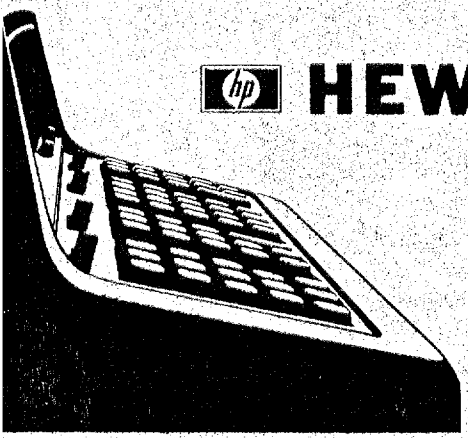
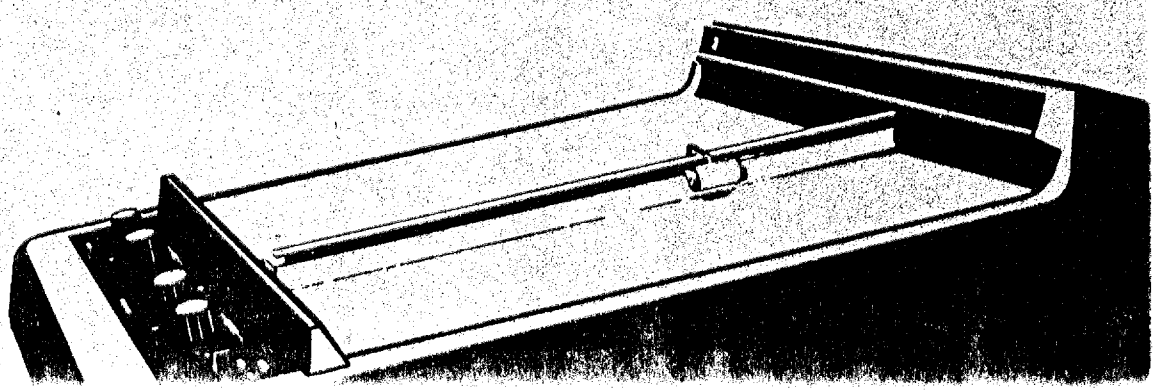


# HEWLETT PACKARD X-Y PLOTTER

Model 9125A

# PROGRAMS



MISCELLANEOUS 09100-76000

76006 - PLOTTER DIAGNOSTIC
This program checks the 9125A for proper execution of commands received from the 9100A.

MATHEMATICS 09100-70000

70026 - MAXIMUM AND MINIMUM OF $y = f(x)$
This program will calculate the approximate maximum and minimum of an analytic function over a given range.

70027 - PLOT OF $y = f(x)$
This program will plot the curve specified by a given analytic function.

70028 - FIRST ORDER DIFFERENTIAL EQUATION PLOT
This program uses a Runge Kutta method to numerically solve a 1st order differential equation and plots the solution for incremented values of the independent variable.

70029 - MAXIMUM AND MINIMUM OF $r = f(\theta)$
This program will calculate the approximate maximum and minimum of a given function with variables in polar coordinates.

70030 - PLOT OF $r = f(\theta)$
This program will plot the curve of a function $r = f(\theta)$ in polar coordinates.

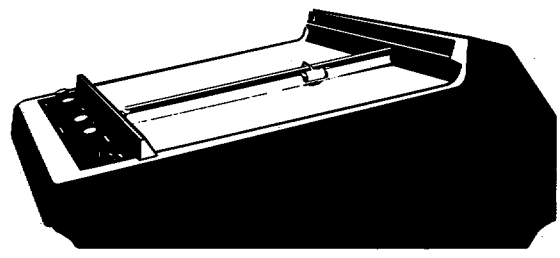
STATISTICS 09100-70800

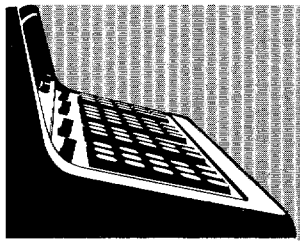
70818 - LINEAR REGRESSION PLOT
This program will plot the set of data points entered by the user and the least squares linear curve determined by these points.

70819 - PARABOLIC REGRESSION AND PLOT
This program will plot the set of data points entered by the user and the least squares second degree curve determined by these points.

70820 - EXPONENTIAL REGRESSION AND PLOT
This program will plot the set of data points entered by the user and the least squares curve of the form $y = ae^{-bx}$ determined by these points.

70821 - POWER CURVE REGRESSION AND PLOT
This program will plot the set of data points entered by the user and plot the least squares curve of the form $y = ax^b$ determined by these points.





PART NO.
09100-76006

# PLOTTER DIAGNOSTIC

The purpose of the Plotter Diagnostic is to test every programmable operation of the 9125A for proper execution.

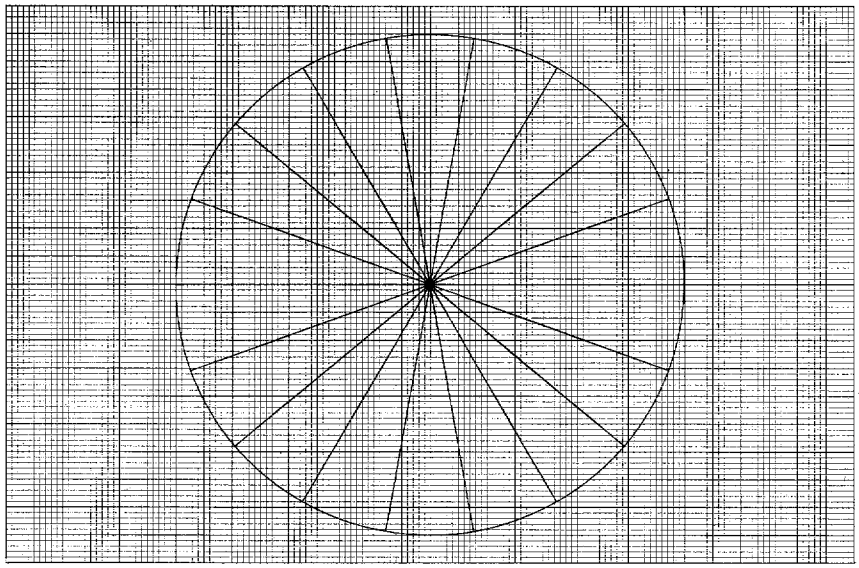
To run the Diagnostic follow these directions:

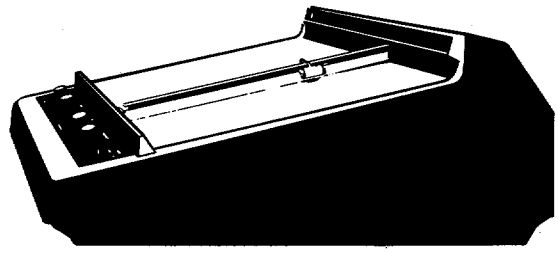
Using Hewlett-Packard graph paper, calibrate the Plotter as explained in the Calibration Section of the Operating Manual.

SET: [ ] [ ON ] on the Calculator and Plotter
SET: [ ] [ RUN ]
SET: [ DEGREES ] [ ]
SET: Decimal Wheel at 3
PRESS: STOP
Set the Origin controls on the 9125A so that the pen is in the middle of the full-size (11" x 17") recording paper.
PRESS: END
Insert the magnetic card into the cardreader.
PRESS: [ ENTER ]
PRESS: END
PRESS: CONTINUE

Proper execution of the program and proper operation of the Plotter is indicated by a circle enclosing 18 spokes.

The 9125A is operating correctly if the circle is well-formed and the spokes are retraced exactly showing only one line width per spoke. The exact diameter of the circle depends where the sensitivity controls are set, but it should be 9 " ± 0.25".





PART NO. 09100-76006

HEWLETT·PACKARD

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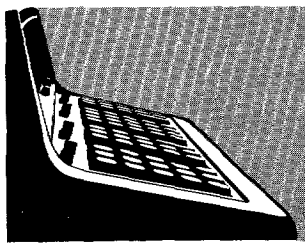
HEWLETT·PACKARD

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 0 | CLEAR | 20 | | | |
| 0 1 | 2 | 02 | | | |
| 0 2 | 2 | 02 | | | |
| 0 3 | 5 | 05 | | | |
| 0 4 | 0 | 00 | | | |
| 0 5 | x→( ) | 23 | | | |
| 0 6 | a | 13 | | | |
| 0 7 | CLEAR x | 37 | | | |
| 0 8 | ↑ | 27 | | | |
| 0 9 | FMT | 42 | | | |
| 0 a | ↓ | 25 | | | |
| 0 b | e | 12 | | | |
| 0 c | ↑ | 27 | | | |
| 0 d | a | 13 | | | |
| 1 0 | TO RECT | 66 | | | |
| 1 1 | FMT | 42 | | | |
| 1 2 | ↓ | 25 | | | |
| 1 3 | e | 12 | | | |
| 1 4 | ↑ | 27 | | | |
| 1 5 | 2 | 02 | | | |
| 1 6 | 0 | 00 | | | |
| 1 7 | + | 33 | | | |
| 1 8 | y→( ) | 40 | | | |
| 1 9 | e | 12 | | | |
| 1 a | 3 | 03 | | | |
| 1 b | 5 | 05 | | | |
| 1 c | 1 | 01 | | | |
| 1 d | IF x>y | 53 | | | |
| 2 0 | 0 | 00 | | | |
| 2 1 | 7 | 07 | | | |
| 2 2 | CLEAR | 20 | | | |
| 2 3 | FMT | 42 | | | |
| 2 4 | ↓ | 25 | | | |
| 2 5 | FMT | 42 | | | |
| 2 6 | ↑ | 27 | | | |
| 2 7 | a | 13 | | | |
| 2 8 | TO RECT | 66 | | | |
| 2 9 | FMT | 42 | | | |
| 2 a | ↓ | 25 | | | |
| 2 b | TO POLAR | 62 | | | |
| 2 c | 2 | 02 | | | |
| 2 d | ↑ | 27 | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 3 0 | ACC + | 60 | | | |
| 3 1 | RCL | 61 | | | |
| 3 2 | 3 | 03 | | | |
| 3 3 | 6 | 06 | | | |
| 3 4 | 0 | 00 | | | |
| 3 5 | IF x<y | 52 | | | |
| 3 6 | 3 | 03 | | | |
| 3 7 | b | 14 | | | |
| 3 8 | GO TO( )( ) | 44 | | | |
| 3 9 | 2 | 02 | | | |
| 3 a | 7 | 07 | | | |
| 3 b | CLEAR | 20 | | | |
| 3 c | FMT | 42 | | | |
| 3 d | ↑ | 27 | | | |
| 4 0 | END | 46 | | | |
| 4 1 | | | | | |
| 4 2 | | | | | |
| 4 3 | | | | | |
| 4 4 | | | | | |
| 4 5 | | | | | |
| 4 6 | | | | | |
| 4 7 | | | | | |
| 4 8 | | | | | |
| 4 9 | | | | | |
| 4 a | | | | | |
| 4 b | | | | | |
| 4 c | | | | | |
| 4 d | | | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 | | | | | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| a | | | | | |
| b | | | | | |
| c | | | | | |
| d | | | | | |

| Storage |
|---|
| F |
| E |
| D |
| C |
| B |
| A |
| 9 |
| 8 |
| 7 |
| 6 |
| 5 |
| 4 |
| 3 |
| 2 |
| 1 |
| 0 |

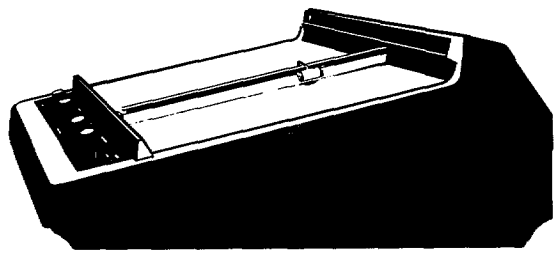


PART NO.
09100-70026

# MAXIMUM AND MINIMUM OF y = f(x)

This program will compute the approximate maximum and minimum of the function f(x) over a specified range of independent variable x.

The technique involved is a search over n increments of the range of x. n is specified by the user.



## USER INSTRUCTIONS

ENTER PROGRAM: (Starting address is 0-0)

PRESS: GO TO ( ) ( )

PRESS: 3

PRESS: c

SET: [PROGRAM] [ ]

Note: Starting at (3)(c), enter program steps which take the independent variable from the X register (x is also in the e register) and program f(x). Place f(x) in the Y register and exit to location 2-7. The last four instructions of the f(x) subroutine should be:

GO TO

2

7

END

Memory locations 3-c through 9-d are available for programming and storage of f(x). The flag is unavailable.

SET: [ ] [RUN]

PRESS: END

PRESS: CONTINUE

ENTER DATA:

$n \rightarrow Z$ n = number of points scanned

$X_{max} \rightarrow Y$

$X_{min} \rightarrow X$

PRESS: CONTINUE

DISPLAY

$0$ ——— Z

$Y_{max}$ ——— Y

$Y_{min}$ ——— X

To enter new range of the independent variable x

To enter new function

Note: To record y = f(x) on the program card replace the END instruction in location 3-b with a STOP instruction.

## EXAMPLE

$$y = \frac{\sin x}{x} \qquad x_{max} = 6\pi \qquad x_{min} = -6\pi$$

SET: [ ] [RADIANS]

The steps which generate f(x) are:

| LOCATION | OPERATION |
|---|---|
| 3 - a | ↑ |
| 3 - b | sin x |
| 3 - c | x ⇄ y |
| 3 - d | ÷ |
| 4 - 0 | GO TO ( )( ) |
| 4 - 1 | 2 |
| 4 - 2 | 7 |
| 4 - 3 | END |

Let: n = 50

Solution:

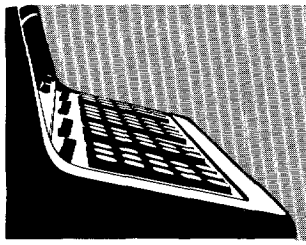
$Y_{max} = 1.000$

$Y_{min} = -.217$

| Step | | Key | Code | Display x | Display y | Display z | Storage f | e | d | c | b | a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | CONTINUE | 47 | | | | | | | | | | |
| | 1 | CLEAR | 20 | | | | | | | | | | ENTER max AND min VALUES OF THE INDEPENDENT VARIABLE, X AND n, THE NUMBER OF POINTS IN THE INTERVAL THAT ARE SCANNED |
| | 2 | STOP | 41 | $X_{min}$ | $X_{max}$ | n | | | | | | | |
| | 3 | x→( ) | 23 | | | | | | | | | | STORE $X_{min}$ AND $X_{max}$ |
| | 4 | c | 16 | | | | | | | | | | |
| | 5 | y→( ) | 40 | | | | | | | | | | |
| | 6 | a | 13 | | | | | | | | | | |
| | 7 | − | 34 | | | | | | | | | | CALCULATE $\Delta X$, INITIALIZE $X_i$, AND STORE $(\Delta X = \frac{X_{max} - X_{min}}{n})$ |
| | 8 | ROLL ↓ | 31 | | | | | | | | | | |
| | 9 | x⇄y | 30 | | | | | | | | | | |
| | a | ÷ | 35 | | | | | | | | | | |
| | b | ROLL ↓ | 31 | | | | | | | | | | |
| | c | − | 34 | | | | | | | | | | |
| | d | ACC + | 60 | | | | | | | | | | |
| 1 | 0 | ENTER EXP | 26 | | | | | | | | | | INITIALIZE STORAGE REGISTERS FOR $X_{min}$ AND $X_{max}$ TO $10^{99}$ AND $10^{-99}$ RESPECTIVELY |
| | 1 | 9 | 11 | | | | | | | | | | |
| | 2 | 9 | 11 | | | | | | | | | | |
| | 3 | x→( ) | 23 | | | | | | | | | | |
| | 4 | d | 17 | | | | | | | | | | |
| | 5 | CHG SIGN | 32 | | | | | | | | | | |
| | 6 | x→( ) | 23 | | | | | | | | | | |
| | 7 | b | 14 | | | | | | | | | | |
| FROM 3-3 → | 8 | RCL | 61 | | | | | | | | | | $X_i = X_i + \Delta X$ |
| | 9 | + | 33 | | | | | | | | | | |
| | a | a | 13 | | | | | | | | | | |
| | b | SET FLAG | 54 | | | | | | | | | | |
| | c | IF x<y | 52 | | | | | | | | | | TEST FOR $X_i = X_{max}$ |
| | d | x⇄y | 30 | | | | | | | | | | |
| 2 | 0 | IF FLAG | 43 | | | | | | | | | | |
| | 1 | y→( ) | 40 | | | | | | | | | | |
| | 2 | e | 12 | | | | | | | | | | STORE $X_i$ IN e AND x REGISTERS |
| | 3 | ↓ | 25 | | | | | | | | | | |
| | 4 | GO TO( )( ) | 44 | | | | | | | | | | |
| | 5 | 3 | 03 | | | | | | | | | | CALCULATE $Y_i = f(X_i)$ |
| | 6 | ~~R~~C | 13 | | | | | | | | | | 16 |
| FROM Y=f(x) CALCULATION → | 7 | d | 17 | | | | | | | | | | |
| | 8 | IF x>y | 53 | | | | | | | | | | |
| | 9 | y→( ) | 40 | | | | | | | | | | |
| | a | d | 17 | | | | | | | | | | TEST FOR NEW $Y_{min}$ OR $Y_{max}$ |
| | b | b | 14 | | | | | | | | | | |
| | c | IF x<y | 52 | | | | | | | | | | |
| | d | y→( ) | 40 | | | | | | | | | | |

PART NO. 09100-70026

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0 | b | 14 | | | | | | | | | |
| | 1 | IF FLAG | 43 | | | | | | | | | |
| | 2 | 1 | 01 | | | | | | | | | |
| | 3 | 8 | 10 | | | | | | | | | |
| | 4 | CLEAR x | 37 | DISPLAY RESULTS IF THROUGH, IF | | | | | | | | |
| | 5 | ↑ | 27 | NOT CONTINUE CALCULATION | | | | | | | | |
| | 6 | b | 14 | | | | | | | | | |
| | 7 | ↑ | 27 | | | | | | | | | |
| | 8 | d | 17 | | | | | | | | | |
| | 9 | CONTINUE | 47 | | | | | | | | | |
| | a | CONTINUE | 47 | | | | | | | | | |
| | b | END | 46 | $Y_{min}$ | $Y_{max}$ | 0 | DISPLAY | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |
| | 0 | | | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |
| | 0 | | | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |

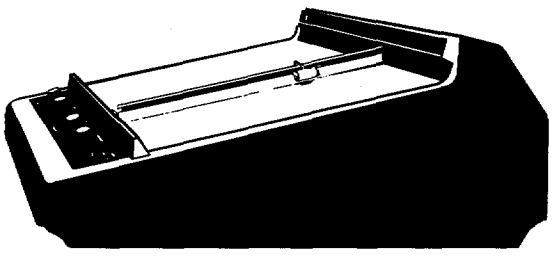


PART NO.
09100-70027

# PLOT OF y = f(x)

This program will plot the function of y = f(x) in rectangular coordinates. The number of plot points per inch, n, is specified by the user, as also are the plotting constants.

