WANG

MATHEMATICS GENERAL PROGRAM LIBRARY GLBR 22

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SYSTEM 2200

2200 General Library

Mathematics

GLBR 22

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INTRODUCTION

Programs of varying complexity and from different fields have been included in this library to provide a sample of the usefulness and versatility of the 2200 series calculators. Programs have been selected bearing in mind their use and possible application. Each one contains a set of instructions which is easy to follow; at least one example per program has been given to facilitate checking and enhance comprehension.

In loading the program tapes advantage may be taken of SKIP and BACKSPACE features. These two features and their use are explained on a following page.

Programs are designed to display all output on the CRT. However, they may be adapted for printing the output on either the 2201 (typewriter) or the 2221 (Hi-Speed Printer).

Note: All operating instructions assume you are at the beginning of the block you desire.

If you wish to load programs that are separated by other blocks, you may use one of two methods.

(1) LOAD each block until you reach the desired block. This would require the repetition of 4 keystrokes for each block between your current position and your desired position. The 4 keystrokes would be:

[CLEAR] , [CR/LF] , [LOAD] , [CR/LF] .

This method would require you to REWIND the tape if you desire a block which you have passed.

(2) Using the SKIP feature will allow you to go from one block to another with less work, and the BACKSPACE feature will allow you to "back-up" to a block that you have passed.

a) SKIP - Subtract from the Block # corresponding to where you wish to be, the Block # corresponding to your current location then subtract 1. This is the # of files to skip to place you at the beginning of the desired block.

For Example,

The last block loaded was 4; you wish to load block 12.

12 - 4 - 1 = 7

Key S, K, I, P, 7, F, [CR/LF]

b) BACKSPACE - Subtract from the block # corresponding to your present location, the block # corresponding to your desired location then add 1. This is the # of files to backspace to place you at the beginning of the desired block.

For Example,

The last block loaded was 12; you wish to load block 4,

12 - 4 + 1 = 9

Key B, A, C, K, S, P, A, C, E, 9, F, [CR/LF]

To change output device from 2216 (CRT display) to 2201 (typewriter) or 2221 (Hi-Speed Printer) the following procedure is used:

1. Choose what output is to be displayed or typed.

2. Insert a statement with the following information:
   For CRT display
   Statement # SELECT PRINT 005
   For Typewriter (2201)
   Statement # SELECT PRINT 211
   For Hi-Speed Printer (2221)
   Statement # SELECT PRINT 215

It may be advisable to change print to the CRT at the end of the program.

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Tape I

ROOTS

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2	ROOTS OF A POLYNOMIAL
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4	REAL ROOTS OF A POLYNOMIAL

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WANG 2200 SERIES PROGRAM

ROOTS OF A QUADRATIC

TITLE

PS.02-2200.01A-00FI-1-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates the real and imaginary roots of a quadratic equation of the form:

$$A1\ X^2 + A2X + A3 = 0$$

BLOCK	SAVE "NAME"	BYTES REQUIRED
1		496

Printed in U.S.A.

PROGRAM DESCRIPTION

Let the quadratic equation be in the form of:

$$A_1 X^2 + A_2 X + A_3 = 0$$

Then the Quadratic Formula for finding the roots of the equation becomes:

$$X = \frac{-A_2 \pm \sqrt{A_2^2 - 4A_1A_3}}{2A_1}$$

The Discriminant is calculated and its value compared against zero. If the discriminant is less than zero then there are imaginary roots, otherwise only real roots exist.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will be on the left hand side of the operating instructions and what is displayed or typed will be on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find the roots of

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

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   ROOTS OF QUADRATIC

   A1, A2, A3
   ?

4. Key A_1 , A_2 , A_3 [CR/LF]

   4. Key 1 , 2 , 3 [CR/LF]

5. Read Answers

The output consists of the real + imaginary parts of the roots. For example, X1 REAL is the real part of root 1 and X1 IMAG is the imaginary part of root 1, if there is an imaginary part.

X1 REAL = -1 X2 REAL = -1
X1 IMAG = 1.4142135624 X2 IMAG = -1.4142135624

6. INSTRUCTION

   MORE INPUT (1 = YES, 0 = NO)

7. If you wish to rerun the program with different values, Key 1 [CR/LF]
   Program will go to Step 3.

   If you do not wish to rerun the program,
   Key 0 [CR/LF] . Program halts.

   7. Key 0 [CR/LF]

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WANG 2200 SERIES PROGRAM

ROOTS OF POLYNOMIALS
TITLE

PS.02-2200.01A-00FI-2-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Finds the real and complex roots of an nth-degree polynomial with real coefficients by Bairstow's algorithm.

BLOCK	SAVE "NAME"	BYTES REQUIRED
2		2531

Printed in U.S.A.

PROGRAM DESCRIPTION

The polynomial must be of the following type:

$$P(X) = A_0 + A_1X + \ldots + A_NX^N$$

NOTE

When the degree of the polynomial is odd and greater than or equal to 3, an extraneous root of zero or near zero will be generated.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS	EXAMPLE
	$P(X) = 24 - 14X - 13X^2 + 2X^3 + X^4$
1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]	
2. Key [RUN] [CR/LF]	
3. INSTRUCTION	DEGREE OF POLYNOMIAL ? ?
4. Key Deg. of Polynomial [CR/LF]	4. Key 4, [CR/LF]
5. INSTRUCTION	ENTER COEFF.: A0, A1, ... AN 1/LINE

Enter the coefficients of the polynomial, one coefficient per line, starting with A_0 and continuing to A_N.

6. Key A_0 [CR/LF]	6. Key 2 4 [CR/LF]
Key A_1 [CR/LF]	Key - 1 4 [CR/LF]
.	Key - 1 3 [CR/LF]
.	Key 2 [CR/LF]
.	Key 1 [CR/LF]
Key A_N [CR/LF]	
7. INSTRUCTION	ROOTS:

When the degree of the polynomial is odd and ≥ 3, an extraneous root of zero or near zero will be generated.

8. Read Answers	8. .9999999998 -1.9999999998 3.0000000001 -4.0000000001

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WANG 2200 SERIES PROGRAM

HALF-INTERVAL SEARCH FOR ROOTS

TITLE

PS.02-2200.01A-00FI-3-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Solves for a root of a function, f(x), by the half-interval search method.

BLOCK	SAVE "NAME"	BYTES REQUIRED
3		652

Printed in U.S.A.

PROGRAM DESCRIPTION

Given a function, f(x), and an interval, this program searches the interval for 2 points with opposite signs (by choosing up to 1000 points at random in the interval). If no change of sign is found, the system prints "NO CHANGE OF SIGN FOUND" and discontinues the search for a root in this interval. If 2 points with opposite signs are found, a root between is calculated by the half-interval search method.

It is possible for errors to occur due to the following reasons:

1. The curve may have no root but the lowest point may be so close to zero that a "crossing point" results from round-off error.

2. There may be two roots so close together that we never find points with opposite signs since we compute numbers only to 8 places.

A function must be entered by the user in line 1 as follows:

```
1 DEFFNC(X) = f(x)
```

For example, the function $f(x) = -3X^5 + X^3 + 1$ is entered as follows:

```
1 DEFFN C(X) = -3*X↑5 + X↑3+1
```

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

$F(x) = X^4 + 2X^3 - 13X^2 - 14X + 24$

Interval -3 to -1.5

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

The function you wish to find the roots of must be entered into the program. This is done by using the DEFFN verb, the function is to be referred to as C(X).

2. Key 1 [DEFFN] C (X) =

2. Key 1 [DEFFN] C (X)
   = X ↑ 4 + 2 * X ↑ 3
   - 1 3 * X ↑ 2 - 1 4 * X
   + 2 4 [CR/LF]

3. Key [RUN] [CR/LF]

4. INSTRUCTION

INTERVAL (LOWER LIMIT, UPPER LIMIT)?
?

5. Key Lower Limit of Interval ,
   Upper Limit of Interval [CR/LF]

5. Key - 3 , - 1 . 5 [CR/LF]

6. Read Answer

ONE ROOT AT -2.000003814699

Program will go to Step 4. If you desire a new root, key a new lower and upper Interval Value. If not, go to next program of interest.

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WANG 2200 SERIES PROGRAM

REAL ROOTS OF A POLYNOMIAL

TITLE

PS.02-2200.01A-00FI-4-0 — 6/1/73

NUMBER — DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Computes, by the Newton-Rhapson method, roots of a polynomial with real coefficients of degree N (N less than 100).

BLOCK	SAVE "NAME"	BYTES REQUIRED
4		1556

Printed in U.S.A.

PROGRAM DESCRIPTION

Computes, by the Newton-Raphson method, roots of a polynomial with real coefficients of degree N ($N < 100$) given estimated values of the roots.

It is assumed that the derivative of the polynomial $\neq 0$ between the root and the estimated value of the root. The polynomial must be in the following form:

$$A_1 * X^N + A_2 * X^{N-1} + \ldots + A_N * X + A_{N+1} = 0$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the OPERATING INSTRUCTIONS and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

$X^3 - 2X^2 - 5X + 6 = 0$

Estimate of Root = 0

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   INPUT DEGREE OF POLYNOMIAL, N
   ?

4. Key N [CR/LF]

4. Key 3 [CR/LF]

5. INSTRUCTION

   INPUT COEFFICIENTS A(1), ...A(N+1)
   4/LINE
   ?

The coefficients are inputed 4 at a time. If necessary, the last line must be completed with zeros to make a set of 4. For example:

$3X^4 + 4X^3 - 2X^2 + X + 7 = 0$

is inputed as follows:

: 3, 4, -2, 1
: 7, 0, 0, 0

6. Key A_1 , A_2 , A_3 , A_4 [CR/LF]

6. Key 1 , - 2 , - 5 , 6 [CR/LF]

Continue, as above, until all coefficients have been inputed.

7. INSTRUCTION

   INPUT YOUR ESTIMATE OF ROOT
   ?

8. Key ESTIMATE [CR/LF]

8. Key 0 [CR/LF]

9. Read Answer

   ROOT IS 1.000000000001

10. INSTRUCTION

ANOTHER ROOT (1 = YES, 0 = NO)

11. If you wish another root

Key 1 CR/LF

If you do not wish another root

Key 0 CR/LF

11. Key 0 CR/LF

If you had desired another root, the program would have gone back to Step 7.

INTEGRATION AND DIFFERENTIATION

BLOCK NO.	PROGRAM TITLE
5	SIMPSON'S RULE
6	NUMERICAL INTEGRATION (ROMBERG'S METHOD)
7	RUNGE-KUTTA
8	GAUSSIAN QUADRATURE (20-point)
9	DERIVATIVE (DIFFERENCE QUOTIENTS)

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WANG 2200 SERIES PROGRAM

SIMPSON'S RULE

TITLE

PS.02-2200.01A-00FI-5-0 6/1/73

NUMBER **DATE**

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Uses Simpson's rule to calculate the definite integral of a known function or of a continuous function for which we have determined emperically a number of equally spaced values, yet do not know its general formula.

BLOCK	SAVE "NAME"	BYTES REQUIRED
5		508

Printed in U.S.A.

PROGRAM DESCRIPTION

Simpson's Rule (f((x)) known)

$$\int_A^B f(x)\,dX \approx \frac{D}{3}\,(f((A)) + 4f(A+\Delta X) + 2f\,(A + 2\Delta X) + \ldots + f((B))\,)$$

Simpson's Rule (f((x)) is <u>not</u> known)

$$\int_A^B f(x)\,dX \approx \frac{D}{3}\,(Y_0 + 4Y_1 + 2Y_2 + 4Y_3 + 2Y_4 + \ldots + 2Y_{n-2} + 4Y_{n-1} + Y_N)$$

Where A = lower limit of integration

B = upper limit of integration

D = increment in X; D must divide B-A an even number of times.

This program utilizes the DATA and DEFFN statements.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

f(x) is known

OPERATING INSTRUCTIONS

EXAMPLE

$f(x) = X^3 + 2X^2 + 3X + 4$

A = 1
B = 2
D = .1

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

a) The DATA statement is to be set-up as follows:

201 DATA 1, A, B, D

where A, B and D are known values

b) The DEFFN statement is to be set-up as follows:

202 DEFFN C(X) = f(x)

2. Key 2 0 1 [DATA] 1 , A , B , D [CR/LF]

3. Key 2 0 2 [DEFFN] C (X) = f(x) [CR/LF]

4. Key [RUN] [CR/LF]

5. Read Answer

2. Key 2 0 1 [DATA] 1 , 1 , 2 , . 1 [CR/LF]

3. Key 2 0 2 [DEFFN] C (X) = X ▲ 3 + 2 * X ▲ 2 + 3 * X + 4 [CR/LF]

INTEGRAL = 16.91666666666

f(x) is not known

OPERATING INSTRUCTIONS

EXAMPLE

A = 1, B = 2, D = .1
$Y_0 = 1$, $Y_1 = 1.331$, $Y_2 = 1.728$
$Y_3 = 2.197$, $Y_4 = 2.744$, $Y_5 = 3.375$
$Y_6 = 4.096$, $Y_7 = 4.913$, $Y_8 = 5.832$
$Y_9 = 6.859$, $Y_{10} = 8$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

This part of the program uses DATA and DEFFN statements. The DEFFN is not executed, however, it is required so that the program will compile. The statements are to be set-up as:

```
201   DEFFNC(X) = 1
202   DATA 0, A, B, D
203   DATA Y0, Y1, Y2, . . ., YN
```

2. Key 2 0 1 [DEFFN] C (X) = 1
   [CR/LF]

3. Key 2 0 2 [DATA] 0 , A , B
   , D [CR/LF]

   Key 2 0 3 [DATA] Y_0 , Y_1 ,
   Y_2 , . . . Y_{N-1} , Y_N [CR/LF]

4. Key [RUN] [CR/LF]

5. Read

3. Key 2 0 2 [DATA] 0 , 1 , 2
   , . 1 [CR/LF]

   Key 2 0 3 [DATA] 1 , 1 . 3 3
   1 , . . . 6 . 8 5 9 , 8 [CR/LF]

INTEGRAL = 3.75

WANG 2200 SERIES PROGRAM

NUMERICAL INTEGRATION (ROMBERG'S METHOD)
TITLE

PS.02-2200.01A-00FI-6-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the definite integral of a function to 4 significant digits using the trapezoidal rule with Romberg's extrapolation method.

