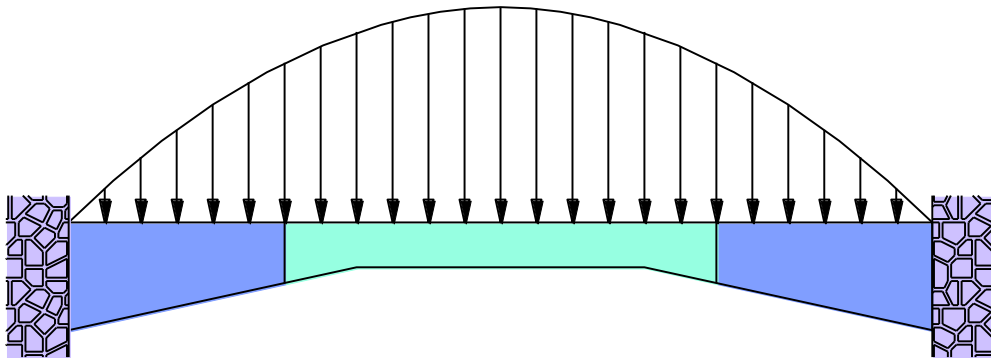
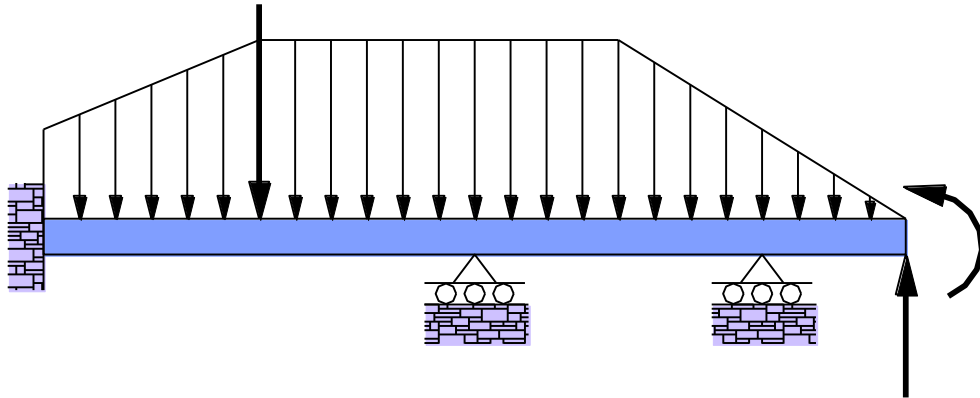


Beam49 User's Manual



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Introduction

Overview

Beam49 is a beam analysis program for the HP 49g and 50g calculators. It computes the reactions at the supports and shear, bending moment, slope, and deflection at a user-specified number of increments.

- The program can be executed from any directory.
- Use any consistent units; results are in terms of the same length and force units as the input.
- Cantilever members may have the support located at either end. The following support types are permitted for beams with two or more supports: all supports pinned, left end fixed, or both ends fixed. Overhangs are allowed.
- The loading may include any combination of concentrated loads; applied moments; and uniform, linear, and nonlinear distributed loads.
- The modulus of elasticity and/or moment of inertia may be variable. Tapered cross sections are defined by entering the moment of inertia as an algebraic expression.
- Redundant reactions and the slope and deflection are computed by the moment-area method.
- Results are rounded to seven significant digits.

Installing the Library

1. Backup your calculator data.
2. Download the library to the HP 49g or 50g.
3. Recall the library to the stack.
4. Install the library into port 0 or 1. For example, execute 1 **[STO]** to store it in port 1.
5. Purge the variable that contains the library.
6. Press **[ON]** **[F3]** simultaneously to warmstart the calculator and attach the library.

Accessing the Library

Press **[→]** **[2]** **Beam49** to display the library menu.

Alternatively, you can assign the program « 1707 MENU » to a user key.
Press that user key to display the Beam49 menu.

[NXT] toggles between the two pages of the menu.

Deleting the Library

1. Enter :n:1707, where n is the port number.
2. Press **[TOOL]** **PURGE** to purge the library from port memory.

Input

The RVM command computes the reactions, shear, and bending moment. The beam length, number of increments, support locations, and at least one load must be entered. For a statically indeterminate beam of variable EI, the variable E and/or variable I data are also required for calculating the reactions.




The θY command computes the slope and deflection. Unless previously defined, modulus of elasticity and moment of inertia input is required.

A command line prompt is used to enter a single value and an input form is used to enter two or three values.