The program was written to be used in conjunction with program 09100-70026, Maximum and Minimum of y = f(x).



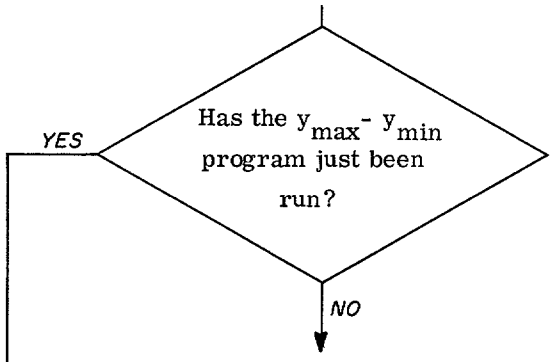
## USER INSTRUCTIONS

PRESS: STOP

Use the Origin controls to place the pen in the lower left corner of the paper. (At the intersection of the border lines if chart paper is used.)

SET: Decimal wheel at 6 or less

ENTER PROGRAM: (Starting address is 0-0)




PRESS: GO TO ( )( )

PRESS: 3

PRESS: c

SET: PROGRAM

Note: Starting at (3)(c), enter program steps which take the independent variable from the X register (x is also in the e register) and program f(x). Place f(x) in the Y register and exit to location 2-7. The last four instructions of the f(x) subroutine should be:

GO TO

2

7

END

Memory locations 3-c through 9-d are available for programming and storage of f(x). The flag is available.

SET: RUN

PRESS: END

PRESS: CONTINUE

ENTER CONSTANTS*:

$y_{shift}$ → Y

$x_{shift}$ → X

## USER INSTRUCTIONS (con't)

PRESS: CONTINUE

ENTER CONSTANTS*:

n → Z plot points/inch

$y_{scale}$ → Y

$x_{scale}$ → X

PRESS: CONTINUE

Note: The function f(x) will now be plotted. To interrupt or stop the plot at its completion, PRESS: STOP.

To re-run program, return to beginning of USER INSTRUCTIONS and proceed as before. The magnetic card need not be re-entered.

* See general Plotter instructions.

## EXAMPLE

Plot $y = \frac{\sin x}{x}$ for $-6\pi \leq x \leq 6\pi$

SET: RADIANS

Run the max-min of f(x) program. Letting n = 50 in this program, we find that

$$y_{min} \approx -.22$$

$$y_{max} \approx 1.$$

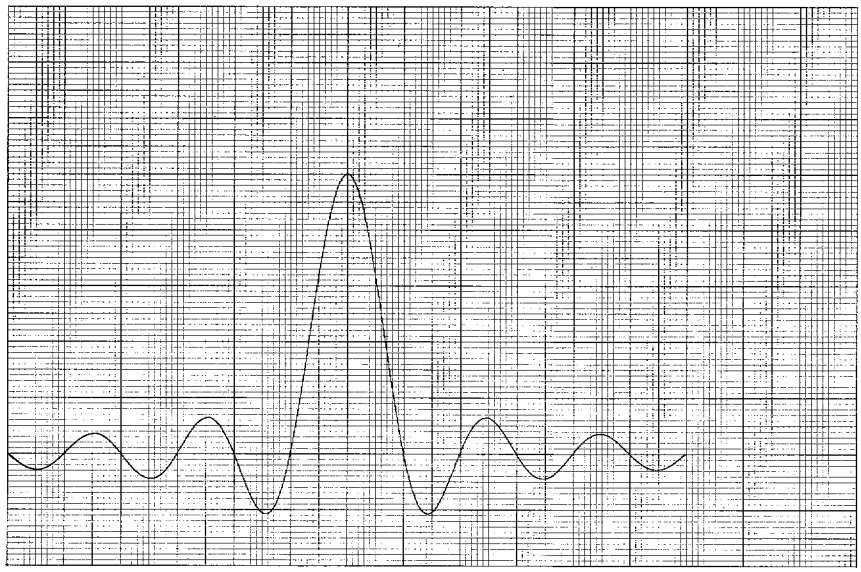
Choose $y_{scale} = \frac{1 - (-.22)}{10} \approx .15 \ \frac{\text{units}}{\text{inch}}$

$y_{shift} = -.4$

$x_{scale} = \frac{6\pi - (-6\pi)}{15} \approx \pi$ units/inch

$x_{shift} = -6\pi$ units

n = 15 plot points/inch



PART NO. 09100-70027



| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | CLEAR | 20 | | | | | | | | | | |
| | 1 | STOP | 41 | $X_{shift}$ | $Y_{shift}$ | 0 | | | | | | | ENTER TRANSLATION CONSTANTS |
| | 2 | $x\rightarrow()$ | 23 | | | | | | | | | | |
| | 3 | c | 16 | | | | | | | | | | STORE TRANSLATION CONSTANTS |
| | 4 | $y\rightarrow()$ | 40 | | | | | | | | | | |
| | 5 | d | 17 | | | | | | | | | | |
| | 6 | CLEAR | 20 | | | | | | | | | | |
| | 7 | STOP | 41 | $X_{scale}$ | $Y_{scale}$ | n | | | | | | | ENTER SCALING CONSTANTS AND NUMBER OF POINTS PER INCH TO BE PLOTTED |
| | 8 | ROLL ↑ | 22 | | | | | | | | | | |
| | 9 | ÷ | 35 | | | | | | | | | | CALCULATE AND STORE $\Delta X = \frac{X_{scale}}{n}$ |
| | a | $y\rightarrow()$ | 40 | | | | | | | | | | |
| | b | b | 14 | | | | | | | | | | |
| | c | × | 36 | | | | | | | | | | |
| | d | 5 | 05 | | | | | | | | | | |
| 1 | 0 | 0 | 00 | | | | | | | | | | |
| | 1 | 0 | 00 | | | | | | | | | | |
| | 2 | ÷ | 35 | | | | | | | | | | |
| | 3 | $y\rightarrow()$ | 40 | | | | | | | | | | CALCULATE AND STORE $\frac{X_{scale}}{500}$ AND $\frac{500}{Y_{scale}}$ |
| | 4 | a | 13 | | | | | | | | | | |
| | 5 | ROLL ↑ | 22 | | | | | | | | | | |
| | 6 | ÷ | 35 | | | | | | | | | | |
| | 7 | b | 14 | | | | | | | | | | |
| | 8 | $y\rightarrow()$ | 40 | | | | | | | | | | |
| | 9 | b | 14 | | | | | | | | | | |
| | a | ↑ | 27 | | | | | | | | | | |
| | b | c | 16 | | | | | | | | | | |
| | c | $x\rightleftarrows y$ | 30 | | | | | | | | | | INITIALIZE X TO $X_{shift} - \Delta X$ AND STORE |
| | d | − | 34 | | | | | | | | | | |
| 2 | 0 | ACC + | 60 | | | | | | | | | | |
| | 1 | RCL | 61 | | | | | | | | | | |
| | 2 | + | 33 | | | | | | | | | | |
| | 3 | $y\rightarrow()$ | 40 | | | | | | | | | | CALCULATE, STORE AND POSITION $X = X + \Delta X$ |
| | 4 | e | 12 | | | | | | | | | | |
| | 5 | ↓ | 25 | | | | | | | | | | |
| | 6 | GO TO ( )( ) | 44 | | | | | | | | | | |
| | 7 | 3 | 03 | | | | | | | | | | BRANCH TO CALCULATE f(x) |
| | 8 | c | 16 | | | | | | | | | | |
| | 9 | d | 17 | | | | | | | | | | |
| | a | − | 34 | | | | | | | | | | CALCULATE $Y_{plot} = \frac{500}{Y_{scale}} [Y - Y_{shift}]$ |
| | b | b | 14 | | | | | | | | | | |
| | c | × | 36 | | | | | | | | | | |
| | d | e | 12 | | | | | | | | | | |

FROM 3-a

PART NO. 09100-70027

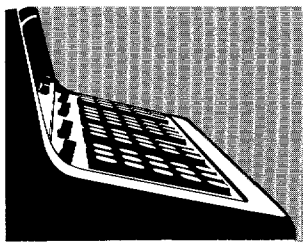
| Step | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 0 | ↑ | 27 | | | | | | | | | |
| 1 | ⊏ | 16 | | | | | | | | | |
| 2 | — | 34 | | | | | | | | | |
| 3 | a | 13 | | | | | | | | | |
| 4 | ÷ | 35 | | | | | | | | | |
| 5 | ↓ | 25 | | | | | | | | | |
| 6 | FMT | 42 | | | | | | | | | |
| 7 | ↓ | 25 | | | | | | | | | |
| 8 | GO TO ( )( ) | 44 | | | | | | | | | |
| 9 | 2 | 02 | | | | | | | | | |
| a | 1 | 01 | | | | | | | | | |
| b | END | 46 | | | | | | | | | |
| c | | | | | | | | | | | |
| d | | | | | | | | | | | |
| 0 | | | | | | | | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| a | | | | | | | | | | | |
| b | | | | | | | | | | | |
| c | | | | | | | | | | | |
| d | | | | | | | | | | | |
| 0 | | | | | | | | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| a | | | | | | | | | | | |
| b | | | | | | | | | | | |
| c | | | | | | | | | | | |
| d | | | | | | | | | | | |

CALCULATE $X_{plot} = \frac{500}{X_{scale}} [X - X_{shift}]$

PLOT THE CALCULATED LINE SEGMENT

BRANCH TO CALCULATE NEXT PLOT COORDINATES

FROM 2-8



PART NO.
09100-70028

# 1st ORDER DIFFERENTIAL EQUATION PLOT

This program may be used to solve and plot the solution of a wide variety of first order (homogenous or non-homogenous, linear or non-linear) differential equations of the form

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

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

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

where

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

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

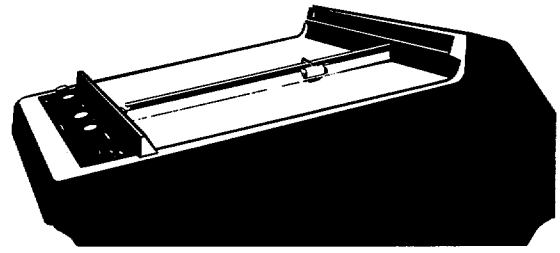
$$r = hf(X_i + \frac{h}{2}, Y_i + \frac{q}{2})$$

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

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

The solution is plotted as successive $Y_i$'s are calculated.

Reference: Numerical Analysis
by Kaiser S. Kunz
McGraw-Hill Book Co., Inc. 1957



## USER INSTRUCTIONS

PRESS: STOP

Using the Origin controls, locate the pen in the lower left corner of the paper.

SET: Decimal Wheel at 6 or less

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

PRESS: GO TO (0)(4)

SET: PROGRAM

ENTER $X_{shift}$: Instruction locations 0-4 through 0-7 are available.*

PRESS: STEP PROGRAM

ENTER $X_{scale}$: Instruction locations 0-9 through 0-b are available.*

PRESS: STEP PROGRAM

ENTER $Y_{shift}$: Instruction locations 0-d through 1-2 are available.*

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

ENTER $Y_{scale}$: Instruction locations 1-5 through 1-7 are available.*

*PRESS: CONTINUE to fill in any instruction locations not used.

SET: RUN

PRESS: GO TO (2)(8)

PRESS: CONTINUE

DISPLAY

0 —— Z
0 —— Y
1 —— X

ENTER INITIAL CONDITIONS: $Y_o \rightarrow Z$, $X_o \rightarrow Y$, $h \rightarrow X$

PRESS: CONTINUE

DISPLAY

0 —— Z
0 —— Y
2 —— X

PRESS: GO TO (2)(8)

SET: PROGRAM

## USER INSTRUCTIONS (con't)

Starting at instruction location 2-8, enter the program steps which take X from the X register (also in the e register) and Y from the Y register (also in the d register) and generate f(x, y). Leave f(x, y) in the Y register and fill in the remaining instruction locations with continues. Note that 43 locations are available (2-8 through 5-8).

SET: RUN

PRESS: GO TO (2)(5)

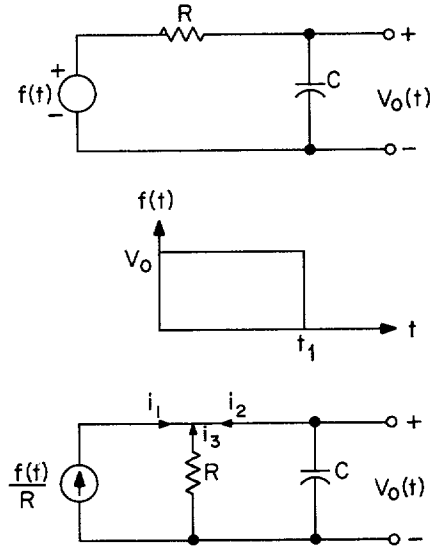
PRESS: CONTINUE

At each increment of the independent variable, the following display will be observed:

0 —— Z
$Y_i$ —— Y
$X_i$ —— X

and the line segment between successive solution points will be plotted.

## EXAMPLE




$V_o(0) = 0$
$t_o = 0$
$h = .05$

$$i_1 + i_2 + i_3 = 0$$

$$\frac{f(t)}{R} - \frac{V_o(t)}{R} - C\frac{dV_o(t)}{dt} = 0$$

Initial Conditions: $t_o = 0$, $V_o(0) = 0$

$$\frac{dV_o(t)}{dt} = -\frac{V_o(t)}{CR} + \frac{f(t)}{CR}$$

Increment h = .05

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

EXAMPLE (con't)

The equation becomes

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

$$\frac{dV_o(t)}{dt} = -V_o(t); \quad t > 4$$

The program steps that form $V_o = f(t, V_o)$ appear on Page. 1. See User Instructions.

Let:

$X_{shift} = 0$ units $\qquad Y_{shift} = 0$ units

$X_{scale} = 1 \frac{units}{inch} \qquad Y_{scale} = \frac{.1 \text{ units}}{inch}$

The steps which enter these values are given below.

PRESS: GO TO (0)(4)

SET: [PROGRAM] [ ]

PRESS: 0

PRESS: CONTINUE

PRESS: CONTINUE

PRESS: CONTINUE

EXAMPLE (con't)

PRESS: STEP PROGRAM

PRESS: 1

PRESS: CONTINUE

PRESS: CONTINUE

PRESS: STEP PROGRAM

PRESS: 0

PRESS: CONTINUE

PRESS: CONTINUE

PRESS: CONTINUE

PRESS: STEP PROGRAM

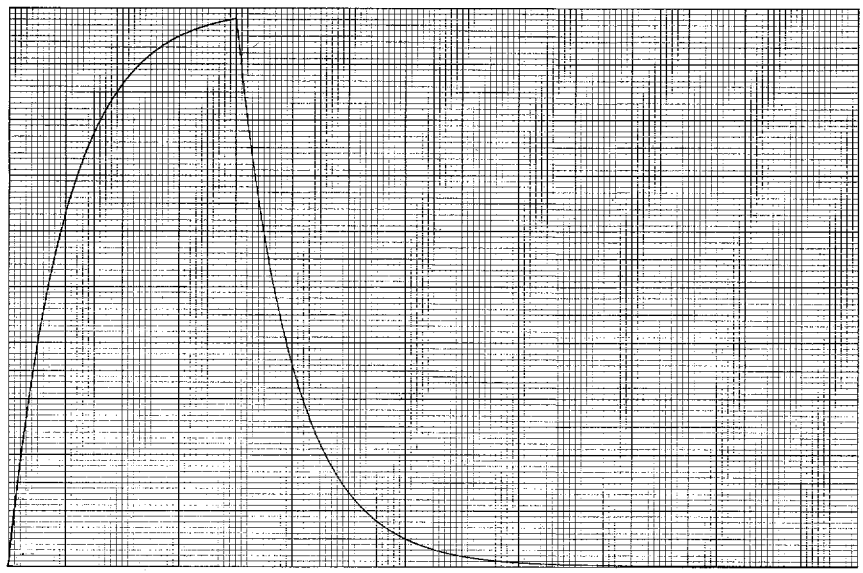
PRESS: STEP PROGRAM

PRESS: .