BLOCK	SAVE "NAME"	BYTES REQUIRED
6		1015

Printed in U.S.A.

PROGRAM DESCRIPTION

The integral $\int_A^B f(x)\,dX$ can be approximated numerically by using the trapezoidal rule.

However, the trapezoidal rule alone is a very time consuming process. In order to obtain faster results, Romberg's improved formula is used.

Arrange the approximated areas in two-dimensional array as follows:

A (0,0)

A (1,0) A (1,1)

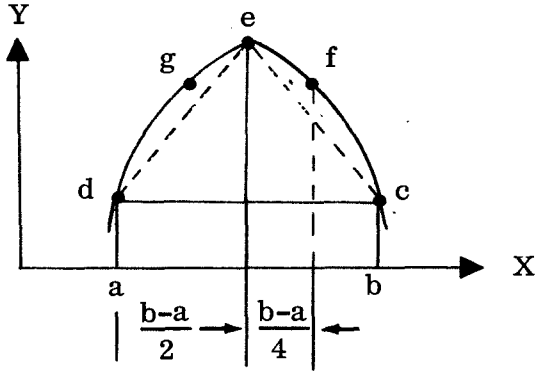
A (2,0) A (2,1) A (2,2)

M A (3,0) A (3,1) A (3,2) A (3,3)

↓

.
.
.

N →



A (0,0) = AREA (abcd)

A (1,0) = AREA (abced)

A (2,0) = AREA (abcfegd)

If $h \equiv b - a$

T_h [f(x) ≡ Trapezoidal Rule operator on f(x) for interval "h"]

For N = 0

$A(0,0) = T_h [f(x)]$

$A(1,0) = T_{\frac{h}{2}} [f(x)]$

$A(2,0) = T_{\frac{h}{4}} [f(x)]$

.
.
.

For N > 0, the Romberg's improved formula will be used.

PROGRAM DESCRIPTION (Cont)

$$A_{M,N} = \frac{4^N A_{M,N-1} - A_{M-1,N-1}}{4^N - 1} \qquad \begin{array}{l} N = M,\ M+1,\ M+2,\ \ldots \\ M = 1,\ 2,\ 3,\ 4,\ \ldots \end{array}$$

e.g.

$$A_{1,1} = \frac{4\ A(1,0) - A(0,0)}{4-1}$$

If the program cannot compute the integral to 4 significant digits, the closest approximation is printed out. The user may obtain a better approximation by integrating over subintervals and summing the results.

The function to be integrated, f(x), must be defined in the program in statement no. 1.

NOTE

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OPERATING INSTRUCTIONS

EXAMPLE

$$f(x) = X^5 + X^3 + X - 5$$

Find $\int_1^2 f(x)\ dx$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter the function to be integrated, f(x), on line 1 of the program as follows:

1 DEFFN C(X) = f(x)

For example, $f(x) = X^2 \text{ Cos}(X)$ is entered as

1 DEFFN C(X) = X▲ 2 * Cos(X)

2. Key 1 [DEFFN] C (X) = f(x)

2. Key 1 [DEFFN] C (X) = X ▲ 5 + X ▲ 3 + X - 5 [CR/LF]

3. Key [RUN] [CR/LF]

4. INSTRUCTION

INPUT "LOWER LIMIT, UPPER LIMIT" (TO END PROGRAM INPUT EQUAL LIMITS)

?

5. Key A , B [CR/LF]

5. Key 1 , 2 [CR/LF]

6. Read Answer

INTEGRAL = 10.75000000008

Program will go back to Step 4.

WANG 2200 SERIES PROGRAM

RUNGE-KUTTA

TITLE

PS.02-2200.01A-00FI-7-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Solves a system of N ($N \leq 10$) first-order differential equations with initial conditions using a Runge-Kutta 4th order method with Runge's coefficients.

BLOCK	SAVE "NAME"	BYTES REQUIRED
7		1425

PROGRAM DESCRIPTION

Let $X^1 = \frac{dX}{dt}$, given the system of equations

$$X_1^1 = F_1 (T, X_1, X_2, \ldots, X_N)$$

$$X_2^1 = F_2 (T, X_1, X_2, \ldots, X_N)$$

$$\vdots$$

$$X_N^1 = F_N (T, X_1, X_2, \ldots, X_N)$$

with initial conditions T_0, $X_1 (T_0)$, $X_2 (T_0)$, . . ., $X_N (T_0)$.

This program will solve the above system of 1st-order differential equations using a Runge-Kutta 4th order method with Runge's coefficients.

OPERATING INSTRUCTIONS

EXAMPLE

$F_1(X) = X(2)$

$F_2(X) = -.1\ X(2) - 3.2^2\ X(1)$

$T_0 = 0 \qquad T_L = 1$

$X_1(0) = 1$

$D = .2$

$X_2(0) = 0$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Denote X_1^1 by F(1) and enter the system of equations in lines 10 → 98 as follows:

10 F(1) = F_1 (which is an expression in T, X((1)), . . ., X((N)))

11 F(2) = F_2

.
.
.

F(N) = F_N

2. Key 1 0 F (1) = F_1 [CR/LF]

   Key 1 1 F (2) = F_2 [CR/LF]

   Continue until all equations have been entered.

2. Key 1 0 F (1) = X (2) [CR/LF]

   Key 1 1 F (2) = - . 1 * X (2) - 3 . 2 ▲ 2 * X (1) [CR/LF]

OPERATING INSTRUCTIONS (Cont)

The number of equations (N), the initial conditions ($X_1((T_0))$, $X_2((T_0))$, . . ., $X_N((T_0))$), the step size (D), and the terminal value for T (T_L) are entered in data statements 100-200 as follows:

100 DATA N

101 DATA T_0, $X_1(T_0)$, $X_2(T_0)$, . . .

102 DATA . . . $X_{N-1}(T_0)$, $X_N(T_0)$

103 DATA D, T_L

3. Key 1 0 0 [DATA] N [CR/LF]

   Key 1 0 1 [DATA] T_0 , $X_1(T_0)$, . . . , $X_N(T_0)$ [CR/LF]

   Key 1 0 3 [DATA] D , T_L [CR/LF]

4. Key [RUN] [CR/LF]

5. Read Answers

3. Key 1 0 0 [DATA] 2 [CR/LF]

   Key 1 0 1 [DATA] 0 , 1 , 0 [CR/LF]

   Key 1 0 3 [DATA] . 2 , 1 [CR/LF]

T_0	X 1	X 2
	1	0
.2	.803549013334	-1.889243818666
.4	.2971322076144	-3.00134413195
.6	-.3149770953372	-2.917708563705
.8	-.7914064549472	-1.695622615095
1	-.9487702573037	.163927511844

WANG 2200 SERIES PROGRAM

GAUSSIAN QUADRATURE

TITLE

PS. 02-2200. 01A-00FI-8-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Approximates the definite integral of a function over a given integral.

BLOCK	SAVE "NAME"	BYTES REQUIRED
8		936

PROGRAM DESCRIPTION

Approximates the definite integral of a function over a given interval by dividing the interval into a specified number of equal subintervals and summing the results of 20-point Gaussian quadratures done over each subinterval.

$$\int_A^B f(x)dx = \sum_{i=1}^{N} W_I f(x_I)$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

$f(x) = X^2 \text{ Cos}(X)$

Find $\int_0^3 f(x)\, dX$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter the function to be integrated, f(x), in statement 1 of the program as follows:

1 DEFFN C(X) = f(x)

For example, $f(x) = X^5 + X^3 + X - 5$ is entered as:

1 DEFFN C(X) = X ▲ 5 + X ▲ 3 + X - 5

2. Key 1 [DEFFN] C (X) = f(x)

2. Key 1 [DEFFN] C (X) = X ▲ 2 * Cos (X) [CR/LF]

3. Key [RUN] [CR/LF]

4. INSTRUCTION

ENTER LOWER LIMIT OF INTEGRATION, UPPER LIMIT OF INTEGRATION
?

5. Key Lower Limit , Upper Limit [CR/LF]

5. Key 0 , 3 [CR/LF]

6. INSTRUCTION

ENTER NO. OF SUBINTERVALS

7. Key # of Subintervals [CR/LF]

7. Key 1 [CR/LF]

8. Read Answer

INTEGRAL = -4.9521149

9. INSTRUCTION

CHANGE NUMBER OF SUBINTERVALS
("1" - - YES, "0" - - NO)

OPERATING INSTRUCTIONS (Cont)

10. If you wish to change # of subintervals, Key 1 [CR/LF]

    Program will go to Step 6.

    If you do not wish to change # of subintervals, Key 0 [CR/LF] .

    Go to step 11.

10. Key 0 [CR/LF]

11. INSTRUCTION

    NEW INTEGRATION LIMITS?

    ("1" -- YES, "0" -- NO)

12. If you wish new integration limits, Key 1 [CR/LF]

    Program will go to Step 4.

    If you do not wish new integration limits, Key 0 [CR/LF]

    Program will end.

12. Key 0 [CR/LF]

WANG 2200 SERIES PROGRAM

DERIVATIVE

TITLE

PS.02-2200.01A-00FI-9-0 — 6/1/73

NUMBER — **DATE**

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Gives a good approximation to the derivative of the function, f(x), at the point X = a.

BLOCK	SAVE "NAME"	BYTES REQUIRED
9		436

Printed in U.S.A.

PROGRAM DESCRIPTION

Gives a good approximation to the derivative of the function, f(x), at the point x = a, and shows successive difference quotients for values of X approaching a from the right.

$$\text{Difference Quotient} = \frac{F(x) - F(a)}{x-a}$$

where a = point of interest

$x = a + .5 \uparrow N$

N = loop values of 1 to 10

Derivative at a = 2* Dif. Quot at 10th loop - Dif Quot at 9th

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

$f(x) = X^5 + X^3 + X-5$

Find $\frac{d(f((x)))}{dX}$ at X = 1

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter the function, f(x), in line 1 of the program as follows:

1 DEFFN C(X) = f(x)

For example, the function f(x) = Sin(X) + Cos (2X) would be entered as follows:

1 DEFFN C(X) = Sin(X) + Cos(2*X).

2. Key 1 [DEFFN] C (X) = f(x)

2. Key 1 [DEFFN] C (X) = X ↑ 5 + X ↑ 3 + X - 5 [CR/LF]

3. Key [RUN] [CR/LF]

4. INSTRUCTION

ENTER VALUE OF X (TO END PROGRAM INPUT 99999)
?

5. Key X [CR/LF]

5. Key 1 [CR/LF]

6. Read Difference Table and Derivative at X

X	DIFFERENCE QUOTIENT
1.5	18.9375
1.25	13.01953125
1.125	10.8068847656
1.0625	9.856704712
1.0313	9.4171457312
1.0156	9.2058296832
1.0078	9.1022362752
1.0039	9.0509494016
1.002	9.0254326272
1.001	9.0127058944

DERIVATIVE AT X - 1 IS: 8.9999791616

7. INSTRUCTION — ENTER VALUE OF X

8. Program goes to Step 5.

LINEAR ALGEBRA

BLOCK NO.	PROGRAM TITLE
10	MATRIX INVERSION (GAUSS-JORDAN ELIMINATION METHOD)
11	MATRIX INVERSION (GAUSS-JORDAN DONE IN PLACE)
12	EIGENVALUE AND EIGENVECTOR
13	VECTOR OPERATIONS
14	VECTOR ANALYSIS
15	SOLUTION OF SIMULTANEOUS EQUATIONS (GAUSS-JORDAN)
16	MATRIX ADDITION, SUBTRACTION, AND SCALAR MULTIPLICATION
17	MATRIX MULTIPLICATION
18	SOLUTION OF SIMULTANEOUS EQUATIONS (GAUSS-SEIDEL)
19	LINEAR PROGRAMMING
20	COMPLEX DETERMINANT

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WANG 2200 SERIES PROGRAM

MATRIX INVERSION (GAUSS-JORDAN ELIMINATION METHOD)
TITLE

PS.02-2200.01A-00FI-10-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Inverts an N x N matrix with real elements by the Gauss-Jordan elimination method.