Input data are entered on the stack when an indefinite number of arguments are allowed—for support locations, loads, and variable E and I data. Enter any number of support locations in any order. For all other stack input, enter the data in the sequence requested by the prompt. For example, at the $X_M?$ prompt any number of applied moments may be entered in any order, but each moment M must be immediately preceded by its location X. Similarly, the prompt $X1_X2_W?$ indicates that any number of uniform and/or nonlinear distributed loads may be entered in any order, but each load W must be immediately preceded by the start and end locations, in that order.

The menu keys activated for stack input are described in the following table:

Stack Input Menu

Key	Description
OVER	Executes the OVER command. Note:  executes SWAP and  launches the stack editor.
L	Length. Enters the location of the right-hand end of the beam.
?	Redraws the prompt.
HELP	Displays some help text.
CANCL	Prompts to cancel program execution.
OK	Resumes program execution (same as  ^{CONT} ON).

An error message is displayed for any invalid input and the user is required to correct the problem before continuing. The stack editor is handy for viewing, reordering, or editing the stack.

Commands

RVM

Computes the reactions, vertical shear, and bending moment.

Input:

- Enter the length L and number of increments N.
Results are computed at an increment of L/N .



- Input the support locations.
- If the beam has two or more supports and the left end is supported, select the support type.
- If the beam is statically indeterminate, select the flexural rigidity type.
 - If EI is constant, E and I data are not required for calculating the reactions.
 - If E is variable, input the variable E data.
 - If I is variable, input the variable I data.
- Input any concentrated loads.
- Input any applied moments.
- Input any uniform and/or nonlinear distributed loads.
- Input any linear distributed loads.
- Press **YES** or **NO** to review loads input before computing the results.
 - If yes, choose which load categories to add or review.
When REVIEW? is displayed, loads have already been entered for that category.
 - Press yes to review, revise, or delete the previously entered data.

Remarks: Once all loads have been entered, any existing results in the current directory will be overwritten. To save current results and run RVM for another beam, switch to a different directory.

The program calculates the reactions, then superposes the effect of each load and reaction to compute the shear and bending moment at N increments. Reactions for statically indeterminate members are determined by the moment-area method.

Number of increments: A greater number of increments generally improves accuracy—up to a point. However, for more increments the program generates more data. Thus, more time and memory are required to compute and store the results. Regardless of the value entered, the program always uses at least 20 and no more than 1250 increments.

If AutoAdjust N is checked, the program may adjust the number of increments to a value close to the user-entered number, but one that yields a reasonable increment. The user-entered value might also be revised in order to produce an increment that results in all or most of the entered locations positioned a whole number of increments from either end. If the calculator is low on available RAM, the program will limit the number of increments in order to reserve enough RAM so that the θY program can be executed subsequently without running out of memory.

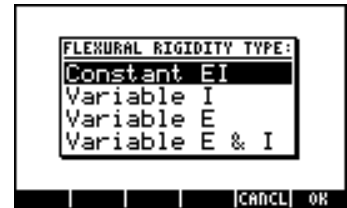
If AutoAdjust N is unchecked, the user-entered value is not altered (provided $20 \leq N \leq 1250$).

θY

Computes the slope and deflection.

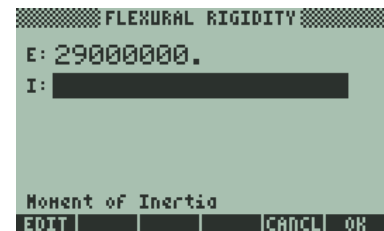
Input:

- If the beam is statically determinate, select the flexural rigidity type.
If statically indeterminate, this was defined while executing RVM.



- Constant EI
 - Enter the modulus of elasticity E and moment of inertia I.

If a real number > 0 is stored in the variable E? and/or I?, that value is used as the default value. Otherwise, no value is the default. The screenshot to the right depicts how the input form opens with 29E6 stored in the variable E? and nothing stored in I? (? is **ALPHA** **→** 3).



- Variable I
 - Enter the modulus of elasticity. **F1** enters the default value, if one was stored.
 - If the beam is statically determinate, input the variable I data.
- Variable E
 - If the beam is statically determinate, input the variable E data.
 - Enter the moment of inertia. **F1** enters the default value, if one was stored.
- Variable E & I (statically determinate beam)
 - Input the variable E data.
 - Input the variable I data.

For statically indeterminate beams of variable EI, the program uses the variable E and/or variable I data that were used for computing the reactions.


