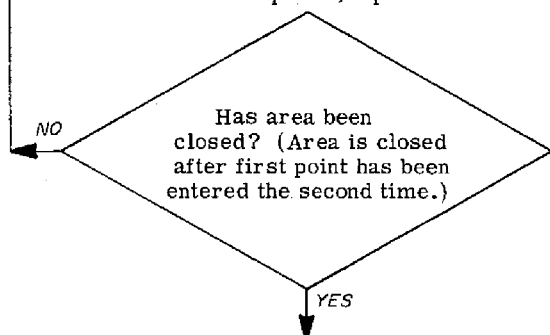
PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	——	Z
0	——	Y
i	——	X

ENTER DATA: $Y_i \rightarrow Y$, $X_i \rightarrow X$



PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0	——	Z
area	——	Y
n + 1	——	X

Note: If there are n distinct data sets, there will be n+1 entries (the first point entered twice).

EXAMPLES

Note: When traversing counterclockwise, the area will be displayed as a negative number.

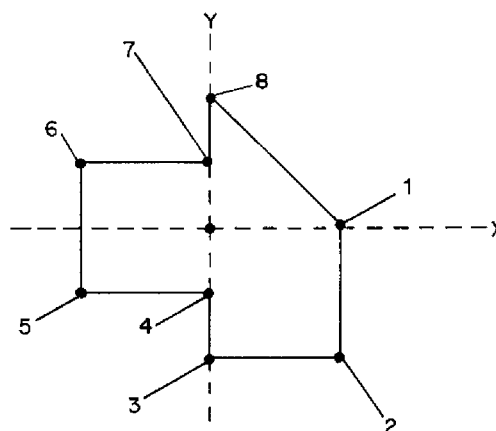
DATA:

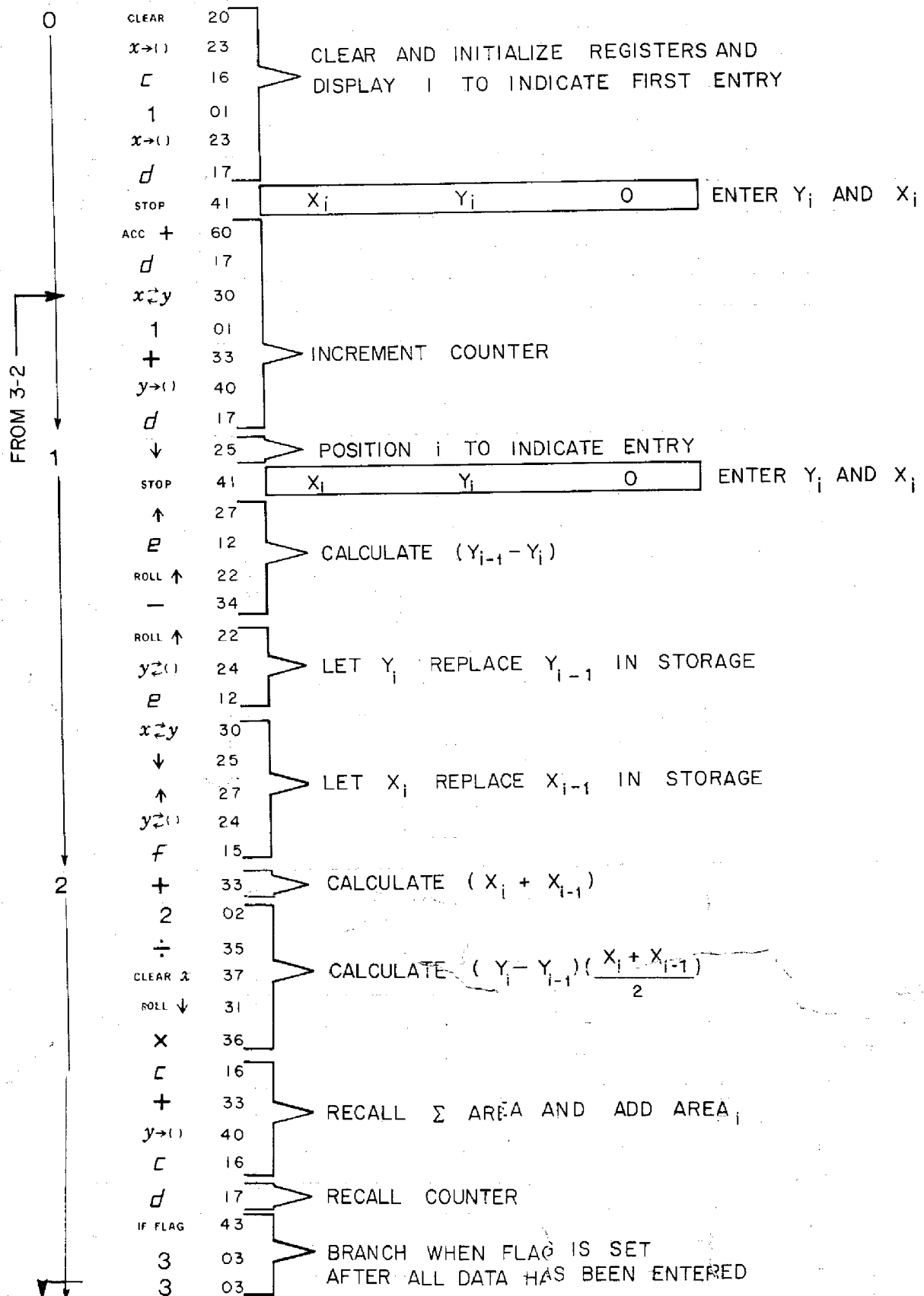
Point (i)	Coordinates (x,y)
1	1, 0
2	1, -1
3	0, -1
4	0, -.5
5	-1, -.5
6	-1, .5
7	0, .5
8	0, 1
1	1, 0