BLOCK	SAVE "NAME"	BYTES REQUIRED
10		1374

Printed in U.S.A.

PROGRAM DESCRIPTION

Inverts an N x N matrix by the Gauss-Jordan Elimination method.

This program is written for a value of $N \leq 6$.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Invert

$$\begin{pmatrix} 3 & -6 & 1 & 0 \\ 3 & 0 & 0 & 1 \\ 2 & -1 & 1 & 0 \\ 3 & -1 & 1 & 0 \end{pmatrix}$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

4. Key N [CR/LF]

5. INSTRUCTION

INPUT N
?

4. Key 4 [CR/LF]

INPUT MATRIX
?

The matrix is entered row by row. The end of a row is signaled by a CR/LF immediately following a ? . For example, the row 1, 2, 3, 4, 5, will be entered as follows:

1, 2, 3, 4, 5, CR/LF

? CR/LF

Elements of each row are separated by comma.

6. Key Row 1 [CR/LF] [CR/LF]

Key Row 2 [CR/LF] [CR/LF]

.
.
.

Key Row N [CR/LF] [CR/LF]

6. Key 3 , - 6 , 1 , 0
[CR/LF] , [CR/LF]

Key 3 , 0 , 0 , 1
[CR/LF] , [CR/LF]

Key 2 , - 1 , 1 , 0
[CR/LF] , [CR/LF]

Key 3 , - 1 , 1 , 0
[CR/LF] , [CR/LF]

OPERATING INSTRUCTIONS (Cont)

7. Read A^{-1}

8.00000000E-14	0	-1.000000000002	1.000000000001
-.1999999999999	0	-8.00000000E-13	.2000000000005
-.1999999999999	0	3.000000000001	-1.8
-6.00000000E-13	1	3.000000000005	-3.000000000002

WANG 2200 SERIES PROGRAM

MATRIX INVERSION (GAUSS-JORDAN DONE IN PLACE)
TITLE

PS.02-2200.01A-00FI-11-0	6/1/73
NUMBER	DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Inverts a real N x N matrix by a modified Gauss-Jordan elimination method done in place.

BLOCK	SAVE "NAME"	BYTES REQUIRED
11		1792

Printed in U.S.A.

PROGRAM DESCRIPTION

Inverts a real N x N matrix by a modified Gauss-Jordan elimination method done in place.

The value of N must be ≤ 10, for program as written.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Invert

$$\begin{pmatrix} 1 & 10 & 1 \\ 2 & 0 & 1 \\ 3 & 3 & 2 \end{pmatrix}$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION — ENTER N
4. Key N [CR/LF] — 4. Key 3 [CR/LF]
5. INSTRUCTION — ENTER MATRIX

> Enter the matrix row by row. The end of a row is signaled by a [CR/LF] immediately following a ? . Elements separated by commas.

6. Key Row 1 [CR/LF] [CR/LF] — 6. Key 1 , 1 0 , 1 [CR/LF] [CR/LF]
   Key Row 2 [CR/LF] [CR/LF] — Key 2 , 0 , 1 [CR/LF] [CR/LF]
   .
   .
   .
   Key Row N [CR/LF] [CR/LF] — Key 3 , 3 , 2 [CR/LF] [CR/LF]
7. Read A^{-1}

.4285714285715	2.428571428572	-1.428571428572
.1428571428571	.1428571428572	-.1428571428572
-.8571428571429	-3.857142857143	2.857142857143

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WANG 2200 SERIES PROGRAM

EIGENVALUE & EIGENVECTOR

TITLE

PS.02-2200.01A-00FI-12-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates the eigenvalues and eigenvectors of a real symmetrix matrix of dimension N by a modified Jacobi method.

BLOCK	SAVE "NAME"	BYTES REQUIRED
12		1816

Printed in U.S.A.

PROGRAM DESCRIPTION

Calculates the eigenvalues and eigenvectors of a real symmetric matrix of dimension N by a modified Jacobi method.

This program has been written for a value of $N \leq 5$.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find the eigenvalues and eigenvectors of the following matrix:

$$\begin{pmatrix} 2 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 2 \end{pmatrix}$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — INPUT N

4. Key Size of Matrix (N) [CR/LF] — 4. Key 3 [CR/LF]

5. INSTRUCTION — INPUT MATRIX

> Enter the matrix 1 row at a time. The end of a row is signaled as a [CR/LF] immediately following a question mark (?).
>
> For example, the row 1, 2, 3, 4, 5 would be entered as follows:
>
> ? 1, 2, 3, 4, 5 [CR/LF]
> ? [CR/LF]

6. Key Row 1 (Each element separated by a comma) [CR/LF] [CR/LF]

   Continue until all rows have been entered.

6. Key 2 , - 1 , 0 [CR/LF]
   [CR/LF]

   Key - 1 , 2 , - 1 [CR/LF]
   [CR/LF]

   Key 0 , - 1 , 2 [CR/LF] [CR/LF]

7. Read Answers

EIGENVALUE	EIGENVECTOR
.585786437638	.5000000687136
	.707106684026
	.5000000686963
3.414213562347	-.4999999301902
	.7071068783449
	-.4999999323975
2.000000000017	-.7071067819649
	1.10833000E-09
	.7071067804077

WANG 2200 SERIES PROGRAM

VECTOR OPERATIONS
TITLE

PS.02-2200.01A-00FI-13-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

This program performs vector addition, vector subtraction, dot product, and cross product of two vectors in 3-space.

BLOCK	SAVE "NAME"	BYTES REQUIRED
13		427

Printed in U.S.A.

PROGRAM DESCRIPTION

This program performs vector addition, vector subtraction, dot product, and cross product of 2 vectors in 3-space.

Given 2 vectors $A = (X_1, Y_1, Z_1)$, $B = (X_2, Y_2, Z_2)$

$$A + B = (X_1 + X_2, Y_1 + Y_2, Z_1 + Z_2)$$

$$A - B = (X_1 - X_2, Y_1 - Y_2, Z_1 - Z_2)$$

$$AB = X_1X_2 + Y_1Y_2 + Z_1Z_2$$

$$A \times B = (Y_1Z_2 - Z_1Y_2, Z_1X_2 - X_1Z_2, X_1Y_2 - Y_1X_2)$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION
4. Key X_1 , Y_1 , Z_1 [CR/LF]
5. INSTRUCTION
6. Key X_2 , Y_2 , Z_2 [CR/LF]

8. INSTRUCTION
9. If you wish to rerun program,
   Key 1 [CR/LF]
   Program will go to Step 3.

   If you do not wish to rerun program,
   Key 0 [CR/LF]
   Program will halt.

EXAMPLE

Let A = (1, 5, 7)

Let B = (2, -3, 4)

Find A+B, A-B, AB, AxB

VECTOR A?

4. Key 1 , 5 , 7 [CR/LF]

VECTOR B?

6. Key 2 , - 3 , 4 [CR/LF]

A + B = (3, 2, 11)

A - B = (-1, 8, 3)

AB = 15

AXB = (41, 10, -13)

MORE INPUT ? (1 = YES, 0 = NO)

9. Key 0 [CR/LF]

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WANG 2200 SERIES PROGRAM

VECTOR ANALYSIS

TITLE

PS.02-2200.01A-00FI-14-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Computes the magnitude of vectors, the angle between vector and axes, and the angle between two vectors.

BLOCK	SAVE "NAME"	BYTES REQUIRED
14		969

Printed in U.S.A.

PROGRAM DESCRIPTION

Computes the magnitude of vectors, the angle between vector and axes, and the angle between 2 vectors.

Given vectors $V_1 = (X_1, Y_1, Z_1)$, $V_2 = (X_2, Y_2, Z_2)$

For Vector V_1:

Magnitude = $\sqrt{X_1^2 + Y_1^2 + Z_1^2}$

Angle between vector and X-axis = $\cos^{-1}\left(X_1 / \sqrt{X_1^2 + Y_1^2 + Z_1^2}\right)$

Angle between vector and Y-axis = $\cos^{-1}\left(Y_1 / \sqrt{X_1^2 + Y_1^2 + Z_1^2}\right)$

Angle between vector and Z-axis = $\cos^{-1}\left(Z_1 / \sqrt{X_1^2 + Y_1^2 + Z_1^2}\right)$

For Vector V_2:

Same formulae except $X_1 = X_2$, $Y_1 = Y_2$, $Z_1 = Z_2$

Angle between vectors = $\cos^{-1}\left(\dfrac{X_1X_2 + Y_1Y_2 + Z_1Z_2}{\sqrt{X_1^2 + Y_1^2 + Z_1^2}\ \sqrt{X_2^2 + Y_2^2 + Z_2^2}}\right)$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

$V_1 = (1, -4, 2)$ $V_2 = (7, -5, -6)$

Find for each vector:

magnitude, angle between vector and each axis (X, Y, Z).

Also find angle between the vectors.

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — INPUT VECTORS 1/LINE (X, Y, Z, CARRIAGE RETURN)

4. Key X_1 , Y_1 , Z_1 [CR/LF] — 4. Key 1 , - 4 , 2 [CR/LF]

5. Key X_2 , Y_2 , Z_2 [CR/LF] — 5. Key 7 , - 5 , - 6 [CR/LF]

6. Read Answers

FOR VECTOR 1
Magnitude= 4.582575695
Angle betw. vector and X-axis= 77.3956180095
Angle betw. vector and Y-axis=-29.20593249611
Angle betw. vector and Z-axis= 64.12331048455

FOR VECTOR 2
Magnitude= 10.488088482
Angle betw. vector and X-axis= 48.13145697353
Angle betw. vector and Y-axis=-61.5278660993
Angle betw. vector and Z-axis=-55.10477315649

Angle betw. vectors = 71.81453706833

7. INSTRUCTION — MORE INPUT? (1=YES, 0=NO)

8. If you wish to rerun program:

   Key 1 [CR/LF]

   Program will go to Step 3.

   If you do not wish to rerun program:

   Key 0 [CR/LF]

   Program will halt.

8. Key 0 [CR/LF]

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WANG 2200 SERIES PROGRAM

SOLUTION OF SIMULTANEOUS EQUATIONS (GAUSS-JORDAN ELIMINATION)
TITLE

PS.02-2200.01A-00FI-15-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Solves N linear equations in N unknowns using Gauss-Jordan Elimination method.

BLOCK	SAVE "NAME"	BYTES REQUIRED
15		1333

Printed in U.S.A.

PROGRAM DESCRIPTION

Solves N Linear equations in N unknowns. The system of equations is put into the following form: AX = B where A = coefficient matrix, B = column matrix of constants, X = column vector of unknowns. ($N \leq 7$)

$$A_{11}X_1 + A_{12}X_2 + \ldots + A_{1N}X_N = B_1$$

$$A_{21}X_1 + A_{22}X_2 + \ldots + A_{2N}X_N = B_2$$

$$\vdots$$

$$A_{N1}X_1 + A_{N2}X_2 + \ldots + A_{NN}X_N = B_N$$

Ref. Kuo, Shan S. "Numerical Methods and Computers", Addison-Wesley, p. 154

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Solve

$$3X_1 + 2X_2 + 4X_3 + X_4 = 5$$

$$2X_1 + \quad + 2X_3 + 5X_4 = 1$$

$$2X_1 + X_2 + 2X_3 + X_4 = 3$$

$$2X_1 + 4X_2 + 3X_3 + X_4 = 4$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — NO. OF UNKNOWNS?

4. Key NO. OF UNKNOWNS (N) [CR/LF] — 4. Key 4 [CR/LF]

5. INSTRUCTION — INPUT "AUGMENTED COEFFICIENT MATRIX"

> The augmented coefficient matrix (matrix A with matrix B attached as the N + 1st column) is inputed 1 row at a time. The end of a row is signaled by a [CR/LF] immediately following a question mark (?).
>
> Each element of the row is separated by a comma.
> For example, the row 1, 2, 3, 4, 5 would be inputed as follows:
>
> : 1, 2, 3, 4, 5 [CR/LF]
>
> : [CR/LF]

6. Key ROW 1 OF AUGMENTED MATRIX [CR/LF] [CR/LF]
   .
   .
   .
   Key ROW N OF AUGMENTED COEFFICIENT MATRIX [CR/LF]
   [CR/LF]

6. Key 3 , 2 , 4 , 1 , 5 [CR/LF]
   [CR/LF]
   Key 2 , 0 , 2 , 5 , 1 [CR/LF]
   [CR/LF]
   Key 2 , 1 , 2 , 1 , 3 [CR/LF]
   [CR/LF]
   Key 2 , 4 , 3 , 1 , 4 [CR/LF]
   [CR/LF]

OPERATING INSTRUCTIONS (Cont)

7. Read Answers

```
X(1) = 1.42857142857
X(2) =  .285714285714
X(3) =  .1428571428581
X(4) = -.4285714285715
```

WANG 2200 SERIES PROGRAM

MATRIX ADDITION, SUBTRACTION AND SCALAR MULTIPLICATION
TITLE

PS. 02-2200. 01A-00FI-16-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Adds an N x M matrix B to an N x M matrix A or subtracts matrix B from matrix A or multiplies matrix A by a scalar, k.