Remarks: Before running θY, the RVM program must be executed to generate the bending moment M data. θY calculates M/EI at each increment, then integrates the data to compute the slope and deflection at each increment. Any current slope and deflection data are overwritten.

PLOTD

Plots the selected diagram.

Input: Select a diagram.

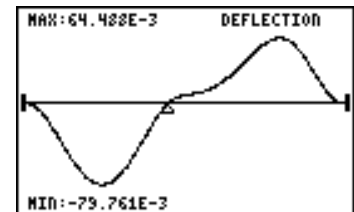
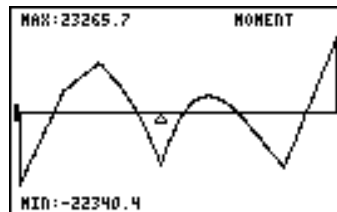
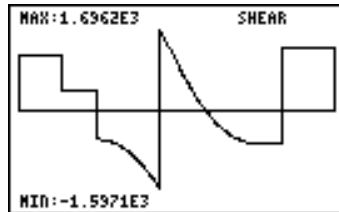
[F1] toggles *Draw the supports* on **SUP ■** or off **SUP**.

Remarks:  activates the graphics cursor.

Press **[ON]** to return to the stack display.
CANCEL



Example plots:



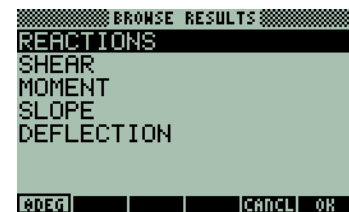
BROWS

Displays the specified results.

Input:





- Optional: Enter specific locations on the stack before pressing **BROWS**.
- Select the results to display.

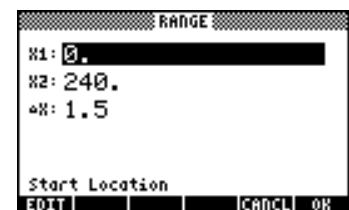
[F1] toggles slope output to degrees **θ DEG** or radians **θ RAD**.



- Input the range (unless locations were entered on the stack or REACTIONS was selected).
Enter the start location X1, end location X2, and increment ΔX.

Press **[ENTER]** with the default values to display all the data.

  resets the current field and   resets all fields to the default values.

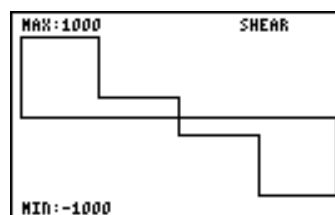


Remarks: Results are displayed in the output browser (see appendix C).

To display results for a few specific points, enter the locations on the stack before executing **BROWS**. Objects on the stack that are invalid locations, such as tagged numbers, are ignored.

Two values are returned at discontinuities—the left- and right-hand limits. When the diagram is constant on some interval and the default minimum increment is used, the interval and the value for that interval are displayed, as shown in the following example.

Example: PLOTD and BROWS output for a shear diagram.



QUERY

Displays all current results for one location.

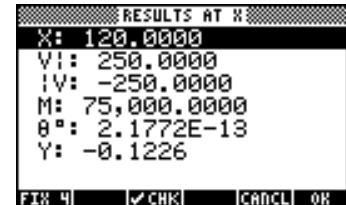
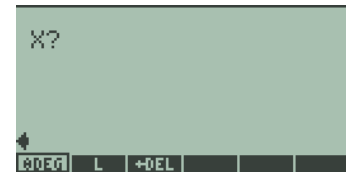
Input: Enter a location.

[F1] toggles slope output to degrees **θ DEG** or radians **θ RAD**.

Press **[ON]** to cancel.
CANCEL

Remarks: The entered location is rounded to the nearest increment.
Results are displayed in the output browser.

Example: For the shear diagram shown on the previous page, shear is undefined at X=120. Thus, the left- and right-hand limits are displayed for shear: V| is the shear to the left of the discontinuity and |V is the shear to the right of the discontinuity.



±MAX

Returns the maximum or minimum value—the one of greater absolute value or the positive value when the maximum and minimum are of equal magnitude.

Input:

- Optional: Enter start and end locations (X1 and X2) before pressing **±MAX**.
- Select from the list of current results.

Remarks: When there are valid locations on stack levels 1 and 2, the max value between those two points is returned to the stack, tagged with $X1 \leq X \leq X2 \text{ Zmax}$, where Z is the result symbol.

Otherwise, the stack is ignored and the max value over the entire length of the beam is returned, tagged with Zmax. **[EVAL]** removes the tag.