SOLUTION:

Area = 2.5

n + 1 = 9





9100A PROGRAM LIBRARY ERRATA SHEET

SEPTEMBER 1968

<u>PROGRAM</u>	<u>PRESENT</u>	<u>CHANGE TO</u>
Mathematics 09100-70008 (UI* 2nd line)	PRESS: GO TO (5) (a)	PRESS: GO TO (5) (0)
Mathematics 09100-70010 (1st equation)	$Y=Y_0 \dots (u+1) (u (u-1))$	$Y=Y_0 \dots (u+1) (u) (u-1)$
Mathematics 09100-70014 (UI 2nd line)	PRESS: GO TO (0) (0)	PRESS: GO TO (6) (0)
Surveying 09100-74004 (Prog. Steps Page 3)	Step Key 7a — c (Code 16)	Step Key 7a — e (Code 12)
Structures 09100-74205 (UI 1st line)	Omission	SET: DEGREES
Statistics 09100-70808 (Title)	$(E_i \neq E_i)$	$(E_i \neq E_j)$
Surveying 09100-74003 (UI 10th line)	ENTER DATA: Point B Nothing Y Point B Easting X	ENTER DATA: Point B Northing Y Point B Easting X

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Mathematics 09100-70008 (1st page, 4th line from bottom)	Y_0'' is obtained . . .	Y_0''' is obtained . . .
Mathematics 09100-70008 (Step page 1)	PAGE 1 Part No. 09100-70008	EXAMPLE Part No. 09100-70008

*UI stands for USER INSTRUCTIONS

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<u>PROGRAM</u>	<u>PRESENT</u>	<u>CHANGE TO</u>
Electronics 09100-71009 (Prog. Steps Page 3)	Step Key 8d b (Code 14)	Step Key 8d a (Code 13)
Electronics 09100-71009 (Prog. Steps Page 4)	Step Key 9-1 a (Code 13)	Step Key 9-1 b (Code 14)
Business 09100-73004 (UI* 5th display)	Z — P Y — R X — S	Z — P Y — R X — 5
Chemical 09100-75501 (UI 1st line 2nd column)	N_i X N =	$N_i \rightarrow$ X N = (Arrow indicates that N_i is entered into X)
Statistics 09100-70801 (Prog. Step Page 1)	25 - X Code 30	25 - X Code 36
Business 09100-73002 (UI 3rd line)	ENTER DATA: N — Z K — Y S — X	ENTER DATA: N — Z IC — Y S — X