PRESS: 1

PRESS: CONTINUE

SET: [ ] [RUN]



| Step | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 0 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | t | $V_o$ | | | | | | | | |
| 8 | ↑ | 27 | | t | $V_o$ | | | | | | | COMPARE t TO 4 AND BRANCH TO APPROPRIATE DIFFERENTIAL EQUATION |
| 9 | 4 | 04 | 4 | | | | | | | | | |
| a | IF $x<y$ | 52 | | | | | | | | | | |
| b | 3 | 03 | | | | | | | | | | |
| c | 7 | 07 | | | | | | | | | | |
| d | ROLL ↑ | 22 | $V_o$ | 4 | t | | | | | | | $t \leq 4$ |
| 3 0 | CHG SIGN | 32 | $-V_o$ | | | | | | | | | |
| 1 | ↑ | 27 | | $-V_o$ | 4 | | | | | | | $\frac{dV_o(t)}{dt} = -V_o(t)+1$ |
| 2 | 1 | 01 | 1 | | | | | | | | | |
| 3 | + | 33 | | $1-V_o$ | | | | | | | | |
| 4 | GO TO ( )( ) | 44 | | | | | | | | | | |
| 5 | 5 | 05 | | | | | | | | | | EXIT |
| 6 | 9 | 11 | | | | | | | | | | |
| 7 | ROLL ↑ | 22 | $V_o$ | 4 | t | | | | | | | $t>4$ |
| 8 | CHG SIGN | 32 | $-V_o$ | | | | | | | | | $\frac{dV_o(t)}{dt} = -V_o(t)$ |
| 9 | ↑ | 27 | | $-V_o$ | 4 | | | | | | | |
| a | GO TO ( )( ) | 44 | | | | | | | | | | |
| b | 5 | 05 | | | | | | | | | | EXIT |
| c | 9 | 11 | | | | | | | | | | |
| d | | | | | | | | | | | | |
| 0 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| a | | | | | | | | | | | | |
| b | | | | | | | | | | | | |
| c | | | | | | | | | | | | |
| d | | | | | | | | | | | | |

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| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FROM 7-b → 0 | 0 | PAUSE | 57 | | | | | | $Y_o$ | h | $X_o$ | |
| | 1 | PAUSE | 57 | | | | | | | | | |
| | 2 | PAUSE | 57 | | | | | | | | | |
| | 3 | ↑ | 27 | | | | | | | | | |
| | 4 | CONTINUE | 47 | | | | | | | | | |
| | 5 | CONTINUE | 47 | | | | | | | | | |
| | 6 | CONTINUE | 47 | | | | | | | | | |
| | 7 | CONTINUE | 47 | | | | | | | | | |
| | 8 | − | 34 | | | | | | | | | |
| | 9 | CONTINUE | 47 | | | | | | | | | |
| | a | CONTINUE | 47 | | | | | | | | | |
| | b | CONTINUE | 47 | | | | | | | | | |
| | c | ÷ | 35 | | | | | | | | | |
| | d | CONTINUE | 47 | | | | | | | | | |
| 1 | 0 | CONTINUE | 47 | | | | | | | | | |
| | 1 | CONTINUE | 47 | | | | | | | | | |
| | 2 | CONTINUE | 47 | | | | | | | | | |
| | 3 | ROLL ↑ | 22 | | | | | | | | | |
| | 4 | − | 34 | | | | | | | | | |
| | 5 | CONTINUE | 47 | | | | | | | | | |
| | 6 | CONTINUE | 47 | | | | | | | | | |
| | 7 | CONTINUE | 47 | | | | | | | | | |
| | 8 | CHG SIGN | 32 | | | | | | | | | |
| | 9 | ÷ | 35 | | | | | | | | | |
| | a | 5 | 05 | | | | | | | | | |
| | b | 0 | 00 | | | | | | | | | |
| | c | 0 | 00 | | | | | | | | | |
| | d | × | 36 | | | | | | | | | |
| 2 | 0 | ROLL ↑ | 22 | | | | | | | | | |
| | 1 | × | 36 | | | | | | | | | |
| | 2 | ↓ | 25 | | | | | | | | | |
| | 3 | FMT | 42 | | | | | | | | | |
| | 4 | ↓ | 25 | | | | | | | | | |
| | 5 | d | 17 | | | | | | | | | |
| | 6 | ↑ | 27 | | | | | | | | | |
| | 7 | b | 14 | | | | | | | | | |
| | 8 | CLEAR | 20 | | | | | | | | | |
| | 9 | 1 | 01 | | | | | | | | | |
| | a | STOP | 41 | h | $X_o$ | ~~$X_o$~~ $Y_o$ | | | | | | |
| | b | x→( ) | 23 | | | | | | | | | |
| | c | c | 16 | | | | | | | | | |
| | d | y→( ) | 40 | | | | | | | | | |

ENTER $X_{shift}$ HERE

ENTER $X_{scale}$ HERE

ENTER $Y_{shift}$ HERE

ENTER $Y_{scale}$ HERE

CALCULATE $X_{plot}$ AND $Y_{plot}$

PLOT $X_{plot}$ AND $Y_{plot}$

RECALL $X_i$ AND $Y_i$

SET STEP INDICATOR

ENTER INITIAL CONDITIONS AND INCREMENT

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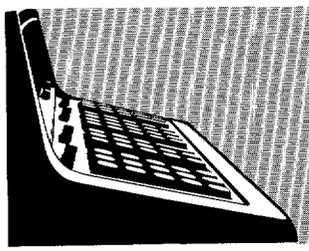
| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0 | b | 14 | | | | | | | | | | STORE ENTRIES |
| | 1 | ↓ | 25 | | | | | | | | | | |
| | 2 | y→( ) | 40 | | | | | | | | | | |
| | 3 | d | 17 | | | | | | | | | | |
| | 4 | CLEAR | 20 | | | | | | | | | | SET STEP INDICATOR |
| | 5 | 2 | 02 | | | | | | | | | | |
| | 6 | STOP | 41 | | | | | | | | | | |
| | 7 | CONTINUE | 47 | | | | | | | | | | |
| | 8 | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | |
| | a | | | | | | | | | | | | |
| | b | | | | | | | | | | | | |
| | c | | | | | | | | | | | | |
| | d | | | | | | | | | | | | |
| 4 | 0 | CONTINUE | 47 | | | | | | | | | | |
| | 1 | | | | | | | | | | | | |
| | 2 | | | | | | | | | | | | |
| | 3 | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | |
| | a | | | | | | | | | | | | |
| | b | | | | | | | | | | | | |
| | c | | | | | | | | | | | | |
| | d | | | | | | | | | | | | |
| 5 | 0 | CONTINUE | 47 | | | | | | | | | | |
| | 1 | | | | | | | | | | | | |
| | 2 | | | | | | | | | | | | |
| | 3 | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | |
| | 8 | CONTINUE | 47 | | | | | | | | | | |
| | 9 | c | 16 | | | | | | | | | | |
| | a | × | 36 | | | | | | | | | | |
| | b | 1 | 01 | | | | | | | | | | |
| | c | IF FLAG | 43 | | | | | | | | | | |
| | d | SET FLAG | 54 | | | | | | | | | | |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | ACC + | 60 | | | | | | | | | | |
| | 1 | SET FLAG | 54 | | | | | | | | | | |
| | 2 | ACC + | 60 | | | | | | | | | | |
| | 3 | f | 15 | | | | | | | | | | |
| | 4 | ↑ | 27 | | | | | | | | | | |
| | 5 | 5 | 05 | | | | | | | | | | |
| | 6 | IF x>y | 53 | | | | | | | | | | BRANCH TO CALCULATE q OR r |
| | 7 | 7 | 07 | | | | | | | | | | |
| | 8 | c | 16 | | | | | | | | | | |
| | 9 | IF x=y | 50 | | | | | | | | | | BRANCH TO CALCULATE s |
| | a | 8 | 10 | | | | | | | | | | |
| | b | d | 17 | | | | | | | | | | |
| | c | e | 12 | | | | | | | | | | |
| | d | x⇄y | 30 | | | | | | | | | | |
| 7 | 0 | ÷ | 35 | | | | | | | | | | CALCULATE $Y_i + \frac{1}{6}[P+2q+2r+s]$ |
| | 1 | d | 17 | | | | | | | | | | |
| | 2 | + | 33 | | | | | | | | | | |
| | 3 | y→( ) | 40 | | | | | | | | | | |
| | 4 | d | 17 | | | | | | | | | | |
| | 5 | CLEAR | 20 | | | | | | | | | | |
| | 6 | d | 17 | | | | | | | | | | |
| | 7 | ↑ | 27 | | | | | | | | | | |
| | 8 | b | 14 | | | | | | | | | | |
| | 9 | GO TO ( )( ) | 44 | | | | | | | | | | BRANCH TO PLOT |
| | a | 0 | 00 | | | | | | | | | | |
| | b | 0 | 00 | | | | | | | | | | |
| | c | ↓ | 25 | | | | | | | | | | |
| | d | 2 | 02 | | | | | | | | | | |
| 8 | 0 | ÷ | 35 | | | | | | | | | | CALCULATE $X_i + \frac{h}{2}, Y_i + \frac{P}{2}, Y_i + \frac{q}{2}$ |
| | 1 | d | 17 | | | | | | | | | | |
| | 2 | + | 33 | | | | | | | | | | |
| | 3 | c | 16 | | | | | | | | | | |
| | 4 | ↑ | 27 | | | | | | | | | | |
| | 5 | 2 | 02 | | | | | | | | | | |
| | 6 | ÷ | 35 | | | | | | | | | | |
| | 7 | b | 14 | | | | | | | | | | |
| | 8 | + | 33 | | | | | | | | | | |
| | 9 | ↓ | 25 | | | | | | | | | | |
| | a | GO TO ( )( ) | 44 | | | | | | | | | | BRANCH TO CALCULATE q OR r |
| | b | 2 | 02 | | | | | | | | | | |
| | c | 8 | 10 | | | | | | | | | | |
| | d | IF FLAG | 43 | | | | | | | | | | CLEAR FLAG |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 0 | ↓ | 25 | | | | | | | | | |
| | 1 | d | 17 | | | | | | | | | |
| | 2 | + | 33 | | | | | | | | | |
| | 3 | c | 16 | | | | | | | | | |
| | 4 | ↑ | 27 | | | | | | | | | |
| | 5 | b | 14 | | | | | | | | | |
| | 6 | + | 33 | | | | | | | | | |
| | 7 | y→( ) | 40 | | | | | | | | | |
| | 8 | b | 14 | | | | | | | | | |
| | 9 | ↓ | 25 | | | | | | | | | |
| | a | GO TO( )( ) | 44 | | | | | | | | | |
| | b | 2 | 02 | | | | | | | | | |
| | c | 8 | 10 | | | | | | | | | |
| | d | END | 46 | | | | | | | | | |
| | 0 | | | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |
| | 0 | | | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |

CALCULATE $X_i + h$, $Y_i + r$

BRANCH TO CALCULATE f(x,y)



# MAXIMUM AND MINIMUM OF r = f(θ)

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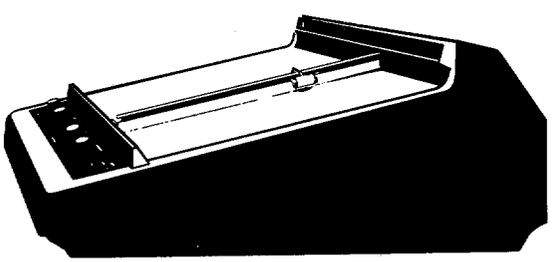
09100-70029

Given a function, r = f(θ), with polar coordinate values, this program will compute the approximate maximum and minimum of the function in rectangular coordinates over a specified range of the independent variable.

The technique involved is a search over n increments of the range of θ. n is specified by the user.



USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address is 0-0)

PRESS: GO TO ( )( )

PRESS: 5

PRESS: 4

SET: [PROGRAM | ]

Note: Starting at 5-4, enter the program steps which will take the independent variable θ from X and e registers and generate f(θ), leave f(θ) in the Y register. The last steps should be

GO TO

2

7

END

Note steps 5-4 through 9-d are available.

SET: [ | RUN]

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

PRESS: CONTINUE

ENTER DATA:

$n \rightarrow Z$ n = number of points to be scanned

$\theta_{max} \rightarrow Y$

$\theta_{min} \rightarrow X$

PRESS: CONTINUE

DISPLAY

$0 \rightarrow Z$

$Y_{max} \rightarrow Y$

$Y_{min} \rightarrow X$

PRESS: CONTINUE

DISPLAY

$0 \rightarrow Z$

$X_{max} \rightarrow Y$

$X_{min} \rightarrow X$

To re-run program, return to beginning of USER INSTRUCTIONS; re-enter program and proceed as before. f(θ) need not be re-generated if it is to be used again.

EXAMPLE

$r = f(\theta) = \sin\theta \cos\theta$

Choose

$n = 50$ and $0 \leq \theta \leq 2\pi$

SET: [ | RADIANS]

Solution:

$-.38 \leq y \leq +.38$

$-.38 \leq x \leq +.38$

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HEWLETT·PACKARD

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 | CLEAR | 20 | ENTER | | |
| 1 | STOP | 41 | $\theta_{min}$ | $\theta_{max}$ | 0 |
| 2 | $y\rightarrow( )$ | 40 | | | |
| 3 | *b* | 14 | | | |
| 4 | — | 34 | | | |
| 5 | ROLL ↓ | 31 | | | |
| 6 | $x\rightleftarrows y$ | 30 | | | |
| 7 | ÷ | 35 | | | |
| 8 | ROLL ↓ | 31 | | | |
| 9 | — | 34 | | | |
| a | ACC + | 60 | | | |
| b | ENTER EXP | 26 | | | |
| c | 9 | 11 | | | |
| d | 9 | 11 | | | |
| 1 | $x\rightarrow( )$ | 23 | | | |
| 2 | *d* | 17 | | | |
| 3 | $x\rightarrow( )$ | 23 | | | |
| 4 | *c* | 16 | | | |
| 5 | CHG SIGN | 32 | | | |
| 6 | $x\rightarrow( )$ | 23 | | | |
| 7 | *a* | 13 | | | |
| 8 | $x\rightarrow( )$ | 23 | | | |
| 9 | 0 | 00 | | | |
| a | RCL | 61 | | | |
| b | + | 33 | | | |
| c | *b* | 14 | | | |
| d | SET FLAG | 54 | | | |
| 2 | IF $x<y$ | 52 | | | |
| 0 | $x\rightleftarrows y$ | 30 | | | |
| 1 | IF FLAG | 43 | | | |
| 2 | $y\rightarrow( )$ | 40 | | | |
| 3 | *e* | 12 | | | |
| 4 | ↓ | 25 | | | |
| 5 | GO TO( )( ) | 44 | | | |
| 6 | 5 | 05 | | | |
| 7 | 4 | 04 | | | |
| 8 | *e* | 12 | | | |
| 9 | $x\rightleftarrows y$ | 30 | | | |
| a | TO RECT | 66 | | | |
| b | ↑ | 27 | | | |
| c | *c* | 16 | | | |
| d | IF $x>y$ | 53 | | | |

HEWLETT·PACKARD

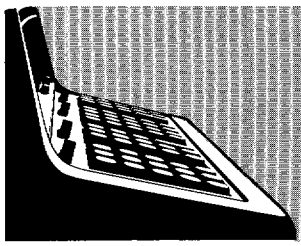
| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 3 | $y\rightarrow( )$ | 40 | | | |
| 1 | *c* | 16 | | | |
| 2 | *a* | 13 | | | |
| 3 | IF $x<y$ | 52 | | | |
| 4 | $y\rightarrow( )$ | 40 | | | |
| 5 | *a* | 13 | | | |
| 6 | ↓ | 25 | | | |
| 7 | *d* | 17 | | | |
| 8 | IF $x>y$ | 53 | | | |
| 9 | $y\rightarrow( )$ | 40 | | | |
| a | *d* | 17 | | | |
| b | ↓ | 25 | | | |
| c | $y\rightleftarrows( )$ | 24 | | | |
| d | 0 | 00 | | | |
| 4 | $y\rightarrow( )$ | 40 | | | |
| 1 | 0 | 00 | | | |
| 2 | IF $x>y$ | 53 | | | |
| 3 | $x\rightarrow( )$ | 23 | | | |
| 4 | 0 | 00 | | | |
| 5 | IF FLAG | 43 | | | |
| 6 | 1 | 01 | | | |
| 7 | 9 | 11 | | | |
| 8 | CLEAR | 20 | | | |
| 9 | $y\rightleftarrows( )$ | 24 | | | |
| a | 0 | 00 | | | |
| b | *d* | 17 | DISPLAY | | |
| c | STOP | 41 | $Y_{min}$ | $Y_{max}$ | 0 |
| d | CLEAR | 20 | | | |
| 5 | *a* | 13 | | | |
| 1 | ↑ | 27 | | | |
| 2 | *c* | 16 | DISPLAY | | |
| 3 | END | 46 | $X_{min}$ | $X_{max}$ | 0 |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| a | | | | | |
| b | | | | | |
| c | | | | | |
| d | | | | | |

HEWLETT·PACKARD

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 5 | | | | | |
| 1 | | | | | |
| 2 | *EXAMPLE* | | | | |
| 3 | | | | | |
| 4 | ↑ | 27 | $\theta$ | $\theta$ | |
| 5 | sin *x* | 70 | $\sin\theta$ | $\theta$ | |
| 6 | $x\rightleftarrows y$ | 30 | $\theta$ | $\sin\theta$ | |
| 7 | cos *x* | 73 | $\cos\theta$ | $\sin\theta$ | |
| 8 | × | 36 | | $\sin\theta\cdot\cos\theta$ | |
| 9 | GO TO( )( ) | 44 | | | |
| a | 2 | 02 | | | |
| b | 7 | 07 | | | |
| c | END | 46 | | | |
| d | | | | | |
| 0 | | | | | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| a | | | | | |
| b | | | | | |
| c | | | | | |
| d | | | | | |

Storage

| | |
|---|---|
| f | $\Delta\theta$ |
| e | $\theta$ |
| d | $Y_{min}$ |
| c | $X_{min}$ |
| b | $\theta_{max}$ |
| a | $X_{max}$ |
| 9 | |
| 8 | |
| 7 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | |
| 1 | |
| 0 | $Y_{max}$ |

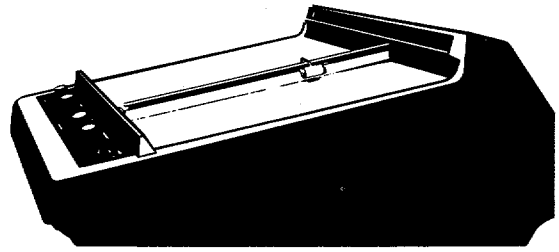


PART NO.
09100-70030

# PLOT OF r = f(θ) IN POLAR COORDINATES

This program will plot the function r = f(θ) in polar coordinates. The number of plot points, n, is specified by the user as also are the plotting constants.

The program was written to be used in conjunction with program 09100-70029, Maximum and Minimum of r = f(θ).



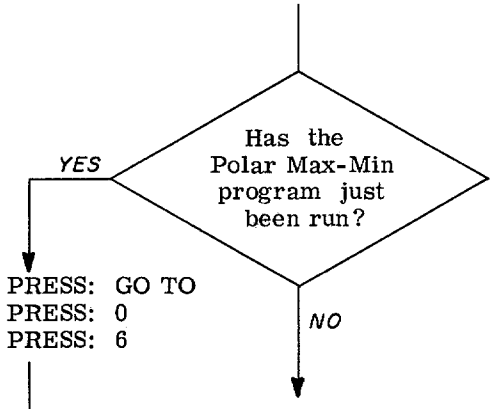
USER INSTRUCTIONS

PRESS: STOP

Using the Origin controls, locate the pen in the lower left corner of the paper.

SET: Decimal wheel at 6 or less

ENTER PROGRAM: (Starting Address is 0-0)




PRESS: GO TO
PRESS: 0
PRESS: 6

PRESS: GO TO ( )( )

PRESS: 5

PRESS: 4

SET: [PROGRAM]

Note: Beginning at location 5-4, enter the program steps which will take the independent variable $\theta$ from the X register ($\theta$ is also in the e register) and generate $f(\theta)$. Leave $f(\theta)$ in the Y register. The last steps should be

GO TO
2
7
END

Note that steps 5-4 through 9-d are available.

SET: [RUN]

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

PRESS: CONTINUE

ENTER TRANSLATION CONSTANTS:

$Y_{shift} \rightarrow Y$

$X_{shift} \rightarrow X$

PRESS: CONTINUE

USER INSTRUCTIONS (con't)

ENTER SCALING CONSTANTS:

$Y_{scale} \rightarrow Y$

$X_{scale} \rightarrow X$

PRESS: CONTINUE

ENTER DATA:

$n \rightarrow Z$ n = number of points to be plotted

$\theta_{max} \rightarrow Y$

$\theta_{min} \rightarrow X$

PRESS: CONTINUE

The function will now be plotted. To interrupt the plot: PRESS: STOP

To re-run program, return to beginning of USER INSTRUCTIONS, re-enter program and proceed as before. $f(\theta)$ need not be generated again unless it is to be changed.