EXTRM

Displays the maximum and minimum values and their locations.

Input: Select from the list of current results.

Remarks: Results are displayed in the output browser as *Location : Value*.

PURGE

Purges the variables created by Beam49 from the current directory.

Input: **YES** or **NO**

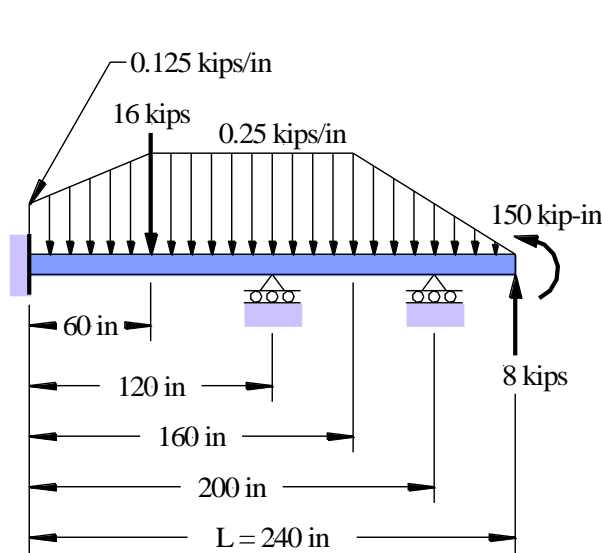
Remarks: **YES** purges ΣDAT, BDat, and the plot parameter variables (ΣPAR and PPAR).

About

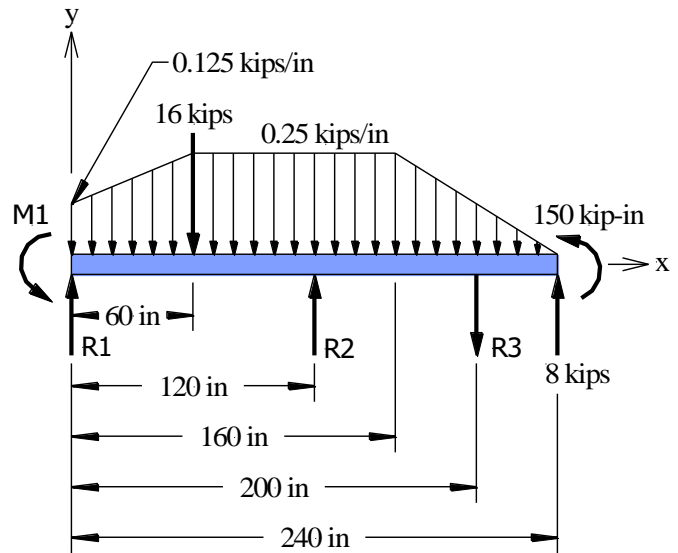
Displays the software version message until any key is pressed.

Examples

Example 1: Constant EI Beam



Beam and Loading



FBD

Compute the reactions, shear, and bending moment.

- 1) Press **RVM**.
- 2) Enter 240 for the length L and a value for the number of increments N.

Press **ENTER** or **OK**.

LENGTH & INCREMENTS

L: 240.

n: 240.

☒ AutoAdjust n

Length of Beam

EDIT | | | [CANCEL] OK

- 3) Input the three support locations.

0 **SPC** 120 **SPC** 200

OK

Support Locations?

7: 0

6: 120

5: 200

4: 0

3: 120

2: 200

1: 0

0 120 200

OVER | L | ? | HELP | [CANCEL] OK

- 4) Select Left End Fixed.

▼ **ENTER**

SUPPORT TYPE:

All 3 Pinned

Left End Fixed

| | | [CANCEL] OK

- 5) Select Constant EI.

ENTER

FLEXURAL RIGIDITY TYPE:

Constant EI

Variable I

Variable E

Variable E & I

| | | [CANCEL] OK

- OK

X_P? +P=↑

7:
6:
5:
4:
3:
2:
1:
60 -16 240 8♦

OVER L ? HELP CANCEL OK

- OK

```

X_M?  +M=Clockwise
7:
6:
5:
4:
3:
2:
1:
240 -150
OVER  L  ?  HELP  CANCEL  OK

```

- OK

X1_X2_W? +W=↑

7:					
6:					
5:					
4:					
3:					
2:					
1:					
60	160	-	.25		
OVER	L	?	HELP	CANCL	OK

- OK

	X1_W1_X2_W2?	+W=↑
8:		0.
7:		-.125
6:		60.
5:		-.25
4:		160.
3:		-.25
2:		240.
1:		0.
OVER	L	? HELP CANCEL OK

When the program finishes computing, press **BROWS** **OK** to display the reactions (kips and kip-in).