BLOCK	SAVE "NAME"	BYTES REQUIRED
16		1528

Printed in U.S.A.

PROGRAM DESCRIPTION

Adds an N x M matrix B to an N x M matrix A or subtracts matrix B from matrix A or multiplies matrix A by a scalar, k.

Size restrictions on matrix is:

$N, M \leq 10$

The user will be asked to specify the operation to be performed.

Input the number:

1 for scalar multiplication
2 for addition
3 for subtraction

FORMULAS USED

SCALAR MULTIPLICATION

Let K = Scalar

$$K \cdot \begin{pmatrix} a_{11} & \cdots & a_{1m} \\ a_{21} & \cdots & a_{2m} \\ \vdots & & \vdots \\ a_{n1} & \cdots & a_{nm} \end{pmatrix} = \begin{pmatrix} k \cdot a_{11} & \cdots & k \cdot a_{1m} \\ k \cdot a_{21} & \cdots & k \cdot a_{2m} \\ \vdots & & \\ k \cdot a_{n1} & \cdots & k \cdot a_{nm} \end{pmatrix}$$

ADDITION

$$\begin{pmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & & \\ a_{n1} & \cdots & a_{nm} \end{pmatrix} + \begin{pmatrix} b_{11} & \cdots & b_{1m} \\ \vdots & & \vdots \\ b_{n1} & \cdots & b_{nm} \end{pmatrix} = \begin{pmatrix} a_{11}+b_{11} & \cdots & a_{1m}+b_{1m} \\ \vdots & & \\ z_{n1}+b_{n1} & \cdots & a_{nm}+b_{nm} \end{pmatrix}$$

PROGRAM DESCRIPTION (Cont)

SUBTRACTION

$$\begin{pmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & & \vdots \\ a_{n1} & \cdots & a_{nm} \end{pmatrix} - \begin{pmatrix} b_{11} & \cdots & b_{1m} \\ \vdots & & \vdots \\ b_{n1} & \cdots & b_{nm} \end{pmatrix} = \begin{pmatrix} a_{11} - b_{11} & \cdots & a_{1m} - b_{1m} \\ \vdots & & \vdots \\ a_{n1} - b_{n1} & \cdots & a_{nm} - b_{nm} \end{pmatrix}$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Solve:

$$\begin{pmatrix} 5 & 7 & 1 \\ 6 & 4 & 8 \\ 9 & 4 & 0 \end{pmatrix} - \begin{pmatrix} 2 & -3 & 4 \\ 1 & 4 & -7 \\ -1 & -2 & -3 \end{pmatrix}$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — INPUT 1 (SCALAR MULT.) or 2 (ADD) OR 3 (SUBTRACT)

4. Key OPERATION CODE [CR/LF] — 4. Key 3 [CR/LF]

If OPERATION CODE is not equal to 1 then go to Step 7.

5. INSTRUCTION — INPUT SCALAR

6. Key SCALAR MULTIPLIER, [CR/LF]

7. INSTRUCTION — INPUT N, M

8. Key # OF ROWS , # OF COLS. CR/LF — 8. Key 3 , 3 [CR/LF]

9. INSTRUCTION — INPUT MATRIX A

Enter the matrix asked for one row at a time. The end of a row is signaled by a [CR/LF] immediately following a question mark (?).

For example, the row 1, 2, 3, 4, 5 is entered as follows:

? 1, 2, 3, 4, 5 [CR/LF]

? [CR/LF]

Please note, a comma is used to separate each element of the row.

OPERATING INSTRUCTIONS (Cont)

10. Key ROW 1 OF MATRIX A

CR/LF CR/LF

.
.
.

Key ROW N OF MATRIX A

CR/LF CR/LF

10. Key 5 , 7 , 1 CR/LF CR/LF

Key 6 , 4 , 8 CR/LF CR/LF

Key 9 , 4 , 0 CR/LF CR/LF

If the operation code = 1 then go to step 13. Otherwise review matrix input technique discussed about.

11. INSTRUCTION

INPUT MATRIX B

12. Key ROW 1 OF MATRIX B

CR/LF CR/LF

.
.
.

Key ROW N OF MATRIX B

CR/LF CR/LF

Key 2 , - 3 , 4 CR/LF CR/LF

Key 1 , 4 , - 7 CR/LF CR/LF

Key - 1 , - 2 , - 3 CR/LF CR/LF

13. Read Answer

3	10	-3
5	0	15
10	6	3

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WANG 2200 SERIES PROGRAM

MATRIX MULTIPLICATION
TITLE

PS.02-2200.01A-00FI-17-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Multiplies the N x M matrix A on the right by the M x P matrix B.

BLOCK	SAVE "NAME"	BYTES REQUIRED
17		1818

Printed in U.S.A.

PROGRAM DESCRIPTION

Multiplies the N x M matrix A on the right by the M x P matrix B. (N, M, P $\leq$ 8)

FORMULA

Let C be the product matrix, then

$$C(I,J) = \sum_{K=1}^{M} A(I,K) * B(K,J) \quad \forall J \leq P, I \leq N$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

$$\begin{pmatrix} 1 & 2 & -1 & 4 \\ 5 & 2 & 1 & 0 \\ 3 & -1 & -2 & -1 \end{pmatrix} * \begin{pmatrix} 1 & 1 & -1 & 2 & 0 \\ 2 & -1 & 0 & 0 & 3 \\ -8 & 7 & 1 & 1 & -1 \\ -3 & 4 & 1 & 9 & 7 \end{pmatrix}$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — INPUT N, M, P

4. Key # ROWS OF MATRIX A ,
   # ROWS OF MATRIX B ,
   # OF COLS. OF MATRIX B
   [CR/LF]

   4. Key 3 , 4 , 5 [CR/LF]

5. INSTRUCTION — INPUT MATRIX A

> Enter the matrix asked for 1 row at a time. The end of a row is signaled by a [CR/LF] immediately following a question mark (?).
> For example, the row 1, 2, 3, 4, 5 is entered as follows:
>
> : 1, 2, 3, 4, 5 [CR/LF]
>
> ? [CR/LF]
>
> Please note each element of a row is separated by a comma.

6. Key ROW 1 OF MATRIX A
   [CR/LF] [CR/LF]
   .
   .
   .
   Key ROW N OF MATRIX A
   [CR/LF] [CR/LF]

   6. Key 1 , 2 , - 1 , 4 [CR/LF]
   [CR/LF]
   Key 5 , 2 , 1 , 0 [CR/LF]
   [CR/LF]
   Key 3 , - 1 , - 2 , - 1
   [CR/LF] [CR/LF]

OPERATING INSTRUCTIONS (Cont)

7. INSTRUCTION — INPUT MATRIX B

Enter matrix in same manner as discussed after Step 5.

8. Key ROW 1 OF MATRIX B
CR/LF CR/LF

.
.
.

Key ROW M OF MATRIX B
CR/LF CR/LF

Key 1 , 1 , - 1 , 2 , 0 CR/LF
CR/LF

Key 2 , - 1 , 0 , 0 , 3 CR/LF
CR/LF

Key - 8 , 7 , 1 , 1 , - 1 CR/LF
CR/LF

Key - 3 , 4 , 1 , 9 , 7 CR/LF
CR/LF

9. Read Answer

1	8	2	37
35			
1	10	-4	11
5			
20	-14	-6	-5
-8			

WANG 2200 SERIES PROGRAM

SOLUTION OF SIMULTANEOUS EQUATIONS (GAUSS-SEIDEL ITERATIVE METHOD)

TITLE

PS.02-2200.01A-00FI-18-0 — 6/1/73

NUMBER — DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Solves N simultaneous equations in N unknowns by Gauss-Seidel iterative method.

BLOCK	SAVE "NAME"	BYTES REQUIRED
18		1572

Printed in U.S.A.

PROGRAM DESCRIPTION

Solves N ($N \leq 8$) simultaneous equations in N unknowns by the Gauss-Seidel iterative method. This method is used primarily when the diagonal elements of the coefficients matrix are large compared to the remaining elements. It has the advantage that round-off errors are not accumulated. The system of equations is put into the following form: AX=B where A = coefficient matrix, X = column matrix of unknowns, B = column matrix of constants.

$$A_{11}X_1 + A_{12}X_2 + \ldots + A_{1N}X_N = B_1$$
$$A_{21}X_1 + A_{22}X_2 + \ldots + A_{2N}X_N = B_2$$
$$\vdots$$
$$A_{N1}X_1 + A_{N2}X_2 + \ldots + A_{NN}X_N = B_N$$

The user sets the number of iterations allowed (if convergence does not occur, "CONVERGENCE TOO SLOW" and the last values of the unknowns calculated are printed out), and delta - the tolerance within which the ratio of 2 successive iterations must lie (delta 1; use .9 or .99 or .999, etc.)

Ref: Kuo, Shan S., "Numerical Methods and Computers", Addison-Wesley, p. 178

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Solve the system:

$$12X_1 - 3X_2 + X_3 + 4X_4 = 25$$

$$X_1 + 15X_2 - 7X_3 - X_4 = 6$$

$$4X_1 + X_2 - 20X_3 + 5X_4 = -34$$

$$2X_1 - 8X_2 + X_3 + 10X_4 = 29$$

Max. No. of Iterations = 50

Delta = .999

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   INPUT NO. OF UNKNOWNS, MAX. NO. OF ITERATIONS,
   DELTA

4. Key # of Unknowns , Max. # of Iterations , DELTA
   [CR/LF]

4. Key 4 , 5 0 , . 9 9 9
   [CR/LF]

5. INSTRUCTION

   INPUT COEFF. MATRIX A AND THEN COLUMN MATRIX B

Enter matrix A one row at a time, then enter the column matrix B as one row. The end of a row is signaled by a [CR/LF] immediately following a question mark (?). For example, the row 1, 2, 3, 4, 5 will be entered as follows:

: 1, 2, 3, 4, 5 [CR/LF]

? [CR/LF]

Note elements of a row are separated by a comma.

OPERATING INSTRUCTIONS (Cont)

6. Key Row 1 of Matrix A, CR/LF CR/LF . . . Key Row N of Matrix A, CR/LF CR/LF	6. Key 1 2 , - 3 , 1 , 4 CR/LF CR/LF Key 1 , 1 5 , - 7 , - 1 CR/LF CR/LF Key 4 , 1 , - 2 0 , 5 CR/LF CR/LF Key 2 , - 8 , 1 , 1 0 CR/LF CR/LF
7. Key Column Matrix B, CR/LF CR/LF	7. Key 2 5 , 6 , - 3 4 , 2 9 CR/LF CR/LF
8. Read Answers	X(1) = .9999999999992 X(2) = 2.000000000001 X(3) = 3 X(4) = 4.000000000002

WANG 2200 SERIES PROGRAM

LINEAR PROGRAMMING

TITLE

PS.02-2200.01A-00FI-19-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Solves the following linear programming problem by the simplex method: Minimize the objective function:

$$C_1X_1 + C_2X_2 + \ldots + C_mX_m$$

BLOCK	SAVE "NAME"	BYTES REQUIRED
19		2692

Printed in U.S.A.

PROGRAM DESCRIPTION

Solves the following linear programming problem by the simplex method:

Minimize the objective function:

$$C_1X_1 + C_2X_2 + \ldots + C_mX_m$$

NOTE: This is equivalent to maximizing the objective function:

$$-C_1X_1 - C_2X_2 - \ldots - C_mX_m$$

Subject to the mixed linear constraints:

$$A_{11}X_1 + A_{12}X_2 + \ldots + A_{1m}X_m \leq (\text{or} \geq) b_1$$

$$A_{21}X_1 + A_{22}X_2 + \ldots + A_{2m}X_m \leq (\text{or} \geq) b_2$$

$$\vdots$$

$$A_{N1}X_1 + A_{N2}X_2 + \ldots + A_{Nm}X_m \leq (\text{or} \geq) b_N$$

where the variables $X_1, \ldots, X_m$ are non-negative and the coefficients $b_1, \ldots b_m$ are non-negative.

NOTE 1

Linear equations such as:

$$AX_1 + \ldots + AX_m = b$$

can be used as constraints by entering the following equivalent pair of contraints:

$$AX_1 + \ldots + AX_m \leq b$$

$$AX_1 + \ldots + AX_m \geq b$$

NOTE 2

When minimizing the objective function, the result will have the opposite sign one would expect; hence, the results should be multiplied by -1.

PROGRAM DESCRIPTION (Cont)

NOTE 3

# of variables $\leq$ 5

# of constraints $\leq$ 8

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Maximize the objective function:

$$5X_1 + 3X_2 + 2X_3$$

Constraints:

$$4X_1 + 5X_2 + X_3 \geq 10$$

$$5X_1 + 2X_2 - X_3 \leq 10$$

$$3X_1 + 8X_2 + 2X_3 \leq 12$$

$$-X_1 + 5X_2 + 4X_3 \geq 1$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION — NO. OF VARIABLES?
4. Key NO. OF VARIABLES [CR/LF] — 4. Key 3 [CR/LF]
5. INSTRUCTION — NO. OF CONSTRAINTS?
6. Key NO. OF CONSTRAINTS [CR/LF] — 6. Key 4 [CR/LF]
7. INSTRUCTION — ENTER MATRIX A

The user enters the constraints through matrix A. The m + 1 column column of the matrix consists of plus and minus ones; +1 indicates a $\leq$ relation in the constraint and a -1 indicates a $\geq$ relation in the constraint. The matrix is inputed row by row, the end of a row is signaled by a [CR/LF] immediately following a question mark (?). For example, the row 1, 2, 3, 4, -1, 7 would be entered as follows:

: 1, 2, 3, 4, -1, 7 [CR/LF]

? [CR/LF]

Notice that the elements of the row are separated by a comma.