EXAMPLE

Plot $r = \sin\theta \cos\theta$ where $0 \leq \theta \leq 2\pi$

Run the max-min of $r = f(\theta)$ program. Results of this program are:

$$-.4 \leq x \leq .4$$

$$-.4 \leq y \leq .4$$

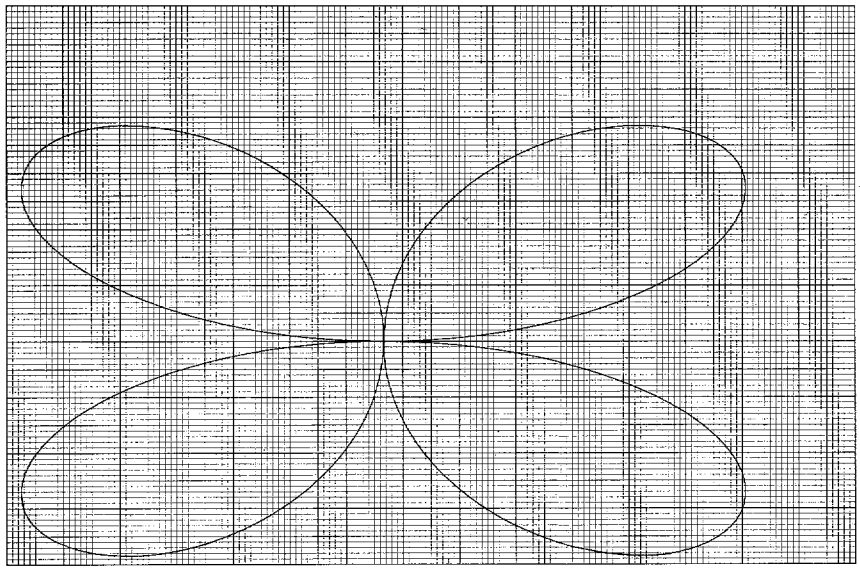
SET: [RADIANS]
Choose

$X_{shift} = Y_{shift} = -0.4$

$X_{scale} = .06 \frac{\text{units}}{\text{inch}}$

$Y_{scale} = 0.1 \frac{\text{units}}{\text{inch}}$

n = 250 plot points



PART NO. 09100-70030

HEWLETT-PACKARD (67)

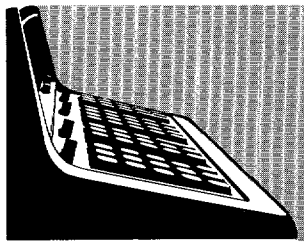
HEWLETT-PACKARD (97)

HEWLETT-PACKARD (97)

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 0 | CLEAR | 20 | ENTER | | |
| 0 1 | STOP | 41 | $X_{shift}$ | $Y_{shift}$ | 0 |
| 0 2 | $x \rightarrow ( )$ | 23 | | | |
| 0 3 | $c$ | 16 | | | |
| 0 4 | $y \rightarrow ( )$ | 40 | | | |
| 0 5 | $d$ | 17 | | | |
| 0 6 | CLEAR | 20 | ENTER | | |
| 0 7 | STOP | 41 | $X_{scale}$ | $Y_{scale}$ | 0 |
| 0 8 | ↑ | 27 | | | |
| 0 9 | 5 | 05 | | | |
| 0 a | 0 | 00 | | | |
| 0 b | 0 | 00 | | | |
| 0 c | $x \rightleftarrows y$ | 30 | | | |
| 0 d | ROLL ↓ | 31 | | | |
| 1 0 | ÷ | 35 | | | |
| 1 1 | $y \rightarrow ( )$ | 40 | | | |
| 1 2 | $b$ | 14 | | | |
| 1 3 | ROLL ↑ | 22 | | | |
| 1 4 | ÷ | 35 | | | |
| 1 5 | $y \rightarrow ( )$ | 40 | | | |
| 1 6 | $a$ | 13 | | | |
| 1 7 | CLEAR | 20 | ENTER | | |
| 1 8 | STOP | 41 | $\theta_{min}$ | $\theta_{max}$ | n |
| 1 9 | $y \rightarrow ( )$ | 40 | | | |
| 1 a | 0 | 00 | | | |
| 1 b | − | 34 | | | |
| 1 c | ROLL ↓ | 31 | | | |
| 1 d | $x \rightleftarrows y$ | 30 | | | |
| 2 0 | ÷ | 35 | | | |
| 2 1 | ↓ | 25 | | | |
| 2 2 | ACC + | 60 | | | |
| 2 3 | $e$ | 12 | | | |
| 2 4 | GO TO ( )( ) | 44 | | | |
| 2 5 | 5 | 05 | | | |
| 2 6 | 4 | 04 | | | |
| 2 7 | $e$ | 12 | | | |
| 2 8 | $x \rightleftarrows y$ | 30 | | | |
| 2 9 | TO RECT | 66 | | | |
| 2 a | ↑ | 27 | | | |
| 2 b | $c$ | 16 | | | |
| 2 c | − | 34 | | | |
| 2 d | $a$ | 13 | | | |
| 3 0 | × | 36 | | | |
| 3 1 | $d$ | 17 | | | |
| 3 2 | ROLL ↑ | 22 | | | |
| 3 3 | $x \rightleftarrows y$ | 30 | | | |
| 3 4 | − | 34 | | | |
| 3 5 | $b$ | 14 | | | |
| 3 6 | ÷ | 35 | | | |
| 3 7 | ↓ | 25 | | | |
| 3 8 | $x \rightleftarrows y$ | 30 | | | |
| 3 9 | FMT | 42 | | | |
| 3 a | ↓ | 25 | | | |
| 3 b | RCL | 61 | | | |
| 3 c | + | 33 | | | |
| 3 d | $y \rightarrow ( )$ | 40 | | | |
| 4 0 | $e$ | 12 | | | |
| 4 1 | ↓ | 25 | | | |
| 4 2 | $y \rightleftarrows ( )$ | 24 | | | |
| 4 3 | 0 | 00 | | | |
| 4 4 | $y \rightarrow ( )$ | 40 | | | |
| 4 5 | 0 | 00 | | | |
| 4 6 | IF $x<y$ | 52 | | | |
| 4 7 | 2 | 02 | | | |
| 4 8 | 3 | 03 | | | |
| 4 9 | IF $x=y$ | 50 | | | |
| 4 a | 2 | 02 | | | |
| 4 b | 3 | 03 | | | |
| 4 c | CLEAR | 20 | | | |
| 4 d | FMT | 42 | | | |
| 5 0 | ↑ | 27 | | | |
| 5 1 | END | 46 | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 | | | | | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| a | | | | | |
| b | | | | | |
| c | | | | | |
| d | | | | | |

| Storage | |
|---|---|
| f | $\Delta\theta$ |
| e | $\theta$ |
| d | $Y_{shift}$ |
| c | $X_{shift}$ |
| b | $500 / Y_{scale}$ |
| a | $X_{scale} / 500$ |
| 9 | |
| 8 | |
| 7 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | |
| 1 | |
| 0 | $\theta_{max}$ |



PART NO.
09100-70818

# LINEAR REGRESSION AND PLOT

This program calculates the equation of the straight line of best fit of a set of data points. It also plots each data point and the straight line determined by the calculated equation. The best fit is determined by minimizing the sum of the squares of the deviations of the data points from the line.

The program calculates m and C for the equation:

$$Y = mX + C$$

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

The defining equations are:

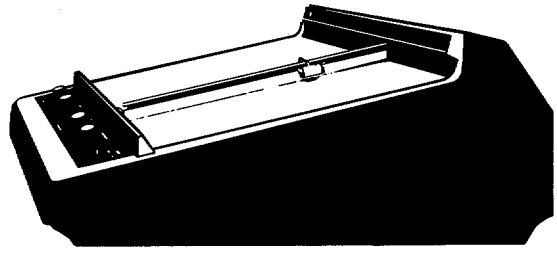
$$m = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(Y_i - \overline{Y})}{\sum_{i=1}^{n} (X_i - \overline{X})^2}$$

$$C = \overline{Y} - m\overline{X}$$

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

$$r = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \overline{X})^2 \sum_{i=1}^{n} (Y_i - \overline{Y})^2}} = \frac{n\sum_{i=1}^{n} X_i Y_i - (\sum_{i=1}^{n} X_i)(\sum_{i=1}^{n} Y_i)}{\sqrt{\left[n\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2\right]\left[n\sum_{i=1}^{n} Y_i^2 - (\sum_{i=1}^{n} Y_i)^2\right]}}$$

Reference: Mathematical Statistics
by John E. Fruend
Prentice-Hall, 1962



## USER INSTRUCTIONS

PRESS: STOP

Note: Use the origin controls to locate the pen in the lower left corner of the paper (on intersection of border lines if graph paper is being used).

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

SET: Decimal wheel at 6 or less

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

PRESS: CONTINUE

ENTER TRANSLATION CONSTANTS*:

$Y_{shift}$ → Y

$X_{shift}$ → X

PRESS: CONTINUE

ENTER SCALING CONSTANTS*:

$Y_{scale}$ → Y

$X_{scale}$ → X

*See General Plotter Instructions

PRESS: CONTINUE

DISPLAY

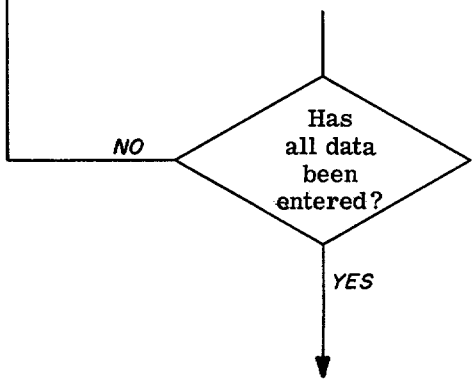
| | |
|---|---|
| i | Z |
| 0 | Y |
| 0 | X |

ENTER DATA: $Y_i$ → Y

$X_i$ → X

PRESS: CONTINUE

Note: $(X_i, Y_i)$ is now plotted




## USER INSTRUCTIONS (con't)

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

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

PRESS: CONTINUE

DISPLAY

| | |
|---|---|
| r | Z |
| C | Y |
| m | X |

PRESS: CONTINUE

ENTER SCALING CONSTANTS: $Y_{scale}$ → Y

$X_{scale}$ → X

PRESS: CONTINUE

Note: The straight line of best fit is now plotted.

As the pen approaches any of the boundaries,
PRESS: STOP

## EXAMPLE

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

Let: $X_{shift} = 25$

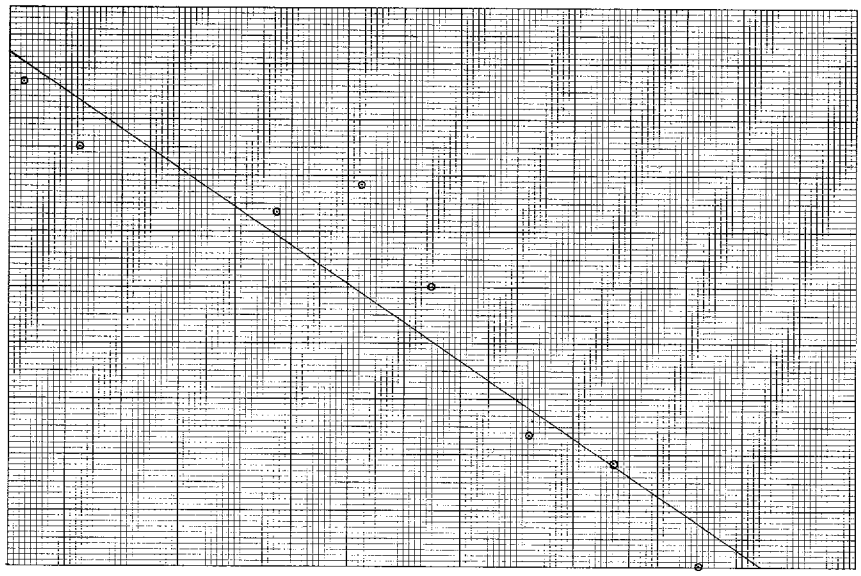
$X_{scale} = \frac{74-25}{15} \approx 4$

$Y_{shift} = 40$

$Y_{scale} = \frac{92-40}{10} \approx 6$

Solution: r = -.96
C = 121.04
m = -1.03

$Y = -1.03X + 121.04$



PROGRAM A PAGE 1 PART NO. 09100-70818

| Step | | Key | Code | Display x | Display y | Display z | Storage F | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | CLEAR | 20 | | | | | | | | | | |
| | 1 | x→( ) | 23 | | | | | | | | | | |
| | 2 | a | 13 | | | | | | | | | | |
| | 3 | x→( ) | 23 | | | | | | | | | | |
| | 4 | b | 14 | | | | | | | | | | CLEAR STORAGE REGISTERS |
| | 5 | x→( ) | 23 | | | | | | | | | | |
| | 6 | c | 16 | | | | | | | | | | |
| | 7 | x→( ) | 23 | | | | | | | | | | |
| | 8 | d | 17 | | | | | | | | | | |
| | 9 | STOP | 41 | $X_{shift}$ | $Y_{shift}$ | 0 | | | | | | | ENTER TRANSLATION CONSTANTS |
| | a | y→( ) | 40 | | | | | | | | | | |
| | b | 9 | 11 | | | | | | | | | | STORE TRANSLATION CONSTANTS AND CLEAR DISPLAY |
| | c | x→( ) | 23 | | | | | | | | | | |
| | d | 8 | 10 | | | | | | | | | | |
| 1 | 0 | CLEAR | 20 | | | | | | | | | | |
| | 1 | STOP | 41 | $X_{scale}$ | $Y_{scale}$ | 0 | | | | | | | ENTER SCALING CONSTANTS |
| | 2 | y→( ) | 40 | | | | | | | | | | |
| | 3 | 7 | 07 | | | | | | | | | | STORE SCALING CONSTANTS |
| | 4 | x→( ) | 23 | | | | | | | | | | |
| | 5 | 0 | 00 | | | | | | | | | | |
| FROM 6-d | 6 | a | 13 | | | | | | | | | | |
| | 7 | ↑ | 27 | | | | | | | | | | |
| | 8 | 1 | 01 | | | | | | | | | | |
| | 9 | + | 33 | | | | | | | | | | INCREMENT COUNTER AND ARRANGE DISPLAY |
| | a | y→( ) | 40 | | | | | | | | | | |
| | b | a | 13 | | | | | | | | | | |
| | c | CLEAR x | 37 | | | | | | | | | | |
| | d | ↑ | 27 | | | | | | | | | | |
| 2 | 0 | STOP | 41 | $X_i$ | $Y_i$ | i | | | | | | | ENTER DATA |
| | 1 | ACC + | 60 | | | | | | | | | | |
| | 2 | ↑ | 27 | | | | | | | | | | |
| | 3 | × | 36 | | | | | | | | | | |
| | 4 | x⇄y | 30 | | | | | | | | | | |
| | 5 | y⇄( ) | 24 | | | | | | | | | | CALCULATE $\sum X_i^2$ |
| | 6 | d | 17 | | | | | | | | | | |
| | 7 | + | 33 | | | | | | | | | | |
| | 8 | y⇄( ) | 24 | | | | | | | | | | |
| | 9 | d | 17 | | | | | | | | | | |
| | a | ↓ | 25 | | | | | | | | | | |
| | b | × | 36 | | | | | | | | | | |
| | c | x⇄y | 30 | | | | | | | | | | CALCULATE $\sum X_i Y_i$ |
| | d | y⇄( ) | 24 | | | | | | | | | | |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0 | b | 14 | | | | | | | | | |
| | 1 | + | 33 | | | | | | | | | |
| | 2 | y⇄( ) | 24 | | | | | | | | | |
| | 3 | b | 14 | | | | | | | | | |
| | 4 | ↓ | 25 | | | | | | | | | |
| | 5 | ROLL ↓ | 31 | | | | | | | | | |
| | 6 | × | 36 | | | | | | | | | |
| | 7 | x⇄y | 30 | | | | | | | | | |
| | 8 | y⇄( ) | 24 | | | | | | | | | |
| | 9 | C | 16 | | | | | | | | | |
| | a | + | 33 | | | | | | | | | |
| | b | y⇄( ) | 24 | | | | | | | | | |
| | c | C | 16 | | | | | | | | | |
| | d | ROLL ↑ | 22 | | | | | | | | | |
| 4 | 0 | y⇄( ) | 24 | | | | | | | | | |
| | 1 | 9 | 11 | | | | | | | | | |
| | 2 | y→( ) | 40 | | | | | | | | | |
| | 3 | 9 | 11 | | | | | | | | | |
| | 4 | ROLL ↓ | 31 | | | | | | | | | |
| | 5 | − | 34 | | | | | | | | | |
| | 6 | x⇄y | 30 | | | | | | | | | |
| | 7 | y⇄( ) | 24 | | | | | | | | | |
| | 8 | 8 | 10 | | | | | | | | | |
| | 9 | y→( ) | 40 | | | | | | | | | |
| | a | 8 | 10 | | | | | | | | | |
| | b | ROLL ↓ | 31 | | | | | | | | | |
| | c | − | 34 | | | | | | | | | |
| | d | 5 | 05 | | | | | | | | | |
| 5 | 0 | 0 | 00 | | | | | | | | | |
| | 1 | 0 | 00 | | | | | | | | | |
| | 2 | × | 36 | | | | | | | | | |
| | 3 | ROLL ↑ | 22 | | | | | | | | | |
| | 4 | × | 36 | | | | | | | | | |
| | 5 | x⇄y | 30 | | | | | | | | | |
| | 6 | y⇄( ) | 24 | | | | | | | | | |
| | 7 | 0 | 00 | | | | | | | | | |
| | 8 | y→( ) | 40 | | | | | | | | | |
| | 9 | 0 | 00 | | | | | | | | | |
| | a | ROLL ↓ | 31 | | | | | | | | | |
| | b | ÷ | 35 | | | | | | | | | |
| | c | x⇄y | 30 | | | | | | | | | |
| | d | y⇄( ) | 24 | | | | | | | | | |