REACTIONS
SHEAR
MOMENT

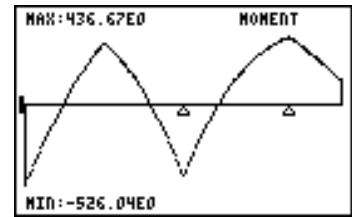
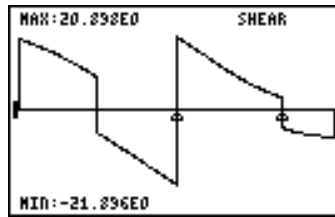
REACTIONS	
R1:	20.354
R2:	42.794
R3:	-8.898
M1:	-526.042

FIN 3

☒CHK

CANCEL OR

The shear and moment diagrams generated by PLOTD.

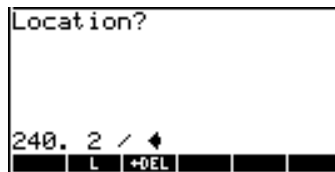


Display the shear and bending moment results for the midpoint $X = L/2$.

QUERY

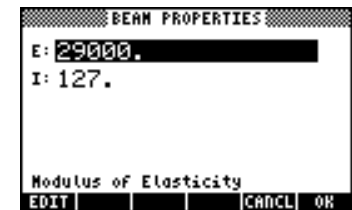
L 2 ÷

ENTER

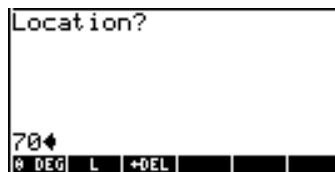


Compute the slope and deflection for a beam of $E = 29000$ ksi and $I = 127$ in⁴.

- 1) Press θY .
- 2) Input the modulus of elasticity E and moment of inertia I.
29 [EEX] 3 [ENTER] 127 [ENTER]
Press [ENTER].

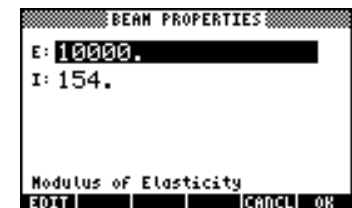


QUERY 70 [ENTER] displays the results for $X = 70$.

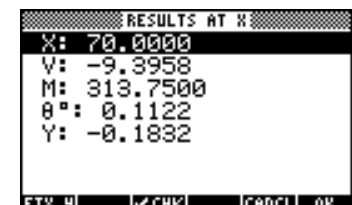
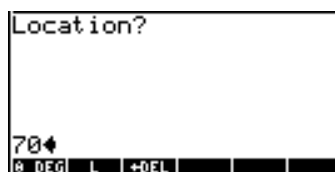


Recalculate the slope and deflection for a beam of $E = 10000$ ksi and $I = 154$ in⁴.

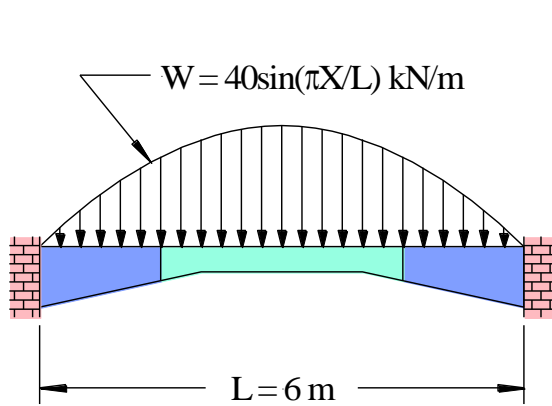
- 1) θY
- 2) Input the modulus of elasticity E and moment of inertia I.
1 [EEX] 4 [ENTER] 154 [ENTER]
[ENTER]



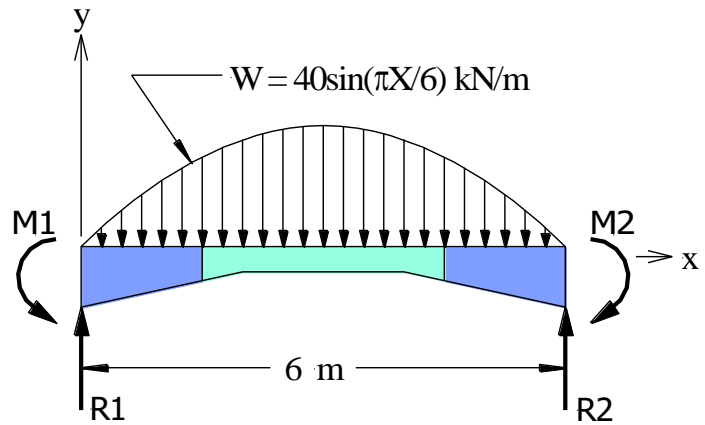
QUERY 70 [ENTER] displays the new results for $X = 70$.