OPERATING INSTRUCTIONS (Cont)

8. Key CONSTRAINT EQ. 1 [CR/LF]
[CR/LF]
.
.
.
Key CONSTRAINT EQ. N [CR/LF]
[CR/LF]

8. Key 4 , 5 , 1 , - 1 , 1 0
[CR/LF] , [CR/LF]
Key 5 , 2 , - 1 , 1 , 1 0
[CR/LF] , [CR/LF]
Key 3 , 8 , 2 , 1 , 1 2
[CR/LF] , [CR/LF]
Key - 1 , 5 , 4 , - 1 , 1
[CR/LF] , [CR/LF]

9. INSTRUCTION — ENTER OBJECTIVE FUNCTION

> The coefficients of the objective function are inputed in the same manner as the constraints. (In this case there is only 1 row to be entered.) Elements are separated by commas.

10. Key OBJECTIVE FUNCTION [CR/LF]
[CR/LF]

10. Key - 5 , - 3 , - 2 [CR/LF]
[CR/LF]

11. Read Answers

OBJ. FUNC. = 16.92307692306

X(1) = 2.461538461539
X(2) = 0
X(3) = 2.307692307693

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WANG 2200 SERIES PROGRAM

COMPLEX DETERMINANT

TITLE

PS.02-2200.01A-00FI-20-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Evaluates the determinant of a matrix with complex elements by the Crout method. The matrix must be square.

BLOCK	SAVE "NAME"	BYTES REQUIRED
20		1739

Printed in U.S.A.

PROGRAM DESCRIPTION

Evaluates the determinant of a matrix with complex elements by the CROUT method. The matrix must be square (N x N, $N \leq 5$).

Ref.: Hildebrand, F.B., "Introduction to Numerical Analysis", McGraw-Hill, pp. 429-39

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find the determinant of

$$\begin{bmatrix} 6-i & 5+4i & 4 \\ 5+5i & 2+3i & 0 \\ -1+i & -5-8i & -1+i \end{bmatrix}$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — ENTER N

4. Key SIZE OF MATRIX (N) [CR/LF] — 4. Key 3 [CR/LF]

5. INSTRUCTION — ENTER MATRIX

> The matrix is entered column by column with each element of the column entered on a separate line. An element a+bi is entered as follows:
>
> ? a, b (NOTE: A comma separates a and b.)

6. INSTRUCTION — COLUMN 1

7. Key a , b [CR/LF] — 7. Key 6 , - 1 [CR/LF]
   Key 5 , 5 [CR/LF]
   Key - 1 , 1 [CR/LF]

   Continue until all elements of Column 1 have been entered.

> If there is a new column to be inputed the program will go back to step 6. The number referring to the column will be updated.
>
> This cycle will be repeated until all columns have been entered. At the end, the program continues with Step 8.

8. Read Answer — DETERMINANT: 99.00000000002 + I* -217.0000000001

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TRIGONOMETRY

BLOCK NO.	PROGRAM TITLE
21	HYPERBOLIC FUNCTIONS & INVERSE HYPERBOLICS
22	SIN, COS, TAN, SINH, COSH, TANH - COMPLEX ARGUMENTS
23	ANGLE CONVERSION I
24	ANGLE CONVERSION II
25	TRIGONOMETRIC POLYNOMIAL
26	PLANE TRIANGLE SOLUTION

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WANG 2200 SERIES PROGRAM

HYPERBOLIC FUNCTIONS & INVERSE HYPERBOLIC
TITLE

PS.02-2200.01A-00FI-21-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

This program computes hyperbolics and inverse hyperbolics for angles in radians.

BLOCK	SAVE "NAME"	BYTES REQUIRED
21		524

Printed in U.S.A.

PROGRAM DESCRIPTION

The program computes hyperbolics and inverse hyperbolics for angles in radians.

Code		
1	Sinh(X)	$= \frac{e^{X} - e^{-X}}{2}$
2	Cosh(X)	$= \frac{e^{X} + e^{-x}}{2}$
3	Tanh(X)	$= \frac{e^{X} - e^{-X}}{e^{X} + e^{-X}}$
4	Arcsinh(X)	$= \text{Log } (X + \sqrt{X^2 + 1})$
5	Arccosh(X)	$= \text{Log } (X + \sqrt{X^2 - 1})$
6	Arctanh(X)	$= \text{Log } (((1 + X))/((1 - X)))/2$

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find the sinh(2), cosh(1) and arcsinh(.5).

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF] .

3. INSTRUCTION

CODE, X? TO END PROGRAM INPUT 0,0
?

> The code is the # to the left of the function you wish to solve for, as described in the program description. The value X is the value (in Radians) for which you wish to solve.

4. Key CODE , X [CR/LF]

4. Key 1 , 2 [CR/LF]

5. Read Answer

SINH(X) = 3.626860407848

6. INSTRUCTION

CODE, X?

> If you wish more values, then go to Step 4. Otherwise either Key 0 , 0 [CR/LF] or [RESET] .

CODE,X?
? 2,1
COSH(X) = 1.543080634815

CODE,X?
? 4, .5
ARCSINH(X) = .4812118250285

CODE,X?
? 0,0

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WANG 2200 SERIES PROGRAM

SIN, COS, TAN, SINH, COSH, TANH - COMPLEX ARGUMENT
TITLE

PS.02-2200.01A-00FI-22-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the values of the sin(Z), cos(Z), tan(Z), sinh(Z), cosh(Z), tanh(Z) where Z is a complex number of the form A + B(i)

BLOCK	SAVE "NAME"	BYTES REQUIRED
22		759

Printed in U.S.A.

PROGRAM DESCRIPTION

Computes the values of the sin(Z), cos(Z), tan(Z), sinh(Z), cosh(Z), tanh(Z) where Z is a complex number of the form A + Bi. (A, B are in radians.)

Ref.: Pennisi, Louis L., "Elements of Complex Variables", Holt, Rinehart and Winston, 1966, p. 100.

Formulae

$\sin(a + bi) = \sin(a)\ \cosh(b) + i\ \cos(a)\ \sinh(b)$

$\cos(a + bi) = \cos(a)\ \cosh(b) - i\ \sin(a)\ \sinh(b)$

$$\tan(a + bi) = \frac{\sin(2a) + i\ \sinh(2b)}{\cos(2a) + \cosh(2b)}$$

$\sinh(a + bi) = \sinh(a)\ \cos(b) + i\ \cosh(a)\ \sin(b)$

$\cosh(a + bi) = \cosh(a)\ \cos(b) + i\ \sinh(a)\ \sin(b)$

$$\tanh(a + bi) = \frac{\sinh(2a) + i\ \sin(2b)}{\cosh(2a) + \cos(2b)}$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find the sin(Z), cos(Z), tan(Z), sinh(Z), cosh(Z), tanh(Z) where Z = 2 + 3i

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — A, B? (TO END PROGRAM INPUT 0, 0)

4. Key A , B [CR/LF] — 4. Key 2 , 3 [CR/LF]

5. Read Answers

```
SIN(A+BI) =  9.154499146904 + -4.168906959951 I
COS(A+BI) = -4.18962569095 + -9.109227893755 I
TAN(A+BI) = -3.76402564E-03 + 1.003238627354 I
SINH(A+BI) = -3,590564589988 + .530921086251 I
COSH(A+BI) = -3.724545504917 + .5118225699898 I
TANH(A+BI) = .9653858790224 + -9.88437503E-03 I
```

6. INSTRUCTION — A, B?

To rerun the program, input values of A, B not = to zero. Otherwise either Key 0 , 0 [CR/LF] or Key [RESET].

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WANG 2200 SERIES PROGRAM

ANGLE CONVERSION I

TITLE

PS.02-2200.01A-00FI-23-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Converts an angle in radians to degrees, minutes and seconds.

BLOCK	SAVE "NAME"	BYTES REQUIRED
23		352

Printed in U.S.A.

PROGRAM DESCRIPTION

Converts an angle given in radians to degrees, minutes, and seconds.

Formulae

$$1 \text{ radian} = \frac{180^\circ}{\pi}$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find degrees, minutes and seconds for the following radians: 1, 6.728

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION

   ANGLE? (TO END PROGRAM INPUT 99999)
4. Key ANGLE [CR/LF]

4. Key 1 [CR/LF]

   57 DEG.
   17 MIN.
   44.8032 SEC.
5. Read Answers
6. INSTRUCTION

   ANGLE?

If you have more input then go to Step 4. Otherwise, either Key 9 9 9 9 9 [CR/LF] or Key [RESET].

Key 6 . 7 2 8 [CR/LF]

25 DEG.
29 MIN.
9.595929 SEC.

ANGLE?

Key 9 9 9 9 9 [CR/LF]

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WANG 2200 SERIES PROGRAM

ANGLE CONVERSION II

TITLE

PS.02-2200.01A-00FI-24-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Converts an angle from Degrees, Minutes and Seconds to radians.

BLOCK	SAVE "NAME"	BYTES REQUIRED
24		306

Printed in U.S.A.

PROGRAM DESCRIPTION

Converts an angle from degrees, minutes, seconds to radians.

Formulae

$$1 \text{ RADIAN} = \frac{180^\circ}{\pi}$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Convert 30 deg. 5 min. 27 sec. to radians.

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   ANGLE (DEG, MIN, SEC, CARRIAGE RETURN)?
   ?

4. Key ANGLE (DEG, MIN, SEC), [CR/LF]

   4. Key 3 0 , 5 , 2 7 [CR/LF]

5. Read Answer

   ANGLE = .5251841307808 RADIANS

6. INSTRUCTION

   MORE INPUT? (1 = YES, 0 = NO)

7. If you have more input:

   Key 1 [CR/LF]

   Program will go to Step 3.

   If you do not have more input:

   Key 0 [CR/LF]

   Program will halt.

   7. Key 0 [CR/LF]

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WANG 2200 SERIES PROGRAM

TRIGONOMETRIC POLYNOMIAL

TITLE

PS.02-2200.01A-00FI-25-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates the value of a trigonometric polynomial of the form:
$f(x) = A_1 \sin(X) + B_1 \cos(X) + A_2 \sin(2X) + B_2 \cos(2X) + \ldots +$
$A_N \sin(NX) + B_N \cos(NX)$.

BLOCK	SAVE "NAME"	BYTES REQUIRED
25		522

Printed in U.S.A.

PROGRAM DESCRIPTION

Calculates the value of a trigonometric polynomial of the form:

$$f(x) = A_1 \sin(X) + B_1 \cos(X) + A_2 \sin(2X) + B_2 \cox(2X) + \ldots + A_N \sin(NX) + B_N \cos(NX).$$

These calculations arise from a study of periodic phenomena when higher harmonics are needed. A classic example is to find the position of a star given the time of year. The program uses the following identities:

$$\sin ((N+1) X) = \sin(NX) \cos(X) + \cos(NX) \sin(X)$$

$$\cos ((N+1) X) = \cos(NX) \cos(X) - \sin(NX) \sin(X).$$

NOTE

X is in radians.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

$F(X) = \sin(X) + \cos(X) + 2\sin(2X) - 5\cos(2X) + 2\sin(3X) + 3\cos(3X) + \sin(4X) + 5\cos(4X)$

Find F(1.25) and F(.8).

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter N and coefficients A_i and B_i in statements 100-900 as follows:

100 DATA N, A_1, B_1, A_2, B_2, . . ., A_N, B_N

For large N's, the DATA statement can be broken up into any number of Data Statements, providing they have line numbers between 100 and 900.

2. Key 1 0 0 [DATA] N , A_1 , B_1 , A_2 , B_2 , ... A_N , B_N [CR/LF]

2. Key 1 0 0 [DATA] 4 , 1 , 1 , 2 , - 5 , 2 , 3 , 1 , 5 [CR/LF]

3. Key [RUN] [CR/LF]

4. INSTRUCTION — INPUT X (TO END PROGRAM INPUT 99999)

5. Key X [CR/LF]

5. Key 1 . 2 5 [CR/LF]

6. Read Answer — F(1.25) = 4.69147137552

7. INSTRUCTION — INPUT X

If you have more input, Key X (program will continue with Step 5). Otherwise, either Key 9 9 9 9 9 [CR/LF] or Key [RESET]. (Program will halt.)

Key . 8 [CR/LF]

F(.8) = 3.996181144629

INPUT X

Key 9 9 9 9 9 [CR/LF]

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WANG 2200 SERIES PROGRAM

PLANE TRIANGLE SOLUTION

TITLE

PS.02-2200.01A-00FI-26-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates the unknown sides and angles of a triangle given one side and any 2 other parts.

BLOCK	SAVE "NAME"	BYTES REQUIRED
26		1478

Printed in U.S.A.