CALCULATE $\sum Y_i^2$

CALCULATE $X_{plot} = \frac{500}{X_{scale}} \left[ X_i - X_{shift} \right]$

$Y_{plot} = \frac{500}{Y_{scale}} \left[ Y_i - Y_{shift} \right]$

| Step | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 0 | 7 | 07 | | | | | | | | | |
| 1 | y→( ) | 40 | | | | | | | | | |
| 2 | 7 | 07 | | | | | | | | | |
| 3 | ROLL ↓ | 31 | | | | | | | | | |
| 4 | ÷ | 35 | | | | | | | | | |
| 5 | ↓ | 25 | | | | | | | | | |
| 6 | x⇄y | 30 | | | | | | | | | |
| 7 | FMT | 42 | | | | | | | | | |
| 8 | ↑ | 27 | | | | | | | | | |
| 9 | FMT | 42 | | | | | | | | | |
| a | ↓ | 25 | | | | | | | | | |
| b | GO TO( )( ) | 44 | | | | | | | | | |
| c | 1 | 01 | | | | | | | | | |
| d | 6 | 06 | | | | | | | | | |
| 7 0 | END | 46 | | | | | | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| a | | | | | | | | | | | |
| b | | | | | | | | | | | |
| c | | | | | | | | | | | |
| d | | | | | | | | | | | |
| 0 | | | | | | | | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| a | | | | | | | | | | | |
| b | | | | | | | | | | | |
| c | | | | | | | | | | | |
| d | | | | | | | | | | | |

PLOT LAST DATA POINT

BRANCH TO RECEIVE NEXT POINT

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | ↓ | 25 | | | | | | | | | | RESET COUNTER |
| | 1 | 1 | 01 | | | | | | | | | | |
| | 2 | − | 34 | | | | | | | | | | |
| | 3 | y→( ) | 40 | | | | | | | | | | |
| | 4 | a | 13 | | | | | | | | | | |
| | 5 | e | 12 | | | | | | | | | | CALCULATE $\bar{Y}$ |
| | 6 | x⇄y | 30 | | | | | | | | | | |
| | 7 | ÷ | 35 | | | | | | | | | | |
| | 8 | y⇄( ). | 24 | | | | | | | | | | CALCULATE $\bar{X}$ |
| | 9 | f | 15 | | | | | | | | | | |
| | a | ÷ | 35 | | | | | | | | | | |
| | b | y→( ) | 40 | | | | | | | | | | |
| | c | e | 12 | | | | | | | | | | |
| | d | × | 36 | | | | | | | | | | |
| 1 | 0 | e | 12 | | | | | | | | | | CALCULATE $\sum(X_i-\bar{X})^2$ |
| | 1 | × | 36 | | | | | | | | | | |
| | 2 | d | 17 | | | | | | | | | | |
| | 3 | x⇄y | 30 | | | | | | | | | | |
| | 4 | − | 34 | | | | | | | | | | |
| | 5 | y→( ) | 40 | | | | | | | | | | |
| | 6 | d | 17 | | | | | | | | | | |
| | 7 | c | 16 | | | | | | | | | | CALCULATE $\sum(Y_i-\bar{Y})^2$ |
| | 8 | ↑ | 27 | | | | | | | | | | |
| | 9 | f | 15 | | | | | | | | | | |
| | a | ↑ | 27 | | | | | | | | | | |
| | b | × | 36 | | | | | | | | | | |
| | c | a | 13 | | | | | | | | | | |
| | d | × | 36 | | | | | | | | | | |
| 2 | 0 | ↓ | 25 | | | | | | | | | | |
| | 1 | − | 34 | | | | | | | | | | |
| | 2 | y→( ) | 40 | | | | | | | | | | |
| | 3 | c | 16 | | | | | | | | | | |
| | 4 | b | 14 | | | | | | | | | | CALCULATE $\sum(X_i-\bar{X})(Y_i-\bar{Y})$ |
| | 5 | ↑ | 27 | | | | | | | | | | |
| | 6 | f | 15 | | | | | | | | | | |
| | 7 | ↑ | 27 | | | | | | | | | | |
| | 8 | e | 12 | | | | | | | | | | |
| | 9 | × | 36 | | | | | | | | | | |
| | a | a | 13 | | | | | | | | | | |
| | b | × | 36 | | | | | | | | | | |
| | c | ↓ | 25 | | | | | | | | | | |
| | d | − | 34 | | | | | | | | | | |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0 | d | 17 | | | | | | | | | | CALCULATE r |
| | 1 | ↑ | 27 | | | | | | | | | | |
| | 2 | ↓ | 25 | | | | | | | | | | |
| | 3 | $\sqrt{x}$ | 76 | | | | | | | | | | |
| | 4 | ÷ | 35 | | | | | | | | | | |
| | 5 | c | 16 | | | | | | | | | | |
| | 6 | $\sqrt{x}$ | 76 | | | | | | | | | | |
| | 7 | ÷ | 35 | | | | | | | | | | |
| | 8 | d | 17 | | | | | | | | | | CALCULATE m |
| | 9 | ROLL ↑ | 22 | | | | | | | | | | |
| | a | $x \rightleftarrows y$ | 30 | | | | | | | | | | |
| | b | ÷ | 35 | | | | | | | | | | |
| | c | y→( ) | 40 | | | | | | | | | | |
| | d | a | 13 | | | | | | | | | | |
| 4 | 0 | e | 12 | | | | | | | | | | CALCULATE c |
| | 1 | × | 36 | | | | | | | | | | |
| | 2 | f | 15 | | | | | | | | | | |
| | 3 | $x \rightleftarrows y$ | 30 | | | | | | | | | | |
| | 4 | − | 34 | | | | | | | | | | |
| | 5 | a | 13 | | | | | | | | | | |
| | 6 | STOP | 41 | m | c | r | | | | | | | DISPLAY |
| | 7 | y→( ) | 40 | | | | | | | | | | STORE c |
| | 8 | b | 14 | | | | | | | | | | |
| | 9 | CLEAR | 20 | | | | | | | | | | CLEAR DISPLAY AND C REGISTER |
| | a | x→( ) | 23 | | | | | | | | | | |
| | b | c | 16 | | | | | | | | | | |
| | c | FMT | 42 | | | | | | | | | | RESET PEN TO ORIGIN |
| | d | ↑ | 27 | | | | | | | | | | |
| 5 | 0 | STOP | 41 | $X_{scale}$ | $Y_{scale}$ | 0 | | | | | | | ENTER SCALING CONSTANTS |
| | 1 | ACC + | 60 | | | | | | | | | | STORE SCALING CONSTANTS |
| | 2 | ↓ | 25 | | | | | | | | | | |
| | 3 | f | 15 | | | | | | | | | | |
| | 4 | × | 36 | | | | | | | | | | |
| | 5 | 5 | 05 | | | | | | | | | | |
| | 6 | 0 | 00 | | | | | | | | | | |
| | 7 | 0 | 00 | | | | | | | | | | |
| | 8 | ÷ | 35 | | | | | | | | | | CALCULATE Y FROM $X_{plot}$ |
| | 9 | ROLL ↓ | 31 | | | | | | | | | | |
| | a | $y \rightleftarrows$ ( ) | 24 | | | | | | | | | | |
| | b | 8 | 10 | | | | | | | | | | |
| | c | y→( ) | 40 | | | | | | | | | | |
| | d | 8 | 10 | | | | | | | | | | |

FROM 7-b

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | + | 33 | | | | | | | | | |
| | 1 | a | 13 | | | | | | | | | |
| | 2 | × | 36 | | | | | | | | | |
| | 3 | b | 14 | | | | | | | | | |
| | 4 | + | 33 | | | | | | | | | |
| | 5 | ROLL ↑ | 22 | | | | | | | | | |
| | 6 | y⇄( ) | 24 | | | | | | | | | |
| | 7 | 9 | 11 | | | | | | | | | |
| | 8 | y→( ) | 40 | | | | | | | | | |
| | 9 | 9 | 11 | | | | | | | | | |
| | a | ROLL ↓ | 31 | | | | | | | | | |
| | b | − | 34 | | | | | | | | | |
| | c | e | 12 | | | | | | | | | |
| | d | ÷ | 35 | | | | | | | | | |
| 7 | 0 | ↓ | 25 | | | | | | | | | |
| | 1 | × | 36 | | | | | | | | | |
| | 2 | c | 16 | | | | | | | | | |
| | 3 | FMT | 42 | | | | | | | | | |
| | 4 | ↓ | 25 | | | | | | | | | |
| | 5 | ROLL ↑ | 22 | | | | | | | | | |
| | 6 | + | 33 | | | | | | | | | |
| | 7 | y→( ) | 40 | | | | | | | | | |
| | 8 | c | 16 | | | | | | | | | |
| | 9 | GO TO( )( ) | 44 | | | | | | | | | |
| | a | 5 | 05 | | | | | | | | | |
| | b | 3 | 03 | | | | | | | | | |
| | c | END | 46 | | | | | | | | | |
| | d | | | | | | | | | | | |
| | 0 | | | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |

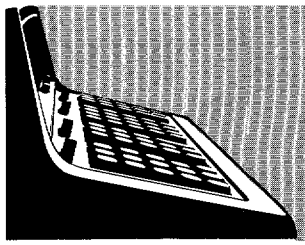
CALCULATE $Y_{plot}$

RECALL $X_{plot}$

PLOT A SEGMENT OF Y = mX+c

CALCULATE NEXT $X_{plot}$ AND STORE

BRANCH TO CALCULATE NEXT $Y_{plot}$



PART NO.
09100-70819

# PARABOLIC REGRESSION AND PLOT

The least square parabola approximating the set of points $(X_1, Y_1) \ldots (X_i, Y_i)$ has the equation:

$$Y = a_0 + a_1 X + a_2 X^2$$

where the constants $a_0$, $a_1$, and $a_2$ are determined by solving simultaneously the following normal equations:

$$\Sigma Y = a_0 n + a_1 \Sigma X + a_2 \Sigma X^2$$

$$\Sigma XY = a_0 \Sigma X + a_1 \Sigma X^2 + a_2 \Sigma X^3$$

$$\Sigma X^2 Y = a_0 \Sigma X^2 + a_1 \Sigma X^3 + a_2 \Sigma X^4$$

In the program, the constant $a_2$ is found by matrix algebra; the determinate (D) involved in the solution is:

$$D = \begin{vmatrix} n & \Sigma X & \Sigma X^2 \\ \Sigma X & \Sigma X^2 & \Sigma X^3 \\ \Sigma X^2 & \Sigma X^3 & \Sigma X^4 \end{vmatrix}$$

The equation for $a_2$ is therefore:

$$a_2 = \frac{\left\{ n(\Sigma X^2 \Sigma X^2 Y - \Sigma X^3 \Sigma XY) - \Sigma X (\Sigma X \Sigma X^2 Y - \Sigma X^2 \Sigma XY) + \Sigma Y \left[ \Sigma X \Sigma X^3 - (\Sigma X^2)^2 \right] \right\}}{D}$$

After finding $a_2$, the solution is reduced to two equations in two unknowns which are:

$$N = a_0 n + a_1 \Sigma X$$

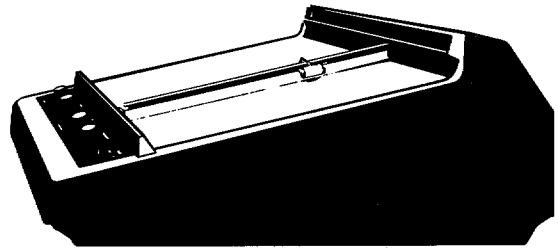
$$M = a_0 \Sigma X + a_1 \Sigma X^2$$

where $M = \Sigma XY - a_2 \Sigma X^3$ $\quad$ $N = \Sigma Y - a_2 \Sigma X^2$

These equations are then solved for $a_0$ and $a_1$.

The program will plot each data point as it is entered and then the least squares curve after the coefficients are calculated.

Reference: Introduction into the Theory of Statistics
Alexander Mood and Franklin Graybill
McGraw-Hill, 1961



USER INSTRUCTIONS

Using the origin controls, locate the pen in the lower left corner of the paper.

SET: Decimal wheel at 6 or less

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

PRESS: END

SET: | PROGRAM | |

ENTER $X_{shift}$: Storage locations 0-0, 0-1, and 0-2 are available.*

PRESS: STEP PROGRAM

ENTER $X_{scale}$: Storage locations 0-4, 0-5, and 0-6 are available.*

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

ENTER $Y_{shift}$: Storage locations 0-b, 0-c, and 0-d are available.*

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

ENTER $Y_{scale}$: Storage locations 1-2, 1-3, and 1-4 are available.*

*If a three digit number is not used, PRESS: CONTINUE at each of the other locations.

SET: | | RUN

PRESS: GO TO (2)(9)

PRESS: CONTINUE

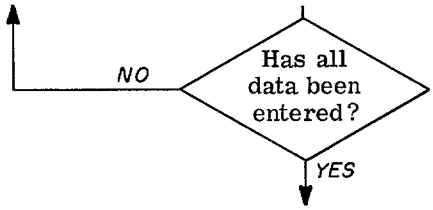
DISPLAY

$i$ —— Z
0 —— Y
0 —— X

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

Note: $(X_i, Y_i)$ will now be plotted.

PRESS: CONTINUE




PRESS: SET FLAG

PRESS: CONTINUE

ENTER PROGRAM B: (Starting Address is (2)(2)

PRESS: GO TO (2)(2)

PRESS: CONTINUE

ENTER PROGRAM C: (Starting Address is (2)(2)

PRESS: GO TO (2)(7)

PRESS: CONTINUE

DISPLAY

$a_0$ —— Z
$a_1$ —— Y
$a_2$ —— X

PRESS: CONTINUE

The least squares parabola will now be plotted. As the pen approaches any border
PRESS: STOP.

## EXAMPLE

| X | Y |
|---|---|
| 3 | 34 |
| 0 | 1 |
| 5 | 75 |
| 2 | 12 |
| 4 | 50 |
| 1 | 5 |
| 7 | 130 |
| 6 | 84 |
| -1 | 0 |

Note: 11 x 17 inch paper is used for this example.

Let:

$X_{shift} = -1$ $\quad X_{scale} = \frac{7-(-1)}{15} \approx .6 \frac{\text{units}}{\text{inch}}$

$Y_{shift} = -2$ $\quad Y_{scale} = \frac{130-(-2)}{10} \approx 16 \frac{\text{units}}{\text{inch}}$

Solution: $Y = .7939 + 3.6989X + 2.0141X^2$

The steps which enter the scale and shift constants are given below:

## EXAMPLE (con't)

PRESS: END

SET: PROGRAM

PRESS: 1

PRESS: CHANGE SIGN

PRESS: CONTINUE

PRESS: STEP PROGRAM

PRESS: .

PRESS: 6

PRESS: CONTINUE

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

PRESS: STEP PROGRAM

PRESS: 2

PRESS: CHANGE SIGN

PRESS: CONTINUE

PRESS: STEP PROGRAM

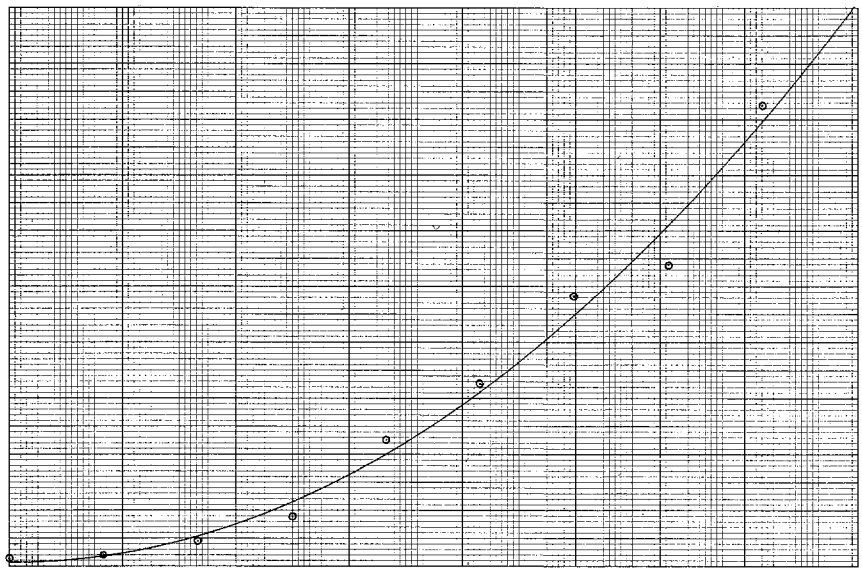
PRESS: STEP PROGRAM

PRESS: 1

PRESS: 6

PRESS: CONTINUE

SET: [ ] [RUN]



PROGRAM A | PAGE 1 | PART NO. 09100-70819

| Step | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 0 | CONTINUE | 47 | | | | | | | | | | ENTER $X_{shift}$ HERE |
| 1 | CONTINUE | 47 | | | | | | | | | | |
| 2 | CONTINUE | 47 | | | | | | | | | | |
| 3 | − | 34 | | | | | | | | | | |
| 4 | CONTINUE | 47 | | | | | | | | | | ENTER $X_{scale}$ HERE |
| 5 | CONTINUE | 47 | | | | | | | | | | |
| 6 | CONTINUE | 47 | | | | | | | | | | |
| 7 | IF FLAG | 43 | | | | | | | | | | |
| 8 | 7 | 07 | | | | | | | | | | |
| 9 | 6 | 06 | | | | | | | | | | |
| a | ÷ | 35 | | | | | | | | | | |
| b | CONTINUE | 47 | | | | | | | | | | ENTER $Y_{shift}$ HERE |
| c | CONTINUE | 47 | | | | | | | | | | |
| d | CONTINUE | 47 | | | | | | | | | | |
| 1 0 | ROLL ↑ | 22 | | | | | | | | | | |
| 1 | − | 34 | | | | | | | | | | |
| 2 | CONTINUE | 47 | | | | | | | | | | ENTER $Y_{scale}$ HERE |
| 3 | CONTINUE | 47 | | | | | | | | | | |
| 4 | CONTINUE | 47 | | | | | | | | | | |
| 5 | ÷ | 35 | | | | | | | | | | |
| 6 | 5 | 05 | | | | | | | | | | |
| 7 | 0 | 00 | | | | | | | | | | |
| 8 | 0 | 00 | | | | | | | | | | |
| 9 | CHG SIGN | 32 | | | | | | | | | | CALCULATE $X_{plot} = \frac{500}{X_{scale}}\left[X - X_{shift}\right]$ |
| a | × | 36 | | | | | | | | | | $Y_{plot} = \frac{500}{Y_{scale}}\left[Y - Y_{shift}\right]$ |
| b | ROLL ↑ | 22 | | | | | | | | | | |
| c | $x \rightleftarrows y$ | 30 | | | | | | | | | | |
| d | CHG SIGN | 32 | | | | | | | | | | |
| 2 0 | × | 36 | | | | | | | | | | |
| 1 | ROLL ↓ | 31 | | | | | | | | | | |
| 2 | FMT | 42 | | | | | | | | | | |
| 3 | ↑ | 27 | | | | | | | | | | POSITION AND PLOT LAST DATA POINT |
| 4 | FMT | 42 | | | | | | | | | | |
| 5 | ↓ | 25 | | | | | | | | | | |
| 6 | GO TO( )( ) | 44 | | | | | | | | | | BRANCH TO AVOID CLEARING THE e AND f REGISTERS AFTER THE FIRST PASS |
| 7 | 2 | 02 | | | | | | | | | | |
| 8 | a | 13 | | | | | | | | | | |
| 9 | CLEAR | 20 | | | | | | | | | | |
| a | 1 | 01 | | | | | | | | | | |
| b | $y \rightleftarrows ( )$ | 24 | | | | | | | | | | INCREMENT COUNTER AND POSITION DISPLAY |
| c | 8 | 10 | | | | | | | | | | |
| d | + | 33 | | | | | | | | | | |