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FEBRUARY 1969

PROGRAM	PRESENT	CHANGE TO
Statistics 09100-70811 (Prog. Steps Page 2)	Step Expression 4-7 $\ln X_i - \frac{\ln X_i}{N}$	Step Expression 4-7 $(\ln x)^2 - \frac{(\ln x)^2}{N}$
Statistics 09100-70811 (Prog. Steps Page 2)	Step Expression 5-3 $\ln Y_i - \frac{\ln Y_i}{N}$	Step Expression 5-3 $(\ln y)^2 - \frac{(\ln y)^2}{N}$
Statistics 09100-70811 (Prog. Steps Page 3)	Step Expression 6-1 $(\ln X_i - \frac{\ln X_i}{N})$ $(\ln Y_i - \frac{\ln Y_i}{N})$	Step Expression 6-1 $(\ln x \ln y) - \frac{(\ln x)(\ln y)}{N}$
Mechanics 09100-72004 (UI between 10th and 11th line)	Omission	PRESS: GO TO (0) (0) or END
Physics 09100-73204 (Example 6th line)	$p = 9.810 \text{ sec.}$	$p = 9.810 \text{ hrs.}$
Miscellaneous 09100-76002 (UI 2nd display)	→ PRESS: CONTINUE dollars — Z 0 — Y 0 — X	→ PRESS: CONTINUE dollars — Z 0 — Y 0 — X
*UI stands for USER INSTRUCTIONS		

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APRIL 1969

PROGRAM

PRESENT

CHANGE TO

Mathematics

09100-70009

Cover Page

1st Formula

$$ax^2 + bx + c = 0$$

$$aX^2 + bX + c = 0$$

Statistics

09100-70815

Cover Page

After 2nd set of formula, add following note: X must not be 0.

Electronics

09100-71002

Example Drawing

Eliminate C7 and connecting wires.

Surveying

09100-74001

Example Page

Starting coordinates - the asterisks (*) after Northing and Easting on Point A should be eliminated.

Statistics

09100-70817

Cover Page

Bottom line of formulas, second equation, reads:

$$pe_x = .6745 \bar{x}$$

Should read: $pe_{\bar{x}} = .6745 \bar{x}$

Summation sign in

$$s = \sqrt{\sum_{i=1}^n \frac{(x_i - \bar{x})^2}{n-1}}$$

09100-70817

JUNE 1969

Statistics

09100-70802

(UI first entry point)

After last entry, SET FLAG before pressing CONTINUE

$f_i \rightarrow Y, X_i \leftarrow X$

Mathematics

09100-70019

(UI for 4th degree, first equation)

$$x^4 + a_3 x^3 + a_2 x^2 + a_1 x + a_0 = 0$$

$$x^4 + a_3 x^3 + a_1 x + a_0 = 0$$

09100-70019

(UI, Exam. 1, Solution)

$$\dots (-.5 \pm .866)$$

$$\dots (-.5 \pm j.866)$$

09100-70024

(Prog. 1, Pg. 3, Register 7, Step 6)

Step 6 Key . (code 21)

Step 6 Key Roll (Code 22)

Statistics

09100-70815

ENTER: $Y_i \rightarrow X$
PRESS: $\log_x$
PRESS:
ENTER: $X_i \rightarrow Y$
PRESS: $\log_x$

ENTER: $Y_i \rightarrow X$
PRESS: $L_n X$
PRESS:
ENTER: $X_i \rightarrow X$
PRESS: $L_n X$

Mathematics

09100-70018

-- for $9 \leq t \leq$

-- for $0 \leq t \leq$

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