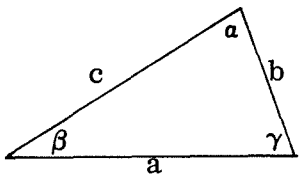
PROGRAM DESCRIPTION

Calculates the unknown sides and angles of a triangle given one side and any 2 other parts.

The user enters the 3 known parts of the triangle when requested, inputed (angles in radians) in the order they appear in the triangle (clockwise or counter-clockwise). The possible ways of entering data are:

TYPE	DESCRIPTION
1	Angle, Angle, Side
2	Angle, Side, Angle
3	Side, Side, Angle
4	Side, Angle, Side
5	Side, Side, Side

Formulae



(counter-clockwise)

Law of Sines

$$\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$$

Law of Cosines

$$a^2 = b^2 + c^2 - 2bc \cos \alpha$$

$$b^2 = c^2 + a^2 - 2ca \cos \beta$$

$$c^2 = a^2 + b^2 - 2ab \cos \gamma$$

PROGRAM DESCRIPTION (Cont)

$$\cos\alpha = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\cos\beta = \frac{c^2 + a^2 - b^2}{2ca}$$

$$\cos\gamma = \frac{a^2 + b^2 - c^2}{2ab}$$

Relations of Function

$$\tan X = \frac{\sin X}{\cos X} = \frac{\sqrt{1 - \cos^2 X}}{\cos X} = \frac{\sin X}{\sqrt{1 - \sin^2 X}}$$

The sum of α, β, and γ is equal to 180° or π radians.

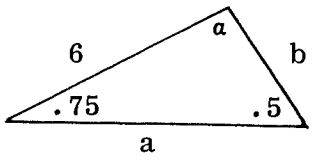
NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find a, b, and α.



1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   PROBLEM TYPE: 0=END, 1=AAS, 2=ASA, 3=SSA, 4=SAS,

   5=SSS

   INPUT PROBLEM TYPE
   ?

4. Key PROBLEM TYPE [CR/LF]

   4. Key 1 [CR/LF]

5. INSTRUCTION

   INPUT 'ANGLE, ANGLE, SIDE'

6. Key ANGLE , ANGLE , SIDE
   [CR/LF]

   6. Key . 5 , . 7 5 , 6 [CR/LF]

7. Read Answers

   SIDE 1 = 11.87652131531
   OPPOSITE ANGLE = 1.8915927 RADIANS
   SIDE 2 = 8.530693988574
   OPPOSITE ANGLE = .75 RADIANS
   SIDE 3 = 6
   OPPOSITE ANGLE = .5 RADIANS

8. INSTRUCTION

   INPUT PROBLEM TYPE

If you have another problem then go to Step 4. Otherwise, either Key 0 [CR/LF] or key [RESET] . (Program will halt.)

GEOMETRY

BLOCK NO.	PROGRAM TITLE
27	COORDINATE CHANGE
28	AREA OF RECTILINEAR SURFACE
29	LINEAR INTERPOLATION
30	LAGRANGIAN INTERPOLATION

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WANG 2200 SERIES PROGRAM

COORDINATE CHANGE

TITLE

PS.02-2200.01A-00FI-27-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

This program converts cartesian coordinates (X,Y) to polar coordinates (R,A) and vice versa.

BLOCK	SAVE "NAME"	BYTES REQUIRED
27		569

Printed in U.S.A.

PROGRAM DESCRIPTION

This program converts cartesian coordinates (X, Y) to polar coordinates (r, a) by:

r = SQR (X*X + Y*Y)

a = arctan(Y/X), a is in degrees.

or (r, a) to (X, Y) by:

X = r*cos(a)

Y = r*sin(a).

OPERATING INSTRUCTIONS

EXAMPLE

Convert from Cartesian coordinates to Polar coordinates.

X	Y
3	4
-1	2
.3	7
-3	7.1

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter data in statements 200-998 as follows for cartesian to polar:

200 DATA 1, X, Y, X1, Y1, X2, Y2, . . . [CR/LF]

Enter data in statements 200-998 as follows for polar to cartesian:

200 DATA -1, R, A, R1, A1, R2, A2, . . . [CR/LF]

2. Data

For Cartesian to Polar:

Key 2 0 0 [DATA] 1 , X
Y , X1 , Y1 , . . . [CR/LF]

For Polar to Cartesian:

Key 2 0 0 [DATA] - 1 ,
R , A , R1 , A1 . . .
[CR/LF]

3. Key [RUN] [CR/LF]

2. Key 2 0 0 [DATA] 1 , 3 ,
4 , - 1 , 2 , . 3 ,
7 , - 3 , 7 . 1 [CR/LF]

OPERATING INSTRUCTIONS (Cont)

4. Read Answers

X	Y	R	A
3	4	5	53.13010156931
-1	2	-2.2360679775	-63.43494788586
.3	7	7.0064256222	87.54596703223
-3	7.1	-7207788269	-67.09422935045

5. Machine will display

either

```
135 READ R,A
          ▲ERR 27
```

or

```
20 READ X,Y
          ▲ERR 27
```

when all data has been read.

WANG 2200 SERIES PROGRAM

AREA OF RECTILINEAR SURFACE

TITLE

PS. 02-2200. 01A-00FI-28-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates the area of a plane surface enclosed by line segments when the coordinates of the vertices are given.

BLOCK	SAVE "NAME"	BYTES REQUIRED
28		370

Printed in U.S.A.

PROGRAM DESCRIPTION

Calculates the area of a plane surface enclosed by line segments when the coordinates of the vertices are given.

$$\text{Area} = \frac{1}{2}\left[(X_1 + X_2)(Y_1 - Y_2) + (X_2 + X_3)(Y_2 - Y_3) + \ldots + (X_N + X_1)(Y_N - Y_1)\right]$$

$(X_1, Y_1), \ldots, (X_N, Y_N)$ are successive vertices (moving in a clockwise direction).

N = number of vertices.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Find the area of the plane surface formed by the line segments with the following vertices.

X	Y
4	8
6	11
11	10
12	6
9	4
5	4

1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — N, X, Y

4. Key # of vertices , Initial X , Initial Y [CR/LF] — 4. Key 6 , 4 , 8 [CR/LF]

5. INSTRUCTION — X I, Y I

6. Key X of Vertex I , Y of Vertex I [CR/LF] — 6. Key 6 , 1 1 [CR/LF]

7. Continue until all vertices have been entered. — 7. Key 1 1 , 1 0 [CR/LF]
   Key 1 2, , 6 [CR/LF]
   Key 9 , 4 [CR/LF]
   Key 5 , 4 [CR/LF]

Program will close the surface to the initial (X,Y) data pair.

8. Read Answer — A = 114.5

9. INSTRUCTION	MORE INPUT (1 = YES, 0 = NO) ?
10. If you have more input: Key 1 CR/LF Program will go to Step 3. If you do not have more input: Key 0 CR/LF Program will halt.	10. Key 0 CR/LF

WANG 2200 SERIES PROGRAM

LINEAR INTERPOLATION
TITLE

PS.02-2200.01A-00FI-29-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

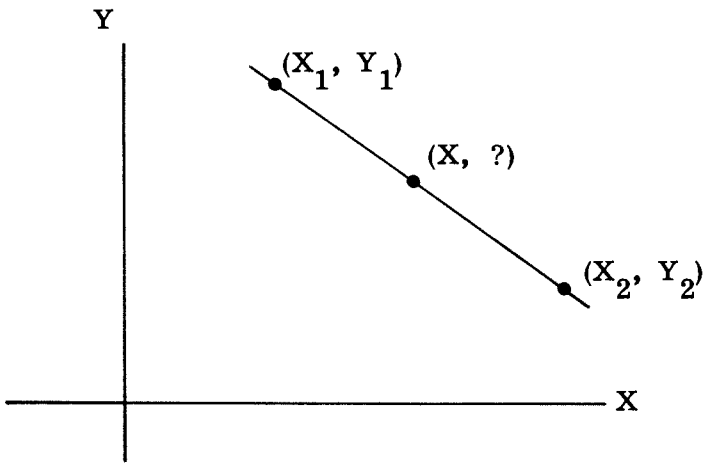
PROGRAM ABSTRACT

Linearly interpolates points on a line given two other points on the line, (X_1, Y_1), (X_2, Y_2).

BLOCK	SAVE "NAME"	BYTES REQUIRED
29		347

Printed in U.S.A.

PROGRAM DESCRIPTION



Two-point form:

$$\frac{Y - Y_1}{X = X_1} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

$$(Y - Y_1)(X_2 - X_1) = (Y_2 - Y_1)(X - X_1)$$

$$Y - Y_1 = \frac{(Y_2 - Y_1)(X - X_1)}{X_2 - X_1}$$

$$Y = Y_1 + \frac{(Y_2 - Y_1)(X - X_1)}{X_2 - X_1}$$

Given any X, Y can be calculated

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Find the Y coordinate for the following X values:

X
1.25
3.25
6.5

when the following two points are on this line: (1, 2), (3, 4).

1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   INPUT KNOWN POINTS (X1, Y1, X2, Y2, CARRIAGE RETURN)
   ?

4. Key X1 , Y_1 , X_2 , Y_2 [CR/LF]

   4. Key 1 , 2 , 3 , 4 [CR/LF]

5. INSTRUCTION

   INPUT X-COORD. OF PT. TO BE INTERPOLATED. TO END PROGRAM INPUT 99999.
   ?

6. Key X-COORD. OF PT. TO BE INTERPOLATED, [CR/LF]

   6. Key 1 . 2 5 [CR/LF]

7. Read Answers

   Y = 2.25

8. INSTRUCTION

   X?

If you have more X-coord. then go to Step 6. Otherwise Key 9 9 9 9 9 [CR/LF] or Key [RESET].

```
X? 3.25
Y = 4.25

X? = 6.5
Y = 7.5

X? 99999

END PROGRAM
```

WANG 2200 SERIES PROGRAM

LAGRANGIAN INTERPOLATION

TITLE

PS.02-2200.01A-00FI-30-0 — 6/1/73

NUMBER — DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Given N ($N \leq 70$) distinct data points, $(X_1, Y_1), \ldots, (X_N, Y_N)$, the Y-coordinates corresponding to inputed X-values are computed by the Lagrangian interpolation formula for unequally spaced data.

BLOCK	SAVE "NAME"	BYTES REQUIRED
30		1707

Printed in U.S.A.

PROGRAM DESCRIPTION

Given N ($N \leq 70$) distinct data points, $(X_1, Y_1), \ldots, (X_N, Y_N)$, the Y-coordinates corresponding to inputed X-values are computed by the Lagrangian interpolation formula for unequally spaced data:

$$P(X) = \sum_{K=1}^{N} \left(\prod_{\substack{I=1 \\ I \neq K}}^{N} \frac{X - XI}{XK - XI} \right) YK$$

P(X) is a polynomial such that curve passes through all the given data points.

Ref.: Kuo, Shan S., "Numerical Methods and Computers", Addison-Wesley, 1965, p. 214

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Find Y for the X-value equal to 3 of the curve that passes through the following points:

X	Y
1	2
2	3
4	5
5	6
6	7

1.	Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]	
2.	Key [RUN] [CR/LF]	
3.	INSTRUCTION	INPUT NUMBER OF KNOWN POINTS, N
4.	Key N [CR/LF]	4. Key 5 [CR/LF]
5.	INSTRUCTION	INPUT KNOWN POINTS (1 POINT TO A LINE) AS FOLLOWS: 'X,Y' ?
6.	Key X , Y [CR/LF]	6. Key 1 , 2 [CR/LF]
7.	Continue until all points have been entered.	7. Key 2 , 3 [CR/LF] Key 4 , 5 [CR/LF] Key 5 , 6 [CR/LF] Key 6 , 7 [CR/LF]
8.	INSTRUCTION	INPUT X-COORDINATE OF POINT TO BE INTERPOLATED. TO END Key 99999. X?
9.	Key X-VALUE [CR/LF]	9. Key 3 [CR/LF]
10.	Read Answer	Y = 3.999999999999
11.	INSTRUCTION	X?

If you desire to compute more Y-coordinates from a given X-coordinate then go to Step 9. Otherwise Key 9 9 9 9 9 [CR/LF] or Key [RESET] .

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NUMBER THEORY

BLOCK NO.	PROGRAM TITLE
31	GREATEST COMMON DIVISOR
32	PRIME FACTORIZATION OF AN INTEGER
33	PERMUTATIONS AND COMBINATIONS

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WANG 2200 SERIES PROGRAM

GREATEST COMMON DIVISOR OF 2 INTEGERS
TITLE

PS.02-2200.01A-00FI-31-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the greatest common divisor of 2 integers by the Euclidean algorithm.

BLOCK	SAVE "NAME"	BYTES REQUIRED
31		397

Printed in U.S.A.

PROGRAM DESCRIPTION

Computes the greatest common divisor of two integers by the Euclidean algorithm.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Find the greatest common divisor of 45 and 285.

1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

*** GREATEST COMMON DIVISOR OF TWO INTEGERS***

4. INSTRUCTION

INPUT 'INTEGER,INTEGER'. TO END PROGRAM INPUT '0,0'
?