FROM 9-8 OR 6-b

| Step | | Key | Code | Display x | Display y | Display z | Storage f | e | d | c | b | a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0 | y→( ) | 40 | | | | | | | | | | |
| | 1 | 8 | 10 | | | | | | | | | | |
| | 2 | CLEAR x | 37 | | | | | | | | | | |
| | 3 | ↑ | 27 | | | | | | | | | | |
| | 4 | STOP | 41 | $X_i$ | $Y_i$ | 0 | ENTER DATA POINT | | | | | | |
| | 5 | IF FLAG | 43 | | | | | | | | | | BRANCH IF ALL DATA POINTS HAVE BEEN ENTERED |
| | 6 | 6 | 06 | | | | | | | | | | |
| | 7 | c | 16 | | | | | | | | | | |
| | 8 | ACC + | 60 | | | | | | | | | | CALCULATE $\sum X$ AND $\sum Y$ |
| | 9 | ↑ | 27 | | | | | | | | | | CALCULATE $\sum X^2$ |
| | a | × | 36 | | | | | | | | | | |
| | b | ROLL ↓ | 31 | | | | | | | | | | |
| | c | y⇄( ) | 24 | | | | | | | | | | |
| | d | b | 14 | | | | | | | | | | |
| 4 | 0 | + | 33 | | | | | | | | | | CALCULATE $\sum X^2 Y$ |
| | 1 | y⇄( ) | 24 | | | | | | | | | | |
| | 2 | b | 14 | | | | | | | | | | |
| | 3 | x⇄y | 30 | | | | | | | | | | |
| | 4 | × | 36 | | | | | | | | | | |
| | 5 | x⇄y | 30 | | | | | | | | | | |
| | 6 | y⇄( ) | 24 | | | | | | | | | | |
| | 7 | d | 17 | | | | | | | | | | |
| | 8 | + | 33 | | | | | | | | | | |
| | 9 | y⇄( ) | 24 | | | | | | | | | | |
| | a | d | 17 | | | | | | | | | | |
| | b | ↓ | 25 | | | | | | | | | | |
| | c | × | 36 | | | | | | | | | | |
| | d | ROLL ↓ | 31 | | | | | | | | | | |
| 5 | 0 | y⇄( ) | 24 | | | | | | | | | | CALCULATE $\sum XY$ |
| | 1 | c | 16 | | | | | | | | | | |
| | 2 | + | 33 | | | | | | | | | | |
| | 3 | y⇄( ) | 24 | | | | | | | | | | |
| | 4 | c | 16 | | | | | | | | | | |
| | 5 | ↓ | 25 | | | | | | | | | | |
| | 6 | ↑ | 27 | | | | | | | | | | |
| | 7 | × | 36 | | | | | | | | | | |
| | 8 | × | 36 | | | | | | | | | | |
| | 9 | x⇄y | 30 | | | | | | | | | | CALCULATE $\sum X^3$ |
| | a | y⇄( ) | 24 | | | | | | | | | | |
| | b | a | 13 | | | | | | | | | | |
| | c | + | 33 | | | | | | | | | | |
| | d | y⇄( ) | 24 | | | | | | | | | | |

FROM 3-7

FROM 0-9

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | a | 13 | | | | | | | | | | |
| | 1 | x⇄y | 30 | | | | | | | | | | |
| | 2 | × | 36 | | | | | | | | | | |
| | 3 | x⇄y | 30 | | | | | | | | | | |
| | 4 | y⇄( ) | 24 | | | | | | | | | | CALCULATE $\sum X^4$ |
| | 5 | 9 | 11 | | | | | | | | | | |
| | 6 | + | 33 | | | | | | | | | | |
| | 7 | y⇄( ) | 24 | | | | | | | | | | |
| | 8 | 9 | 11 | | | | | | | | | | |
| | 9 | GO TO( )( ) | 44 | | | | | | | | | | |
| | a | 0 | 00 | | | | | | | | | | BRANCH TO CALCULATE $X_{plot}$ AND $Y_{plot}$ |
| | b | 0 | 00 | | | | | | | | | | |
| | c | ↓ | 25 | | | | | | | | | | |
| | d | 1 | 01 | | | | | | | | | | |
| 7 | 0 | − | 34 | | | | | | | | | | CALCULATE n = NUMBER OF DATA POINTS ENTERED |
| | 1 | y→( ) | 40 | | | | | | | | | | |
| | 2 | 8 | 10 | | | | | | | | | | |
| | 3 | a | 13 | | | | | | | | | | |
| | 4 | ↑ | 27 | | | | | | | | | | |
| | 5 | f | 15 | | | | | | | | | | |
| | 6 | × | 36 | | | | | | | | | | |
| | 7 | 2 | 02 | | | | | | | | | | BEGIN TO CALCULATE D |
| | 8 | × | 36 | | | | | | | | | | |
| | 9 | b | 14 | | | | | | | | | | |
| | a | × | 36 | | | | | | | | | | |
| | b | ↑ | 27 | | | | | | | | | | |
| | c | × | 36 | | | | | | | | | | |
| | d | STOP | 41 | | | | | | | | | | |
| 8 | 0 | 0 | 00 | | | | | | | | | | |
| | 1 | | | | | | | | | | | | |
| | 2 | | | | | | | | | | | | |
| | 3 | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | |
| | 6 | | | | | | | | | | | | |
| | 7 | | | | | | | | | | | | |
| | 8 | | | | | | | | | | | | |
| | 9 | | | | | | | | | | | | |
| | a | | | | | | | | | | | | CLEAR STORAGE REGISTERS |
| | b | | | | | | | | | | | | |
| | c | | | | | | | | | | | | |
| | d | | | | | | | | | | | | |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 0 | 0 | 00 | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |
| a | 0 | 0 | 00 | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | | | | | | | | | | | |
| d | 0 | 0 | 00 | | | | | | | | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | a | | | | | | | | | | | |
| | b | | | | | | | | | | | |
| | c | | | | | | | | | | | |
| | d | END | 46 | | | | | | | | | |

NOTE: STEPS 8-0 THROUGH d-c SHOULD CONTAIN ZEROS, STEP d-d SHOULD CONTAIN THE END STATEMENT.

| Step | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 0 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | × | 36 | | | | | | | | | | |
| 3 | ↓ | 25 | | | | | | | | | | |
| 4 | − | 34 | | | | | | | | | | |
| 5 | f | 15 | | | | | | | | | | |
| 6 | ↑ | 27 | | | | | | | | | | |
| 7 | × | 36 | | | | | | | | | | |
| 8 | x⇄y | 30 | | | | | | | | | | |
| 9 | y⇄( ) | 24 | | | | | | | | | | |
| a | 9 | 11 | | | | | | | | | | |
| b | x⇄y | 30 | | | | | | | | | | |
| c | × | 36 | | | | | | | | | | |
| d | ROLL ↓ | 31 | | | | | | | | | | |
| 3 0 | − | 34 | | | | | | | | | | |
| 1 | b | 14 | | | | | | | | | | CALCULATE D |
| 2 | ROLL ↑ | 22 | | | | | | | | | | |
| 3 | × | 36 | | | | | | | | | | |
| 4 | x⇄y | 30 | | | | | | | | | | |
| 5 | y⇄( ) | 24 | | | | | | | | | | |
| 6 | 8 | 10 | | | | | | | | | | |
| 7 | y→( ) | 40 | | | | | | | | | | |
| 8 | 8 | 10 | | | | | | | | | | |
| 9 | x⇄y | 30 | | | | | | | | | | |
| a | × | 36 | | | | | | | | | | |
| b | ROLL ↓ | 31 | | | | | | | | | | |
| c | + | 33 | | | | | | | | | | |
| d | a | 13 | | | | | | | | | | |
| 4 0 | ROLL ↑ | 22 | | | | | | | | | | |
| 1 | x⇄y | 30 | | | | | | | | | | |
| 2 | × | 36 | | | | | | | | | | |
| 3 | × | 36 | | | | | | | | | | |
| 4 | ROLL ↓ | 31 | | | | | | | | | | |
| 5 | − | 34 | | | | | | | | | | |
| 6 | y⇄( ) | 24 | | | | | | | | | | |
| 7 | d | 17 | | | | | | | | | | |
| 8 | y→( ) | 40 | | | | | | | | | | |
| 9 | 3 | 03 | | | | | | | | | | |
| a | f | 15 | | | | | | | | | | CALCULATE $\sum X(\sum X^2Y - \sum X^2 \sum XY)$ |
| b | × | 36 | | | | | | | | | | |
| c | b | 14 | | | | | | | | | | |
| d | ↑ | 27 | | | | | | | | | | |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0 | c | 16 | | | | | | | | | |
| | 1 | × | 36 | | | | | | | | | |
| | 2 | ↓ | 25 | | | | | | | | | |
| | 3 | − | 34 | | | | | | | | | |
| | 4 | f | 15 | | | | | | | | | |
| | 5 | × | 36 | | | | | | | | | |
| | 6 | y→() | 40 | | | | | | | | | |
| | 7 | 4 | 04 | | | | | | | | | |
| | 8 | ↑ | 27 | | | | | | | | | |
| | 9 | a | 13 | | | | | | | | | |
| | a | × | 36 | | | | | | | | | |
| | b | b | 14 | | | | | | | | | |
| | c | ↑ | 27 | | | | | | | | | |
| | d | × | 36 | | | | | | | | | |
| 6 | 0 | ↓ | 25 | | | | | | | | | |
| | 1 | − | 34 | | | | | | | | | |
| | 2 | e | 12 | | | | | | | | | |
| | 3 | × | 36 | | | | | | | | | |
| | 4 | ↓ | 25 | | | | | | | | | |
| | 5 | y⇄() | 24 | | | | | | | | | |
| | 6 | 4 | 04 | | | | | | | | | |
| | 7 | − | 34 | | | | | | | | | |
| | 8 | y⇄() | 24 | | | | | | | | | |
| | 9 | 3 | 03 | | | | | | | | | |
| | a | b | 14 | | | | | | | | | |
| | b | × | 36 | | | | | | | | | |
| | c | a | 13 | | | | | | | | | |
| | d | ↑ | 27 | | | | | | | | | |
| 7 | 0 | c | 16 | | | | | | | | | |
| | 1 | × | 36 | | | | | | | | | |
| | 2 | ↓ | 25 | | | | | | | | | |
| | 3 | − | 34 | | | | | | | | | |
| | 4 | ↓ | 25 | | | | | | | | | |
| | 5 | y⇄() | 24 | | | | | | | | | |
| | 6 | 8 | 10 | | | | | | | | | |
| | 7 | ↑ | 27 | | | | | | | | | |
| | 8 | ↓ | 25 | | | | | | | | | |
| | 9 | y⇄() | 24 | | | | | | | | | |
| | a | 3 | 03 | | | | | | | | | |
| | b | ROLL ↑ | 22 | | | | | | | | | |
| | c | × | 36 | | | | | | | | | |
| | d | END | 46 | | | | | | | | | |

CALCULATE $\sum Y\left[\sum X \sum X^3 - (\sum X^2)^2\right]$

CALCULATE $n(\sum X^2 \sum X^2 Y - \sum X^3 \sum XY)$

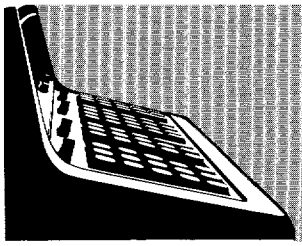
| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 0 | | | | | | | | | | | | |
| | 1 | | | | | | | | | | | | |
| | 2 | FMT | 42 | | | | | | | | | | PLOT A SECTION OF THE CURVE ( $\frac{1}{6}$ INCH) |
| | 3 | ↓ | 25 | | | | | | | | | | |
| | 4 | GO TO ( )( ) | 44 | | | | | | | | | | BRANCH TO CALCULATE NEXT CURVE COORDINATE |
| | 5 | 8 | 10 | | | | | | | | | | |
| | 6 | 1 | 01 | | | | | | | | | | |
| | 7 | ROLL ↑ | 22 | | | | | | | | | | CALCULATE $a_2$ |
| | 8 | $y \rightleftarrows ( )$ | 24 | | | | | | | | | | |
| | 9 | $d$ | 17 | | | | | | | | | | |
| | a | ROLL ↑ | 22 | | | | | | | | | | |
| | b | $x \rightleftarrows y$ | 30 | | | | | | | | | | |
| | c | − | 34 | | | | | | | | | | |
| | d | ↓ | 25 | | | | | | | | | | |
| 3 | 0 | $x \rightleftarrows y$ | 30 | | | | | | | | | | |
| | 1 | ÷ | 35 | | | | | | | | | | |
| | 2 | ↑ | 27 | | | | | | | | | | |
| | 3 | ↓ | 25 | | | | | | | | | | |
| | 4 | $y \rightleftarrows ( )$ | 24 | | | | | | | | | | CALCULATE N |
| | 5 | $e$ | 12 | | | | | | | | | | |
| | 6 | $b$ | 14 | | | | | | | | | | |
| | 7 | ROLL ↑ | 22 | | | | | | | | | | |
| | 8 | × | 36 | | | | | | | | | | |
| | 9 | ROLL ↓ | 31 | | | | | | | | | | |
| | a | − | 34 | | | | | | | | | | |
| | b | $y \rightleftarrows ( )$ | 24 | | | | | | | | | | |
| | c | $c$ | 16 | | | | | | | | | | |
| | d | $a$ | 13 | | | | | | | | | | |
| 4 | 0 | ROLL ↑ | 22 | | | | | | | | | | CALCULATE M |
| | 1 | × | 36 | | | | | | | | | | |
| | 2 | ↓ | 25 | | | | | | | | | | |
| | 3 | − | 34 | | | | | | | | | | |
| | 4 | $d$ | 17 | | | | | | | | | | |
| | 5 | × | 36 | | | | | | | | | | |
| | 6 | $c$ | 16 | | | | | | | | | | |
| | 7 | ↑ | 27 | | | | | | | | | | |
| | 8 | $f$ | 15 | | | | | | | | | | |
| | 9 | × | 36 | | | | | | | | | | |
| | a | ROLL ↓ | 31 | | | | | | | | | | |
| | b | − | 34 | | | | | | | | | | CALCULATE $a_1 = \frac{N\sum X - nM}{(\sum X)^2 - n\sum X^2}$ |
| | c | $y \rightleftarrows ( )$ | 24 | | | | | | | | | | |
| | d | $b$ | 14 | | | | | | | | | | |

| Step | | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0 | d | 17 | | | | | | | | | | |
| | 1 | × | 36 | | | | | | | | | | |
| | 2 | ↓ | 25 | | | | | | | | | | |
| | 3 | ROLL ↓ | 31 | | | | | | | | | | |
| | 4 | × | 36 | | | | | | | | | | |
| | 5 | ROLL ↓ | 31 | | | | | | | | | | |
| | 6 | − | 34 | | | | | | | | | | |
| | 7 | b | 14 | | | | | | | | | | |
| | 8 | x⇄y | 30 | | | | | | | | | | |
| | 9 | ÷ | 35 | | | | | | | | | | |
| | a | y→( ) | 40 | | | | | | | | | | |
| | b | a | 13 | | | | | | | | | | |
| | c | ↓ | 25 | | | | | | | | | | |
| | d | × | 36 | | | | | | | | | | |
| 6 | 0 | c | 16 | | | | | | | | | | |
| | 1 | x⇄y | 30 | | | | | | | | | | CALCULATE $a_0 = \frac{N - a_1 \Sigma X}{m}$ |
| | 2 | − | 34 | | | | | | | | | | |
| | 3 | d | 17 | | | | | | | | | | |
| | 4 | ÷ | 35 | | | | | | | | | | |
| | 5 | y→( ) | 40 | | | | | | | | | | |
| | 6 | d | 17 | | | | | | | | | | |
| | 7 | a | 13 | | | | | | | | | | |
| | 8 | ↑ | 27 | | | | | | | | | | |
| | 9 | e | 12 | | | | | | | | | | POSITION DISPLAY |
| | a | x→( ) | 23 | | | | | | | | | | |
| | b | c | 16 | | | | | | | | | | |
| | c | STOP | 41 | $a_2$ | $a_1$ | $a_0$ | | | | | | | DISPLAY |
| | d | CLEAR | 20 | | | | | | | | | | |
| 7 | 0 | FMT | 42 | | | | | | | | | | RESET PEN |
| | 1 | ↑ | 27 | | | | | | | | | | |
| | 2 | SET FLAG | 54 | | | | | | | | | | |
| | 3 | GO TO( )( ) | 44 | | | | | | | | | | SET FLAG AND BRANCH TO |
| | 4 | 0 | 00 | | | | | | | | | | OBTAIN $X_{scale}$ AND $X_{shift}$ |
| | 5 | 0 | 00 | | | | | | | | | | |
| | 6 | ↑ | 27 | | | | | | | | | | |
| | 7 | 6 | 06 | | | | | | | | | | |
| | 8 | ÷ | 35 | | | | | | | | | | |
| | 9 | ↓ | 25 | | | | | | | | | | |
| | a | + | 33 | | | | | | | | | | CALCULATE $\Delta X = \frac{X_{scale}}{6}$ AND $X = X_{shift} - \Delta X$ |
| | b | x⇄y | 30 | | | | | | | | | | |
| | c | CHG SIGN | 32 | | | | | | | | | | |
| | d | x⇄y | 30 | | | | | | | | | | |

FROM 0-9

FROM 2-6

| Step | Key | Code | Display x | Display y | Display z | Storage f | Storage e | Storage d | Storage c | Storage b | Storage a | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 0 | ACC + | 60 | | | | | | | | | | |
| 1 | RCL | 61 | | | | | | | | | | INCREMENT X BY ΔX |
| 2 | + | 33 | | | | | | | | | | |
| 3 | y→( ) | 40 | | | | | | | | | | |
| 4 | e | 12 | | | | | | | | | | |
| 5 | ↓ | 25 | | | | | | | | | | |
| 6 | ↑ | 27 | | | | | | | | | | |
| 7 | ↑ | 27 | | | | | | | | | | |
| 8 | × | 36 | | | | | | | | | | |
| 9 | c | 16 | | | | | | | | | | |
| a | × | 36 | | | | | | | | | | |
| b | a | 13 | | | | | | | | | | CALCULATE $a_0 + a_1X + a_2X^2$ |
| c | ROLL ↑ | 22 | | | | | | | | | | AND POSITION DISPLAY |
| d | × | 36 | | | | | | | | | | |
| 9 0 | d | 17 | | | | | | | | | | |
| 1 | + | 33 | | | | | | | | | | |
| 2 | ↓ | 25 | | | | | | | | | | |
| 3 | + | 33 | | | | | | | | | | |
| 4 | e | 12 | | | | | | | | | | |
| 5 | ↑ | 27 | | | | | | | | | | |
| 6 | GO TO ( )( ) | 44 | | | | | | | | | | |
| 7 | 0 | 00 | | | | | | | | | | BRANCH TO CALCULATE $X_{plot}$ AND $Y_{plot}$ |
| 8 | 0 | 00 | | | | | | | | | | |
| 9 | END | 46 | | | | | | | | | | |
| a | | | | | | | | | | | | |
| b | | | | | | | | | | | | |
| c | | | | | | | | | | | | |
| d | | | | | | | | | | | | |
| 0 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| a | | | | | | | | | | | | |
| b | | | | | | | | | | | | |
| c | | | | | | | | | | | | |
| d | | | | | | | | | | | | |





# EXPONENTIAL REGRESSION AND PLOT

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

$$y = ae^{bx}$$

The program also plots each point and the least squares curve after the unknowns have been calculated.