5. Key INTEGER 1 , INTEGER 2 [CR/LF]

5. Key 4 5 , 2 8 5 [CR/LF]

6. Read Answer

G.C.D. = 15

7. INSTRUCTION

INPUT 'INTEGER, INTEGER'
?

If you wish to find the G.C.D. of other integer pairs go to Step 5.
Otherwise, Key 0 , 0 [CR/LF] or Key [RESET] .

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WANG 2200 SERIES PROGRAM

PRIME FACTORIZATION OF INTEGERS
TITLE

PS.02-2200.01A-00FI-32-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Factors any integer into a product of prime numbers.

BLOCK	SAVE "NAME"	BYTES REQUIRED
32		386

Printed in U.S.A.

PROGRAM DESCRIPTION

Factors any integer into a product of prime numbers.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

Find the Prime Factors of 84.

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   INPUT NUMBER TO BE FACTORED. TO END PROGRAM INPUT 0
   ?

4. Key # to be Factored [CR/LF]

4. Key 8 4 [CR/LF]

5. Read Answer

   FACTORS

   1

   2 ▲ 2

   3 ▲ 1

   7 ▲ 1

   (NOTE: $84 = 7 \times 3 \times (2^2) \times 1$)

6. INSTRUCTION

   NUMBER?

If you wish to compute the prime factors of some other value, then go to Step 4. Otherwise Key 0 [CR/LF] or Key [RESET].

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WANG 2200 SERIES PROGRAM

PERMUTATIONS AND COMBINATIONS

TITLE

PS.02-2200.01A-00FI-33-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates the number of permutations and the number of combinations of N items taken R at a time.

BLOCK	SAVE "NAME"	BYTES REQUIRED
33		621

Printed in U.S.A.

PROGRAM DESCRIPTION

Calculates the number of permutations and the number of combinations of N items taken R at a time.

FORMULAS USED

N ITEMS TAKEN R AT A TIME.

$$\text{\# of Permutations} = \frac{N!}{(N-R)!} = (N)\ (N-1)\ (N-2)\ \ldots\ (N-R+1)$$

$$\text{\# of Combinations} = \frac{N!}{R!\ (N-R)!} = \frac{\text{\# of Permutations}}{R!}$$

! means factorial

Example

5! = 5*4*3*2*1

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION appears on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Find the # of Permutations and combinations for the following:

a) 6 items, 4 at a time

b) 15 items, 2 at a time

c) 3 items, 2 at a time

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   INPUT 'N,R'. TO END PROGRAM INPUT VALUES<=0.
   ?

4. Key N , R [CR/LF]

   4. Key 6 , 4 [CR/LF]

5. Read Answer:

   NO. OF PERMUTATIONS IS 360
   NO. OF COMBINATIONS IS 15

6. INSTRUCTION

   INPUT 'N,R'

If you wish to calculate the combination and permutations for other N,R values, go to Step 4. Otherwise,

Key 0 , 0 [CR/LF] or Key [RESET].

Key 1 5 , 2 [CR/LF]

NO. OF PERMUTATIONS IS 210
NO. OF COMBINATIONS IS 105

INPUT 'N,R'

Key 3 , 2 [CR/LF]

NO. OF PERMUTATIONS IS 6
NO. OF COMBINATIONS IS 3

INPUT 'N, R'

OPERATING INSTRUCTIONS (Cont)

Key 0 , 0 CR/LF

End Program

MISCELLANEOUS MATHEMATICS

BLOCK NO.	PROGRAM TITLE
34	LOG B TO BASE A
35	SECOND DEGREE EQUATION I
36	EXPLICIT SECOND DEGREE EQUATION
37	SECOND DEGREE EQUATION II
38	ALGEBRA OF COMPLEX NUMBERS
39	HYPERGEOMETRIC FUNCTION
40	SQUARE ROOT OF A COMPLEX NUMBER
41	BESSEL FUNCTION
42	GAMMA FUNCTION
43	FOURIER ANALYSIS (DEFINED FUNCTION)
44	FOURIER ANALYSIS (TABULATED FUNCTION

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WANG 2200 SERIES PROGRAM

LOG B TO BASE A

TITLE

PS.02-2200.01A-00FI-34-0 — NUMBER

6/1/73 — DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Computes LOG B to Base A by $LOG_A(B) = LOG_e(B)/LOG_e(A)$

BLOCK	SAVE "NAME"	BYTES REQUIRED
34		182

Printed in U.S.A.

PROGRAM DESCRIPTION

Computes Log B to Base A by:

$$\text{Log}_A(B) = \frac{\text{Log}_e(B)}{\text{Log}_e(A)}$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTION

EXAMPLE

Evaluate:

$\text{Log}_{2.5}(3)$

$\text{Log}_{6}(2)$

1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION

INPUT A, B. TO END PROGRAM INPUT 0.0
?

4. Key A , B [CR/LF]

4. Key 2 . 5 , 3 [CR/LF]

5. Read Answer

LOG (3) TO BASE 2.5 = 1.198977846715

6. INSTRUCTION

INPUT A, B

If you wish to evaluate other A, B values go to Step 4. Otherwise, Key 0 , 0 [CR/LF] or Key [RESET] .

Key 6 , 2 [CR/LF]

Log(2) to BASE 6 = .3868528072346

INPUT A, B

Key 0 , 0 [CR/LF]

End Program

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WANG 2200 SERIES PROGRAM

SECOND DEGREE EQUATION I

TITLE

PS.02-2200.01A-00FI-35-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Converts the explicit form of a second degree equation to the general form.

BLOCK	SAVE "NAME"	BYTES REQUIRED
35		288

Printed in U.S.A.

PROGRAM DESCRIPTION

This program converts the explicit form of a second-degree equation to the general form:

Given: $Y = PX + Q \pm \sqrt{RX^2 + SX + T}$

Desired: $AX^2 + BXY + CY^2 + DX + EY + F = 0.$

The method of expansion is to gather rational terms to the left, square both sides of the equation, re-gather and combine to attain the desired coefficients in the general form:

$$Y - PX - Q = \pm \sqrt{RX^2 + SX + T^2}$$

$$(P^2 - R)X^2 + (-2P)XY + (1)Y^2 + (2PQ-S)X + (-2Q)Y + (Q^2 - T) = 0$$

A B C D E F

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Convert

$$Y = 4X + 2 \pm \sqrt{6X^2 + 7X + 8}$$

to the general form.

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] , [CR/LF]

3. INSTRUCTION

   INPUT P, Q, R, S, T

4. Key P , Q , R , S , T
   [CR/LF]

   4. Key 4 , 2 , 6 , 7 , 8 [CR/LF]

5. Read Answer

   A = 10

   B = -8

   C = 1

   D = 9

   E = -4

   F = -4

6. INSTRUCTION

   MORE INPUT? (1 = YES, 0 = NO)
   ?

7. If you wish to convert another problem:

   Key 1 [CR/LF]

   Go to Step 3.

   If you do not wish to convert another problem:

   Key 0 [CR/LF]

   Program halts.

   Key 0 [CR/LF]

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WANG 2200 SERIES PROGRAM

EXPLICIT SECOND DEGREE EQUATION

TITLE

PS.02-2200.01A-00FI-36-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Converts an explicit second degree equation from Y = f(x) to X = g(Y)

BLOCK	SAVE "NAME"	BYTES REQUIRED
36		372

Printed in U.S.A.

PROGRAM DESCRIPTION

This program converts a second-degree equation in explicit form: i.e. $Y = F(X)$ to $X = f(Y)$

Given: $Y = PX + Q \pm \sqrt{RX^2 + SX + T}$

Desired: $X = P'Y + Q' \pm \sqrt{R'Y^2 + S'Y + T'}$

The original equation is converted to general form and is then manipulated to calculate the coefficients for the desired equation.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Convert

$$Y = 2X + 5 \pm \sqrt{8X^2 + 9X + 4}$$

to a function of Y.

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — ENTER P, Q, R, S, T

4. Key P , Q , R , S , T [CR/LF] — 4. Key 2 , 5 , 8 , 9 , 4 [CR/LF]

5. Read Answer — P1 = -.5
   Q1 = 1.375
   R1 = .5
   S1 = -3.875
   T1 = 7.140625

6. INSTRUCTION — MORE INPUT? (1 = YES, 0 = NO)

7. If you wish to convert another equation: — 7. Key 0 [CR/LF]

   Key 1 [CR/LF]

   Go to Step 3.

   If you do not wish to convert another equation:

   Key 0 [CR/LF]

   Program halts.

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WANG 2200 SERIES PROGRAM

SECOND DEGREE EQUATION II

TITLE

PS.02-2200.01A-00FI-37-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Converts a general second degree equation to its explicit form.

BLOCK	SAVE "NAME"	BYTES REQUIRED
37		324

Printed in U.S.A.

PROGRAM DESCRIPTION

This program converts the general form of a second-degree equation to explicit form:

Given: $AX^2 + BXY + CY^2 + DX + EY + F = 0$

Desired: $X = PY + Q \pm \sqrt{RY^2 + SY + T}$

By setting up the general form for a quadratic solution and dividing through by A, we get the expansion:

$$X = \left(\frac{-B}{2A}\right) Y + \left(\frac{-D}{2A}\right) \pm \sqrt{\left(\left(\frac{B}{2A}\right)^2 - \frac{C}{A}\right) Y^2 + \left(\frac{BD}{2A^2} - \frac{E}{A}\right) Y + \left(\left(\frac{D}{2A}\right)^2 - \left(\frac{F}{A}\right)\right)}$$

NOTE

The coefficients in the general form should be arranged such that A is the coefficient for the desired dependent variable in the explicit form, i.e.:

Desired: $X = PY \ldots$ Use $AX^2 + BXY$

$Y = PX \ldots$ $Y^2 + BXY$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Convert the following general equation to its explicit form

$$X^2 + 2XY + 3Y^2 + 4X + 5Y + 6 = 0$$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   ENTER A, B, C, D, E, F
   ?

4. Key A , B , C , D , E , F
   [CR/LF]

4. Key 1 , 2 , 3 , 4 , 5 , 6
   [CR/LF]

5. Read Answers

   P = -1

   Q = -2

   R = -2

   S = -1

   T = -2

6. INSTRUCTION

   MORE INPUT? (1 = YES, 0 = NO)

7. If you wish to convert another second degree equation:

   Key 1 [CR/LF]

   Go to Step 3.

   Otherwise,

   Key 0 [CR/LF]

   Program halts.

7. Key 0 [CR/LF]

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WANG 2200 SERIES PROGRAM

ALGEBRA OF COMPLEX NUMBERS
TITLE

PS.02-2200.01A-00FI-38-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Calculates the addition, subtraction, multiplication, division and scalar multiplication of 2 complex numbers.

BLOCK	SAVE "NAME"	BYTES REQUIRED
38		420

Printed in U.S.A.

PROGRAM DESCRIPTION

This program performs any sequence of the operations +, -, x, ÷ on complex numbers in the form A + Bi.

Let N = number of complex numbers involved in the calculation.

CODE		OPERATION
1	=	addition
2	=	subtraction
3	=	multiplication
4	=	division

Let R be any of the above operation codes.

Formulae

Let the two complex #'s be A + Bi, C + Di

Addition

$$(A + C) + (B + D)i$$

Subtraction

$$(A - C) + (B - C)i$$

Multiplication

$$(AC - BD) + (AD + BC)i$$

Division

$$\left(\frac{AC + BD}{C^2 + D^2}\right) + \left(\frac{CB - AD}{C^2 + D^2}\right) i$$

OPERATING INSTRUCTIONS

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter data in Statements 600-998 as follows:

600 DATA N, A_1, B_1, R, A_2, B_2, R, . . ., R, A_N, B_N

For example,

(2+3i) * (4-5i) * (7+0i)/(2-3i)/(4+5i) + (3-4i)

is entered as follows:

600 DATA 6, 2, 3, 4, 5, -5, 3, 7, 0, 4, 2, -3, 4, 4, 5, 1, 3, -4

Extra Data Statements may be used to continue calculation.

2. Enter Data *

   Key 6 0 0 [DATA] N , A , B , R , A_1 , B_1 , R, , . . . R , A_N , B_N [CR/LF]

3. Key [RUN] [CR/LF]

4. Read Answer

EXAMPLE

Solve

(3+4i) - (2-8i) ÷ (-1+i) * (0+i) + (2+0i)

2. Key 6 0 0 [DATA] 5 , 3 , 4 , 2 , 2 , - 8 , 4 , - 1 , 1 , 3 , 0 , 1 , 1 [CR/LF]

   Key 6 0 1 [DATA] 2 , 0 [CR/LF]

8.5 5.5I

End Program

*The DATA statement may be broken up into as many statements as desired. However always increase your line number. (See Example.)

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WANG 2200 SERIES PROGRAM

HYPERGEOMETRIC FUNCTION

TITLE

PS.02-2200.01A-00FI-39-0 6/1/73

NUMBER **DATE**

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Evaluates a hypergeometric function of the form:

$$M(Z) = \frac{AZ}{B} + \frac{A(A+1)Z^2}{B(B+1)2!} + \ldots + \frac{A(A+1)\ (A+2)\ \ldots\ (A+N-1)Z^N}{B(B+1)\ (B+2)\ \ldots\ (B+N-1)N!}$$

BLOCK	SAVE "NAME"	BYTES REQUIRED
39		288

Printed in U.S.A.

PROGRAM DESCRIPTION

This program evaluates a hypergeometric function of the form:

$$M(Z) = \frac{AZ}{B} + \frac{A(A+1)Z^2}{B(B+1)2!} + \frac{A(A+1)\ (A+2)Z^3}{B(B+1)\ (B+2)3!} + \ldots + \frac{A(A+1)\ \ldots\ (A+N-1)Z^N}{B(B+1)\ \ldots\ (B+N-1)N!}$$

The larger the number of terms (N), the more accurate the results.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Evaluate

$$e = 1 + \frac{1}{2!} + \frac{1}{3!} + \ldots$$

1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION — A, B, Z, N? (TO END PROGRAM INPUT 0, 0, 0, 0)

4. Key A , B , Z , N [CR/LF] — 4. Key 1 , 1 , 1 , 1 5 [CR/LF]

5. Read Answer — M = 2.718281828458

6. INSTRUCTION — A, B, Z, N?

To evaluate for data, go to Step 4. Otherwise, Key 0 , 0 , 0 , 0 [CR/LF] or Key [RESET] .

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WANG 2200 SERIES PROGRAM

SQUARE ROOT OF A COMPLEX NUMBER

TITLE

PS.02-2200.01A-00FI-40-0	6/1/73
NUMBER	DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Computes the square root of a complex number A + Bi.

BLOCK	SAVE "NAME"	BYTES REQUIRED
40		303

Printed in U.S.A.

PROGRAM DESCRIPTION

Computes the square root of a complex number A + Bi:

$$\sqrt{(A + Bi)} = \sqrt{(A + R)/2} + \frac{B}{|B|} \sqrt{(R - A)/2}$$

where

$$R = \sqrt{A^2 + B^2}$$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION
4. Key A , B [CR/LF]
5. Read Answer

EXAMPLE

Compute

$$\sqrt{9 + 9i}$$

INPUT COMPLEX NO. (A, B, CARRIAGE RETURN)
?

4. Key 9 , 9 [CR/LF]

ANS.: 3.2960523404 1.3652695816 I

Program goes to Step 3. To end Key [RESET].

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WANG 2200 SERIES PROGRAM

BESSEL FUNCTION

TITLE

PS.02-2200.01A-00FI-41-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Calculates values of the Bessel function $J_i(X)$, i an integer.

BLOCK	SAVE "NAME"	BYTES REQUIRED
41		412

Printed in U.S.A.

PROGRAM DESCRIPTION

The Bessel function Ji(X) where i is an integer may be written as

$$J_i(X) = \sum_{n=1}^{\infty} \frac{(-1)^n}{n!} \left(\frac{1}{(i+n)!}\right) \left(\frac{X}{2}\right)^{i+2n}$$

This may also be written in the following form:

$$J_i(X) = \left(\frac{X}{2}\right)^i \frac{1}{i!} \left[\underbrace{\frac{1}{T_o}}_{} - \underbrace{\frac{1}{1(i+1)} \left(\frac{X}{2}\right)^2 T_o}_{T_i} + \frac{1}{2(i+2)} \left(\frac{X}{2}\right)^2 T_i - \ldots\right]$$

Both variables X and i are equal to or greater than zero. Accuracy of the results varies with different values of i and X. For many values of X precision is much better. However, with:

$0 \leq X \leq 10, \quad 0 \leq i \leq 11$ precision is not worse than 10^{-6}

$10 < X \leq 15, \quad 0 \leq i \leq 11$ precision is not worse than 10^{-4}

$15 < X < 18, \quad 0 \leq i \leq 11$ precision is not worse than 10^{-3}

$18 \leq X \leq 20, \quad 3 \leq i \leq 11$ precision is not worse than 10^{-2}

NOTE

The varying degrees of accuracy are due to the loss of precision which occurs, in the first few terms of the series when the difference is calculated between two large numbers relatively close to one another in magnitude.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Compute

$J_1(1)$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION

   INPUT I,X. TO END PROGRAM INPUT 0,0
   ?
4. Key I _ , _ X [CR/LF]

   4. Key 1 _ , _ 1 [CR/LF]
5. Read Answer

   ANS.: .4400505857115
6. INSTRUCTION

   INPUT I,X
   ?

To evaluate more functions, go to Step 4. Otherwise Key 0 _ , _ 0 [CR/LF] or Key [RESET].

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WANG 2200 SERIES PROGRAM

GAMMA FUNCTION

TITLE

PS.02-2200.01A-00FI-42-0 6/1/73

NUMBER DATE

2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Evaluates the gamma function, $\Gamma(X)$, by a polynomial approximation $(-50 < X < 50)$.

BLOCK	SAVE "NAME"	BYTES REQUIRED
42		882

Printed in U.S.A.

PROGRAM DESCRIPTION

Evaluates the gamma function, $\Gamma(X)$, by a polynomial approximation. $(-50 < X < 50)$.

$$\Gamma(X) \approx 1 + b_1X + b_2X^2 + \ldots + b_8X^8, \quad 0 \leq X \leq 1$$

where:

$b_1 = -.57719165$ $\qquad$ $b_5 = -.75670408$

$b_2 = .98820589$ $\qquad$ $b_6 = .48219939$

$b_3 = -.89705694$ $\qquad$ $b_7 = -.19352782$

$b_4 = .91820686$ $\qquad$ $b_8 = .03586834$

The program also uses the following formulae:

$$\Gamma(X+P) = (X+P-1)\,(X+P-2) \ldots X\Gamma(X), \quad X > 0, \quad P = 1, 2, \ldots$$

$$\Gamma(X) = \frac{\Gamma(X+1)}{X}, \quad 0 < X < \infty$$

$$\Gamma^{(X)} = \frac{\Gamma(X+n)}{X(X+1) \ldots (X+n-1)}, \quad -n < X < -n+1, \quad n = 1, 2, \ldots$$

Ref. 1: Abramowitz, M., "Handbook of Mathematical Functions", National Bureau of Standards Applied Mathematics Series .55, May, 1968, p. 257.

Ref. 2: Widder, David V., "Advanced Calculus", Second Edition, Prentice-Hall, Inc. 1961, p. 368.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.

OPERATING INSTRUCTIONS

EXAMPLE

Compute

$\Gamma(6)$, $\Gamma(4.5)$, $\Gamma(1.25)$

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION

INPUT X. TO END PROGRAM INPUT 0.
?

4. Key X [CR/LF]

4. Key 6 [CR/LF]

5. Read Answer

GAMMA(X) = 120

6. INSTRUCTION

X?

If you wish to evaluate the gamma function of other X-values, go to Step 4. Otherwise, Key 0 [CR/LF] or Key [RESET].

X?

Key 4 . 5 [CR/LF]

GAMMA(X) = 11.63172932681

X?

Key 1 . 2 5 [CR/LF]

GAMMA(X) = .9064026774233

X?

Key 0 [CR/LF]

END PROGRAM

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WANG 2200 SERIES PROGRAM

FOURIER ANALYSIS (DEFINED FUNCTION)
TITLE

PS.02-2200.01A-00FI-43-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Calculates the Fourier coefficients of a given 2 periodic function on a discrete set of 2N+1 equally spaced X-values.

BLOCK	SAVE "NAME"	BYTES REQUIRED
43		2102

Printed in U.S.A.

PROGRAM DESCRIPTION

Calculates the Fourier coefficients of a given 2 periodic function on a discrete set of 2N+1 equally spaced X-values. The maximum harmonic, H, to be calculated must be $\leq$N (N=35).

After the coefficients have been determined, the user may evaluate the Fourier series:

$$P(X) = A_0 + A_1 \cos(X) + A_2 \cos(2X) + \ldots + A_H \cos(HX) +$$

$$B_1 \sin(X) + B_2 \sin(2X) + \ldots + B_H \sin(HX)$$

at values of X which are inputed.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

NOTE

X is in radians, to change to degrees:

Key 7, [SELECT], D, [CR/LF]

OPERATING INSTRUCTIONS

EXAMPLE

Find the Fourier coefficients of

$$C(X) = \sin(2X) - (\cos((3X)))^2$$

and evaluate at X = 1.1, 2.01

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

Enter the function, f(x), on line 1 of the program as follows:

1 DEFFNC(X) = f(x)

For example, $f(x) = X^2 \cos(X) + \tan(2X)$ is entered as follows:

1 DEFFN C(X) = X ▲ 2 * cos(X) + tan (2*X)

2. Key 1 [DEFFN] C (X) = f(x) [CR/LF]

2. Key 1 [DEFFN] C (X) = sin(2 * X) - cos(3 * X) ▲ 2 [CR/LF]

3. Key [RUN] [CR/LF]

4. INSTRUCTION — INPUT MAXIMUM HARMONIC TO BE CALCULATED (N)?

5. Key MAXIMUM HARMONIC [CR/LF]

5. Key 6 [CR/LF]

6. Read Answer:

HARMONIC	COSINE COEFF.	SINE COEFF.
0	-.500000001803	0
1	-1.81750140E-08	-1.38243564E-08
2	-8.87098591E-08	.9999999937225
3	-1.45801126E-08	3.14800495E-08
4	-9.10983098E-09	2.06609362E-08
5	7.91183098E-09	1.76607480E-08
6	-.5000000190806	-9.11558356E-08

OPERATING INSTRUCTIONS (Cont)

7.	INSTRUCTION	INPUT X-VALUE TO BE EVALUATED. TO END PROGRAM INPUT 99999 ?
8.	Key X-VALUE [CR/LF]	8. Key 1 . 1 [CR/LF]
9.	Read Answer	Y = -.166619928209
10.	INSTRUCTION	X?

If you wish to evaluate function at other X-values, go to Step 8.
Otherwise, either Key 9 9 9 9 9 [CR/LF] or Key [RESET]

X? 2.01

Y = -1.706978344707

X? 99999

END PROGRAM

WANG 2200 SERIES PROGRAM

FOURIER ANALYSIS (TABULATED FUNCTION)
TITLE

PS.02-2200.01A-00FI-44-0 6/1/73
NUMBER DATE

2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Calculates the Fourier coefficients of a tabulated function in the range 0 to 2π.

BLOCK	SAVE "NAME"	BYTES REQUIRED
44		1528

Printed in U.S.A.

PROGRAM DESCRIPTION

Calculates the Fourier coefficients of a tabulated function in the range 0 to 2π. We assume the interval is divided into 2N+1 subintervals and 2N+1 observations (f((0)), f((1)), . . ., f((2N+1))) have been made corresponding to $X = 2(K-1)\pi/(2N+1)$ for K = 1, 2, . . ., 2N+1. The maximum harmonic, H, to be calculated must be $\leq$ N.

After the coefficients have been determined, the user may evaluate the Fourier series:

$$P(X) = A_0 + A_1 \cos(X) + A_2 \cos(2X) + \ldots + A_H \cos(HX) +$$

$$B_1 \sin(X) + B_2 \sin(2X) + \ldots + B_H \sin(HX)$$

at values of X which are inputed.

NOTE

X is in radians, to change to degree:

Key 5 [SELECT] D [CR/LF]

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

OPERATING INSTRUCTIONS

EXAMPLE

N = 2

$\mu_0 = 0,\ \mu_1 = 1,\ \mu_2 = 2,\ \mu_3 = 1,\ \mu_4 = 0$

H = 2

Evaluate for X = 0, .9

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION

   INPUT N
   ?

> # of observations is equal to 2N+1. For example if you have 11 observations, 2N+1 = 11, N = 5.

4. Key N [CR/LF]

4. Key 2 [CR/LF]

5. INSTRUCTION

   INPUT VALUES OF FUNCTION (4/LINE)

> The observed values of the function are inputed 4/line. The last line must be completed with zeroes to make a set of 4. For example, the observed values, 1, 2, 3, 4, 5 are inputed as follows:
>
> 1, 2, 3, 4
> 5, 0, 0, 0
>
> Please note: Each coefficient is separated by a comma.

OPERATING INSTRUCTIONS (Cont)

6.	Key μ_0 , μ_1 , μ_2 , μ_3 CR/LF Key μ_4 , μ_5 , μ_6 μ_7 CR/LF Continue until all observed values have been entered.	6. Key 0 , 1 , 2 , 1 CR/LF Key 0 , 0 , 0 , 0 CR/LF
7.	INSTRUCTION	INPUT MAXIMUM HARMONIC TO BE CALCULATED (<= N). ?
8.	Key MAX. HARMONIC CR/LF	8. Key 2 CR/LF
9.	Read Answer	HARMONIC COSINE COEFF. SINE COEFF. 0 .8 0 1 -.84721369268 .6155366676791 2 4.72136008E-02 -.1453084854912
10.	INSTRUCTION	INPUT X-VALUE TO BE EVALUATED TO END PROGRAM INPUT 99999 ?
11.	Key X CR/LF	11. Key 0, CR/LF
12.	Read Answer	Y = -6.03180000E-09
13.	INSTRUCTION	INPUT X ?

If you wish to evaluate function for other X-values go to Step 11.
Otherwise, either Key 9 9 9 9 9 CR/LF or Key RESET .

.9

Y = .6032946589709

Input X

99999

END PROGRAM

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