The equation is linearized into

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

or

$$Y = A + bx$$

Using a linear regression method,

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

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

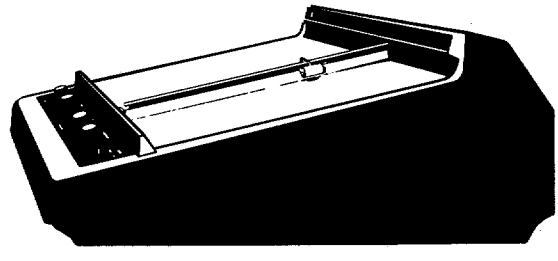
$$a = e^{A}$$

the correlation coefficient is given by

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

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

Reference: Statistical Theory and Methodology in Science and Engineering
by K. A. Brownlee
John Wiley and Sons, 1965



## USER INSTRUCTIONS

Using the origin controls, locate the pen in the lower left corner.

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

SET: Decimal wheel at 6 or less

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

PRESS: CONTINUE

ENTER TRANSLATION CONSTANTS:

$Y_{shift}$ → Y

$X_{shift}$ → X

PRESS: CONTINUE

ENTER SCALING CONSTANTS:

$Y_{scale}$ → Y

$X_{scale}$ → X

→ PRESS: CONTINUE

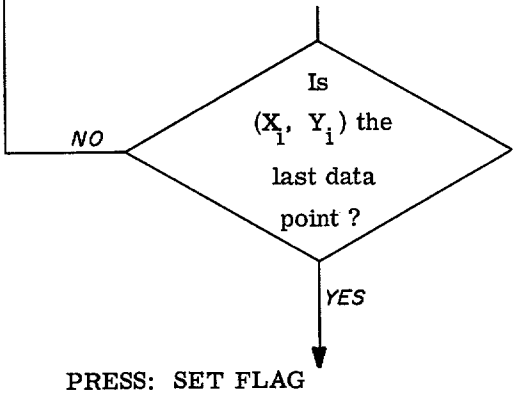
DISPLAY

| | |
|---|---|
| 0 | Z |
| 0 | Y |
| i | X |

Each data point will be plotted as entered.

ENTER DATA: $Y_i$ → Y

$X_i$ → X




PRESS: SET FLAG

PRESS: CONTINUE

## USER INSTRUCTIONS (con't)

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

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

PRESS: CONTINUE

DISPLAY

| | |
|---|---|
| a | Z |
| b | Y |
| r | X |

PRESS: CONTINUE

The least squares curve $y = ae^{bx}$ will now be plotted. To interrupt the plot or stop it when finished, PRESS: STOP.

To re-run program return to beginning of USER INSTRUCTIONS, ENTER PROGRAM B and proceed as before.

## EXAMPLE

| X | Y |
|---|---|
| .5 | 7.12 |
| 1.2 | 11.67 |
| 2.9 | 38.85 |
| 3.3 | 48.03 |
| 4.8 | 138.70 |
| 5.6 | 262.00 |
| 7.4 | 935.64 |

Let: $X_{shift} = .5$ $\quad X_{scale} = \geq \frac{7.4 - .5}{15} \approx .5 \frac{\text{units}}{\text{inch}}$

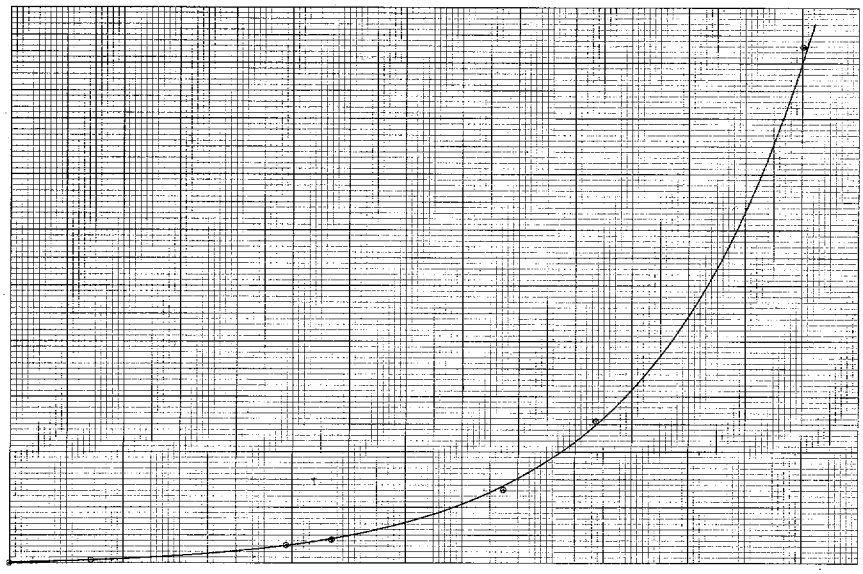
$Y_{shift} = 5$ $\quad Y_{scale} = \geq \frac{935.64 - 5}{10} \approx 100 \frac{\text{units}}{\text{inch}}$

Solution: a = 4.925

b = .705

r = .9998

$Y = 4.925e^{.705X}$



PROGRAM A | PAGE 1 | PART NO. 09100-70820

HEWLETT·PACKARD

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 00 | CLEAR | 20 | ENTER | | |
| 01 | STOP | 41 | $X_{shift}$ | $Y_{shift}$ | 0 |
| 02 | $x\rightarrow()$ | 23 | | | |
| 03 | a | 13 | | | |
| 04 | $y\rightarrow()$ | 40 | | | |
| 05 | b | 14 | | | |
| 06 | CLEAR | 20 | ENTER | | |
| 07 | STOP | 41 | $X_{scale}$ | $Y_{scale}$ | 0 |
| 08 | $x\rightarrow()$ | 23 | | | |
| 09 | c | 16 | | | |
| 0a | $y\rightarrow()$ | 40 | | | |
| 0b | d | 17 | | | |
| 0c | CLEAR | 20 | | | |
| 0d | 1 | 01 | | | |
| 10 | $x\rightarrow()$ | 23 | | | |
| 11 | 0 | 00 | ENTER | | |
| 12 | STOP | 41 | $X_i$ | $Y_i$ | 0 |
| 13 | $x\rightleftarrows y$ | 30 | | | |
| 14 | ln x | 65 | | | |
| 15 | ACC + | 60 | | | |
| 16 | ↑ | 27 | | | |
| 17 | × | 36 | | | |
| 18 | $x\rightleftarrows y$ | 30 | | | |
| 19 | $y\rightleftarrows()$ | 24 | | | |
| 1a | 7 | 07 | | | |
| 1b | + | 33 | | | |
| 1c | $y\rightleftarrows()$ | 24 | | | |
| 1d | 7 | 07 | | | |
| 20 | ↓ | 25 | | | |
| 21 | × | 36 | | | |
| 22 | $x\rightleftarrows y$ | 30 | | | |
| 23 | $y\rightleftarrows()$ | 24 | | | |
| 24 | 9 | 11 | | | |
| 25 | + | 33 | | | |
| 26 | $y\rightleftarrows()$ | 24 | | | |
| 27 | 9 | 11 | | | |
| 28 | ↓ | 25 | | | |
| 29 | ROLL ↓ | 31 | | | |
| 2a | × | 36 | | | |
| 2b | $x\rightleftarrows y$ | 30 | | | |
| 2c | $y\rightleftarrows()$ | 24 | | | |
| 2d | 8 | 10 | | | |
| 30 | + | 33 | | | |
| 31 | $y\rightleftarrows()$ | 24 | | | |
| 32 | 8 | 10 | | | |
| 33 | ROLL ↑ | 22 | | | |
| 34 | $e^x$ | 74 | | | |
| 35 | ROLL ↓ | 31 | | | |
| 36 | a | 13 | | | |
| 37 | − | 34 | | | |
| 38 | c | 16 | | | |
| 39 | ÷ | 35 | | | |
| 3a | b | 14 | | | |
| 3b | ROLL ↑ | 22 | | | |
| 3c | $x\rightleftarrows y$ | 30 | | | |
| 3d | − | 34 | | | |
| 40 | d | 17 | | | |
| 41 | ÷ | 35 | | | |
| 42 | 5 | 05 | | | |
| 43 | 0 | 00 | | | |
| 44 | 0 | 00 | | | |
| 45 | × | 36 | | | |
| 46 | ROLL ↑ | 22 | | | |
| 47 | × | 36 | | | |
| 48 | CLEAR x | 37 | | | |
| 49 | ROLL ↓ | 31 | | | |
| 4a | FMT | 42 | | | |
| 4b | ↓ | 25 | | | |
| 4c | FMT | 42 | | | |
| 4d | ↑ | 27 | | | |
| 50 | $y\rightleftarrows()$ | 24 | | | |
| 51 | 0 | 00 | | | |
| 52 | IF FLAG | 43 | | | |
| 53 | 5 | 05 | | | |
| 54 | b | 14 | | | |
| 55 | 1 | 01 | | | |
| 56 | + | 33 | | | |
| 57 | ↓ | 25 | | | |
| 58 | GOTO( )( ) | 44 | | | |
| 59 | 1 | 01 | | | |
| 5a | 0 | 00 | | | |
| 5b | ↓ | 25 | | | |
| 5c | ↑ | 27 | | | |
| 5d | $y\rightleftarrows()$ | 24 | | | |
| 60 | 8 | 10 | | | |
| 61 | × | 36 | | | |
| 62 | e | 12 | | | |
| 63 | ↑ | 27 | | | |
| 64 | × | 36 | | | |
| 65 | ↓ | 25 | | | |
| 66 | − | 34 | | | |
| 67 | ↑ | 27 | | | |
| 68 | $y\rightleftarrows()$ | 24 | | | |
| 69 | 7 | 07 | | | |
| 6a | $x\rightleftarrows y$ | 30 | | | |
| 6b | $y\rightleftarrows()$ | 24 | | | |
| 6c | 8 | 10 | | | |
| 6d | STOP | 41 | | | |
| 70 | 0 | 00 | | | |
| 71 | | | | | |
| 72 | | | | | |
| 73 | | | | | |
| 74 | | | | | |
| 75 | | | | | |
| 76 | | | | | |
| 77 | | | | | |
| 78 | | | | | |
| 79 | | | | | |
| 7a | | | | | |
| 7b | | | | | |
| 7c | | | | | |
| 7d | 0 | 00 | | | |

**Storage**

| | |
|---|---|
| f | ΔX |
| e | X |
| d | $Y_{scale}$ |
| c | $X_{scale}$ |
| b | $Y_{shift}$ |
| a | $X_{shift}$ |
| 9 | |
| 8 | |
| 7 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | |
| 1 | |
| 0 | |

PROGRAM A PAGE 2 PART NO. 09100-70820

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 80 | 0 | 00 | | | |
| 90 | 0 | 00 | | | |
| 0 | 0 | 00 | | | |
| 1 | END | 46 | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 80 | | | | | |
| 90 | | | | | |
| 0 | | | | | |
| 1 | | | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 80 | | | | | |
| 90 | | | | | |
| 0 | | | | | |
| 1 | | | | | |

Storage

HEWLETT·PACKARD

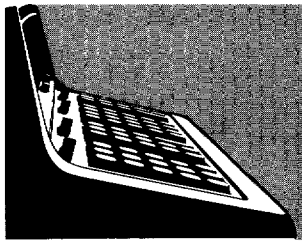
| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 0 | y→( ) | 40 | | | |
| 0 1 | 8 | 10 | | | |
| 0 2 | × | 36 | | | |
| 0 3 | ↓ | 25 | | | |
| 0 4 | y⇄( ) | 24 | | | |
| 0 5 | f | 15 | | | |
| 0 6 | x⇄y | 30 | | | |
| 0 7 | ↑ | 27 | | | |
| 0 8 | × | 36 | | | |
| 0 9 | ROLL ↓ | 31 | | | |
| 0 a | − | 34 | | | |
| 0 b | ↓ | 25 | | | |
| 0 c | y⇄( ) | 24 | | | |
| 0 d | f | 15 | | | |
| 1 0 | y→( ) | 40 | | | |
| 1 1 | 0 | 00 | | | |
| 1 2 | × | 36 | | | |
| 1 3 | ↓ | 25 | | | |
| 1 4 | √x | 76 | | | |
| 1 5 | y⇄( ) | 24 | | | |
| 1 6 | 8 | 10 | | | |
| 1 7 | y→( ) | 40 | | | |
| 1 8 | 8 | 10 | | | |
| 1 9 | x⇄y | 30 | | | |
| 1 a | y⇄( ) | 24 | | | |
| 1 b | 9 | 11 | | | |
| 1 c | × | 36 | | | |
| 1 d | ↑ | 27 | | | |
| 2 0 | RCL | 61 | | | |
| 2 1 | × | 36 | | | |
| 2 2 | ↓ | 25 | | | |
| 2 3 | − | 34 | | | |
| 2 4 | ↑ | 27 | | | |
| 2 5 | y⇄( ) | 24 | | | |
| 2 6 | 9 | 11 | | | |
| 2 7 | ↓ | 25 | | | |
| 2 8 | ÷ | 35 | | | |
| 2 9 | y⇄( ) | 24 | | | |
| 2 a | 0 | 00 | | | |
| 2 b | ↓ | 25 | | | |
| 2 c | ÷ | 35 | | | |
| 2 d | E | 12 | | | |
| 3 0 | ↑ | 27 | | | |
| 3 1 | ↓ | 25 | | | |
| 3 2 | CHG SIGN | 32 | | | |
| 3 3 | × | 36 | | | |
| 3 4 | f | 15 | | | |
| 3 5 | + | 33 | | | |
| 3 6 | x⇄y | 30 | | | |
| 3 7 | y⇄( ) | 24 | | | |
| 3 8 | 8 | 10 | | | |
| 3 9 | x⇄y | 30 | | | |
| 3 a | ÷ | 35 | | | |
| 3 b | ↓ | 25 | | | |
| 3 c | $e^x$ | 74 | | | |
| 3 d | y⇄( ) | 24 | | | |
| 4 0 | 0 | 00 | | | |
| 4 1 | x→( ) | 23 | | | |
| 4 2 | 1 | 01 | | | |
| 4 3 | ROLL ↓ | 31 | | | |
| 4 4 | STOP | 41 | | | |
| 4 5 | CLEAR | 20 | | | |
| 4 6 | C | 16 | | | |
| 4 7 | ↑ | 27 | | | |
| 4 8 | 6 | 06 | | | |
| 4 9 | ÷ | 35 | | | |
| 4 a | B | 13 | | | |
| 4 b | x⇄y | 30 | | | |
| 4 c | − | 34 | | | |
| 4 d | ACC + | 60 | | | |
| 5 0 | RCL | 61 | | | |
| 5 1 | ACC − | 63 | | | |
| 5 2 | + | 33 | | | |
| 5 3 | ACC + | 60 | | | |
| 5 4 | ↓ | 25 | | | |
| 5 5 | y⇄( ) | 24 | | | |
| 5 6 | 0 | 00 | | | |
| 5 7 | y→( ) | 40 | | | |
| 5 8 | 0 | 00 | | | |
| 5 9 | × | 36 | | | |
| 5 a | ↓ | 25 | | | |
| 5 b | $e^x$ | 74 | | | |
| 5 c | y⇄( ) | 24 | | | |
| 5 d | 1 | 01 | | | |
| 6 0 | y→( ) | 40 | | | |
| 6 1 | 1 | 01 | | | |
| 6 2 | × | 36 | | | |
| 6 3 | b | 14 | | | |
| 6 4 | − | 34 | | | |
| 6 5 | d | 17 | | | |
| 6 6 | ÷ | 35 | | | |
| 6 7 | E | 12 | | | |
| 6 8 | ↑ | 27 | | | |
| 6 9 | B | 13 | | | |
| 6 a | − | 34 | | | |
| 6 b | C | 16 | | | |
| 6 c | ÷ | 35 | | | |
| 6 d | 5 | 05 | | | |
| 7 0 | 0 | 00 | | | |
| 7 1 | 0 | 00 | | | |
| 7 2 | × | 36 | | | |
| 7 3 | ROLL ↑ | 22 | | | |
| 7 4 | × | 36 | | | |
| 7 5 | ↓ | 25 | | | |
| 7 6 | x⇄y | 30 | | | |
| 7 7 | FMT | 42 | | | |
| 7 8 | ↓ | 25 | | | |
| 7 9 | GO TO ( )( ) | 44 | | | |
| 7 a | 5 | 05 | | | |
| 7 b | 0 | 00 | | | |
| 7 c | END | 46 | | | |
| 7 d | | | | | |

DISPLAY

| r | b | a |
|---|---|---|
| | | |

Storage

| | |
|---|---|
| f | |
| e | |
| d | |
| c | |
| b | |
| a | |
| 9 | |
| 8 | |
| 7 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | |
| 1 | |
| 0 | |



PART NO.
09100-70821

# POWER CURVE REGRESSION AND PLOT

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

$$Y = aX^b$$

The program will also plot each data point and the curve after the unknowns have been calculated.

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

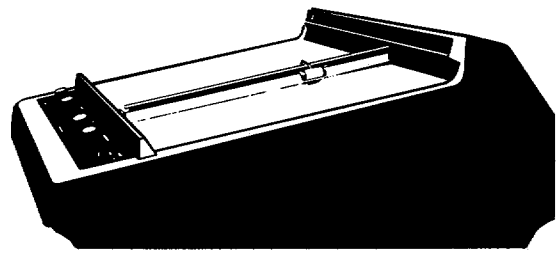
where
$$b = \frac{N\sum(\ln X \ln Y) - \sum \ln X \sum \ln Y}{N\sum(\ln X)^2 - (\sum \ln X)^2}$$

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

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

Note: $X_i > 0$, $Y_i > 0$, $i = 1, \cdots, N$ and $X_{shift} > 0$

Reference: Statistical Theory and Methodology in Science and Engineering
by K. A. Brownlee
John Wiley and Sons, 1965



## USER INSTRUCTIONS

PRESS: STOP

Using the origin controls, locate the pen in the lower left corner of the paper.

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

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

PRESS: CONTINUE

ENTER TRANSLATION CONSTANTS*:

$Y_{shift}$ → Y

$X_{shift}$ → X  Note: $X_{shift} > 0$

PRESS: CONTINUE

ENTER SCALING CONSTANTS*:

$Y_{scale}$ → Y

$X_{scale}$ → X

PRESS: CONTINUE

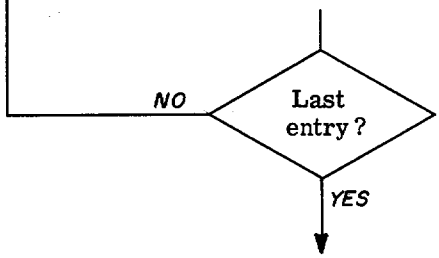
DISPLAY

| | |
|---|---|
| 0 | Z |
| 0 | Y |
| i | X |

Each data point will be plotted as entered.

ENTER DATA: $Y_i$ → Y

$X_i$ → X




PRESS: SET FLAG

PRESS: CONTINUE

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

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

PRESS: CONTINUE

## USER INSTRUCTIONS (con't)

DISPLAY

| | |
|---|---|
| r | Z |
| b | Y |
| a | X |

PRESS: CONTINUE

The Plotter will now plot the least squares curve. To interrupt the plot or stop it when finished, PRESS: STOP.

To re-run program, return to beginning of USER INSTRUCTIONS, ENTER PROGRAM A and proceed as before.

*See general Plotter instructions.

## EXAMPLE

| X | Y |
|---|---|
| 1.2 | 15.25 |
| 1.7 | 6.68 |
| 2.3 | 4.54 |
| 2.9 | 1.74 |
| 4.4 | .87 |
| 4.8 | .51 |
| 5.7 | .33 |
| 7.2 | .23 |
| 8.4 | .17 |

Let:

$X_{shift} = 1.1$  $X_{scale} = \frac{8.4-1.1}{15} \approx .5 \frac{\text{units}}{\text{inch}}$

$Y_{shift} = 0$  $Y_{scale} = \frac{15.25-.17}{10} \approx 2 \frac{\text{units}}{\text{inch}}$

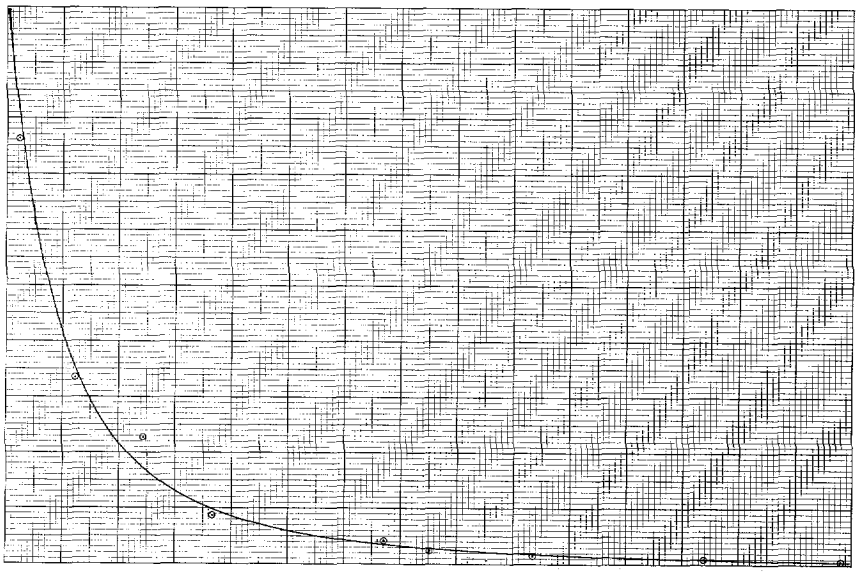
Solution:

r = -.9952

b = -2.384

a = 24.949

$Y = 24.949 X^{-2.384}$



PROGRAM A

PAGE 1

PART NO. 09100-70821

HEWLETT-PACKARD

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 0 | CLEAR | 20 | ENTER | | |
| 0 1 | STOP | 41 | $X_{shift}$ | $Y_{shift}$ | 0 |
| 0 2 | $x\rightarrow()$ | 23 | | | |
| 0 3 | a | 13 | | | |
| 0 4 | $y\rightarrow()$ | 40 | | | |
| 0 5 | b | 14 | | | |
| 0 6 | CLEAR | 20 | ENTER | | |
| 0 7 | STOP | 41 | $X_{scale}$ | $Y_{scale}$ | 0 |
| 0 8 | $x\rightarrow()$ | 23 | | | |
| 0 9 | c | 16 | | | |
| 0 a | $y\rightarrow()$ | 40 | | | |
| 0 b | d | 17 | | | |
| 0 c | CLEAR | 20 | | | |
| 0 d | 1 | 01 | | | |
| 1 0 | $x\rightarrow()$ | 23 | | | |
| 1 1 | 0 | 00 | ENTER | | |
| 1 2 | STOP | 41 | $X_i$ | $Y_i$ | 0 |
| 1 3 | ln x | 65 | | | |
| 1 4 | $x\rightleftarrows y$ | 30 | | | |
| 1 5 | ln x | 65 | | | |
| 1 6 | ACC + | 60 | | | |
| 1 7 | ↑ | 27 | | | |
| 1 8 | × | 36 | | | |
| 1 9 | $x\rightleftarrows y$ | 30 | | | |
| 1 a | $y\rightleftarrows()$ | 24 | | | |
| 1 b | 8 | 10 | | | |
| 1 c | + | 33 | | | |
| 1 d | $y\rightleftarrows()$ | 24 | | | |
| 2 0 | 8 | 10 | | | |
| 2 1 | ↓ | 25 | | | |
| 2 2 | × | 36 | | | |
| 2 3 | $x\rightleftarrows y$ | 30 | | | |
| 2 4 | $y\rightleftarrows()$ | 24 | | | |
| 2 5 | 9 | 11 | | | |
| 2 6 | + | 33 | | | |
| 2 7 | $y\rightleftarrows()$ | 24 | | | |
| 2 8 | 9 | 11 | | | |
| 2 9 | ↓ | 25 | | | |
| 2 a | ROLL ↓ | 31 | | | |
| 2 b | × | 36 | | | |
| 2 c | $x\rightleftarrows y$ | 30 | | | |
| 2 d | $y\rightleftarrows()$ | 24 | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 3 0 | 7 | 07 | | | |
| 3 1 | + | 33 | | | |
| 3 2 | $y\rightleftarrows()$ | 24 | | | |
| 3 3 | 7 | 07 | | | |
| 3 4 | ↓ | 25 | | | |
| 3 5 | $e^x$ | 74 | | | |
| 3 6 | $x\rightleftarrows y$ | 30 | | | |
| 3 7 | $e^x$ | 74 | | | |
| 3 8 | ↑ | 27 | | | |
| 3 9 | b | 14 | | | |
| 3 a | − | 34 | | | |
| 3 b | d | 17 | | | |
| 3 c | ÷ | 35 | | | |
| 3 d | a | 13 | | | |
| 4 0 | ROLL ↑ | 22 | | | |
| 4 1 | $x\rightleftarrows y$ | 30 | | | |
| 4 2 | − | 34 | | | |
| 4 3 | c | 16 | | | |
| 4 4 | ÷ | 35 | | | |
| 4 5 | 5 | 05 | | | |
| 4 6 | 0 | 00 | | | |
| 4 7 | 0 | 00 | | | |
| 4 8 | × | 36 | | | |
| 4 9 | ROLL ↑ | 22 | | | |
| 4 a | × | 36 | | | |
| 4 b | CLEAR x | 37 | | | |
| 4 c | ROLL ↓ | 31 | | | |
| 4 d | $x\rightleftarrows y$ | 30 | | | |
| 5 0 | FMT | 42 | | | |
| 5 1 | ↓ | 25 | | | |
| 5 2 | FMT | 42 | | | |
| 5 3 | ↑ | 27 | | | |
| 5 4 | $y\rightleftarrows()$ | 24 | | | |
| 5 5 | 0 | 00 | | | |
| 5 6 | IF FLAG | 43 | | | |
| 5 7 | 6 | 06 | | | |
| 5 8 | 1 | 01 | | | |
| 5 9 | 1 | 01 | | | |
| 5 a | + | 33 | | | |
| 5 b | ↓ | 25 | | | |
| 5 c | GO TO ( ) ( ) | 44 | | | |
| 5 d | 1 | 01 | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 6 0 | 0 | 00 | | | |
| 6 1 | e | 12 | | | |
| 6 2 | ↑ | 27 | | | |
| 6 3 | × | 36 | | | |
| 6 4 | ROLL ↑ | 22 | | | |
| 6 5 | $y\rightleftarrows()$ | 24 | | | |
| 6 6 | 7 | 07 | | | |
| 6 7 | × | 36 | | | |
| 6 8 | ROLL ↓ | 31 | | | |
| 6 9 | − | 34 | | | |
| 6 a | $y\rightleftarrows()$ | 24 | | | |
| 6 b | f | 15 | | | |
| 6 c | ↓ | 25 | | | |
| 6 d | STOP | 41 | | | |
| 7 0 | 0 | 00 | | | |
| 7 1 | | | | | |
| 7 2 | | | | | |
| 7 3 | | | | | |
| 7 4 | | | | | |
| 7 5 | | | | | |
| 7 6 | | | | | |
| 7 7 | | | | | |
| 7 8 | | | | | |
| 7 9 | | | | | |
| 7 a | | | | | |
| 7 b | | | | | |
| 7 c | | | | | |
| 7 d | ↓ | | | | |

Storage

| | |
|---|---|
| f | ΔX |
| e | X |
| d | $Y_{scale}$ |
| c | $X_{scale}$ |
| b | $Y_{shift}$ |
| a | $X_{shift}$ |
| 9 | |
| 8 | |
| 7 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | |
| 1 | |
| 0 | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 80 | 0 | 00 | | | |
| 81 | | | | | |
| 82 | | | | | |
| 83 | | | | | |
| 84 | | | | | |
| 85 | | | | | |
| 86 | | | | | |
| 87 | | | | | |
| 88 | | | | | |
| 89 | | | | | |
| 8a | | | | | |
| 8b | | | | | |
| 8c | | | | | |
| 8d | | | | | |
| 90 | 0 | 00 | | | |
| 91 | | | | | |
| 92 | | | | | |
| 93 | | | | | |
| 94 | | | | | |
| 95 | | | | | |
| 96 | | | | | |
| 97 | | | | | |
| 98 | | | | | |
| 99 | | | | | |
| 9a | | | | | |
| 9b | | | | | |
| 9c | 0 | 00 | | | |
| 9d | END | 46 | | | |
| 00 | | | | | |
| 01 | | | | | |
| 02 | | | | | |
| 03 | | | | | |
| 04 | | | | | |
| 05 | | | | | |
| 06 | | | | | |
| 07 | | | | | |
| 08 | | | | | |
| 09 | | | | | |
| 0a | | | | | |
| 0b | | | | | |
| 0c | | | | | |
| 0d | | | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| c0 | | | | | |
| c1 | | | | | |
| c2 | | | | | |
| c3 | | | | | |
| c4 | | | | | |
| c5 | | | | | |
| c6 | | | | | |
| c7 | | | | | |
| c8 | | | | | |
| c9 | | | | | |
| ca | | | | | |
| cb | | | | | |
| cc | | | | | |
| cd | | | | | |
| d0 | | | | | |
| d1 | | | | | |
| d2 | | | | | |
| d3 | | | | | |
| d4 | | | | | |
| d5 | | | | | |
| d6 | | | | | |
| d7 | | | | | |
| d8 | | | | | |
| d9 | | | | | |
| da | | | | | |
| db | | | | | |
| dc | | | | | |
| dd | | | | | |
| e0 | | | | | |
| e1 | | | | | |
| e2 | | | | | |
| e3 | | | | | |
| e4 | | | | | |
| e5 | | | | | |
| e6 | | | | | |
| e7 | | | | | |
| e8 | | | | | |
| e9 | | | | | |
| ea | | | | | |
| eb | | | | | |
| ec | | | | | |
| ed | | | | | |

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| f0 | | | | | |
| f1 | | | | | |
| f2 | | | | | |
| f3 | | | | | |
| f4 | | | | | |
| f5 | | | | | |
| f6 | | | | | |
| f7 | | | | | |
| f8 | | | | | |
| f9 | | | | | |
| fa | | | | | |
| fb | | | | | |
| fc | | | | | |
| fd | | | | | |

Storage

| | |
|---|---|
| F | |
| E | |
| D | |
| C | |
| B | |
| A | |
| 9 | |
| 8 | |
| 7 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | |
| 1 | |
| 0 | |

PROGRAM B PAGE 3 PART NO. 09100-70821

| Step | Key | Code | Display x | Display y | Display z |
|---|---|---|---|---|---|
| 0 0 | ↑ | 27 | | | |
| 0 1 | × | 36 | | | |
| 0 2 | x⇄y | 30 | | | |
| 0 3 | y⇄() | 24 | | | |
| 0 4 | 8 | 10 | | | |
| 0 5 | ROLL ↓ | 31 | | | |
| 0 6 | x⇄y | 30 | | | |
| 0 7 | × | 36 | | | |
| 0 8 | ROLL ↓ | 31 | | | |
| 0 9 | − | 34 | | | |
| 0 a | f | 15 | | | |
| 0 b | × | 36 | | | |
| 0 c | ↓ | 25 | | | |
| 0 d | √x | 76 | | | |
| 1 0 | ↑ | 27 | | | |
| 1 1 | y⇄() | 24 | | | |
| 1 2 | 9 | 11 | | | |
| 1 3 | ↓ | 25 | | | |
| 1 4 | × | 36 | | | |
| 1 5 | ROLL ↑ | 22 | | | |
| 1 6 | x⇄y | 30 | | | |
| 1 7 | y⇄() | 24 | | | |
| 1 8 | 8 | 10 | | | |
| 1 9 | y→() | 40 | | | |
| 1 a | 0 | 00 | | | |
| 1 b | e | 12 | | | |
| 1 c | × | 36 | | | |
| 1 d | ↓ | 25 | | | |
| 2 0 | − | 34 | | | |
| 2 1 | ↑ | 27 | | | |
| 2 2 | ↓ | 25 | | | |
| 2 3 | f | 15 | | | |
| 2 4 | CHG SIGN | 32 | | | |
| 2 5 | ÷ | 35 | | | |
| 2 6 | ↓ | 25 | | | |
| 2 7 | ↑ | 27 | | | |
| 2 8 | y⇄() | 24 | | | |
| 2 9 | e | 12 | | | |
| 2 a | × | 36 | | | |
| 2 b | x⇄y | 30 | | | |
| 2 c | y⇄() | 24 | | | |
| 2 d | 0 | 00 | | | |
| 3 0 | − | 34 | | | |
| 3 1 | x⇄y | 30 | | | |
| 3 2 | y⇄() | 24 | | | |
| 3 3 | 8 | 10 | | | |
| 3 4 | x⇄y | 30 | | | |
| 3 5 | ÷ | 35 | | | |
| 3 6 | x⇄y | 30 | | | |
| 3 7 | e^x | 74 | | | |
| 3 8 | y⇄() | 24 | | | |
| 3 9 | 9 | 11 | | | |
| 3 a | ROLL ↓ | 31 | | | |
| 3 b | ÷ | 35 | | | |
| 3 c | e | 12 | | | |
| 3 d | ROLL ↑ | 22 | | | |
| 4 0 | x→() | 23 | | | |
| 4 1 | 0 | 00 | | | |
| 4 2 | y→() | 40 | | | |
| 4 3 | 1 | 01 | | | |
| 4 4 | STOP | 41 | | | |
| 4 5 | CLEAR | 20 | | | |
| 4 6 | c | 16 | | | |
| 4 7 | ↑ | 27 | | | |
| 4 8 | 8 | 10 | | | |
| 4 9 | ÷ | 35 | | | |
| 4 a | a | 13 | | | |
| 4 b | x⇄y | 30 | | | |
| 4 c | − | 34 | | | |
| 4 d | ACC + | 60 | | | |
| 5 0 | RCL | 61 | | | |
| 5 1 | ACC − | 63 | | | |
| 5 2 | + | 33 | | | |
| 5 3 | ACC + | 60 | | | |
| 5 4 | ↓ | 25 | | | |
| 5 5 | ln x | 65 | | | |
| 5 6 | y⇄() | 24 | | | |
| 5 7 | 1 | 01 | | | |
| 5 8 | y→() | 40 | | | |
| 5 9 | 1 | 01 | | | |
| 5 a | × | 36 | | | |
| 5 b | ↓ | 25 | | | |
| 5 c | e^x | 74 | | | |
| 5 d | y⇄() | 24 | | | |
| 6 0 | 0 | 00 | | | |
| 6 1 | y→() | 40 | | | |
| 6 2 | 0 | 00 | | | |
| 6 3 | × | 36 | | | |
| 6 4 | b | 14 | | | |
| 6 5 | − | 34 | | | |
| 6 6 | d | 17 | | | |
| 6 7 | ÷ | 35 | | | |
| 6 8 | e | 12 | | | |
| 6 9 | ↑ | 27 | | | |
| 6 a | a | 13 | | | |
| 6 b | − | 34 | | | |
| 6 c | c | 16 | | | |
| 6 d | ÷ | 35 | | | |
| 7 0 | 5 | 05 | | | |
| 7 1 | 0 | 00 | | | |
| 7 2 | 0 | 00 | | | |
| 7 3 | × | 36 | | | |
| 7 4 | ROLL ↑ | 22 | | | |
| 7 5 | × | 36 | | | |
| 7 6 | ↓ | 25 | | | |
| 7 7 | x⇄y | 30 | | | |
| 7 8 | FMT | 42 | | | |
| 7 9 | ↓ | 25 | | | |
| 7 a | GO TO( )( ) | 44 | | | |
| 7 b | 5 | 05 | | | |
| 7 c | 0 | 00 | | | |
| 7 d | END | 46 | | | |

DISPLAY

| a | b | r |
|---|---|---|
| | | |

Storage

| | |
|---|---|
| f | |
| e | |
| d | |
| c | |
| b | |
| a | |
| 9 | |
| 8 | |
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HEWLETT-PACKARD