Example 2: Variable EI Beam



Beam and Loading



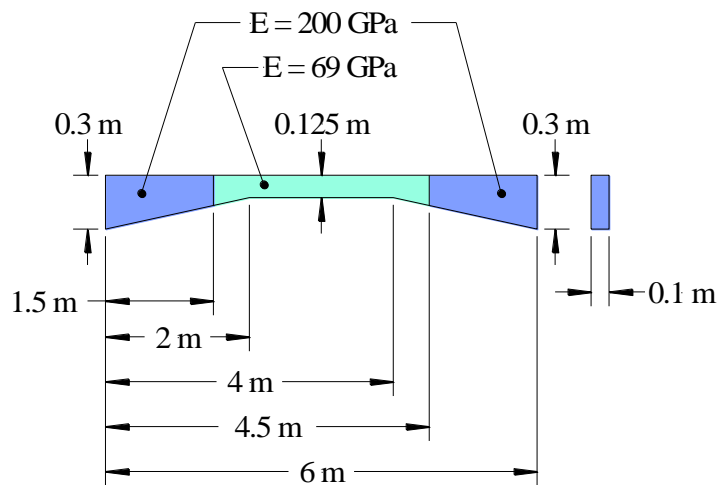
FBD

The moment of inertia for a tapered cross section must be entered as an algebraic expression ' $f(X)$ ', where $X=0$ at the section start location $X1$.

This beam has a rectangular cross section with a constant width w of 0.1 m and a variable depth d . The moment of inertia expression for the left-hand section, where the depth varies linearly, was derived from the equation of a line $y = mx + b$ as follows:

$$d = \frac{0.125 - 0.3}{2 - 0} X + 0.3 = 0.3 - 0.0875 X$$

$$I = \frac{wd^3}{12} = \frac{0.1}{12} d^3 = (8.3333333333E-3)(0.3 - 0.0875 X)^3$$



Beam Dimensions and Moduli of Elasticity

Modulus of Elasticity and Moment of Inertia Input Data

Start Location $X1$ (m)	Modulus of Elasticity E (kN/m ²)	Moment of Inertia I (m ⁴)	Variables (m)
0	200×10^6	' $K*(.3-.0875*X)^3$.'	$K = \frac{0.1}{12} = 8.33333333333E-3$ X = Distance from $X1$
1.5	69×10^6	...	
2	...	$K(.125)^3$	
4	...	' $K*(.125+.0875*X)^3$.'	
4.5	200×10^6	...	

For this example problem, store the moment of inertia data prior to executing RVM as follows:

1. Store the value $8.333333333333\text{E}-3$ in the variable K.
2. Key in the following program containing the start location and moment of inertia for each of the three sections:

```
<< 0. 'K*(.3-.0875*X)^3.'
    2. K .125 3. ^ *
    4. 'K*(.125+.0875*X)^3.' >>
```

Alternatively, stack input data can be stored in a list, instead of a program. Press **[EVAL]** to execute a list.

Checksum: # 1E65h

3. Store the program in the variable I.

Compute the reactions, shear, and bending moment.

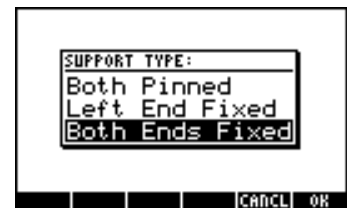
- 1) Press **RVM**.
- 2) Enter 6 for the length L and a value for the number of increments N.
Press **[ENTER]** or **OK**.



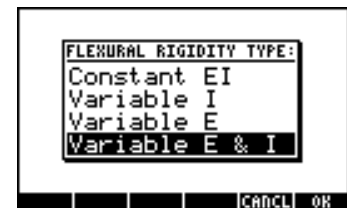
- 3) Input the two support locations.
0 **[SPC]** 6
OK



- 4) Select Both Ends Fixed.
[▲] **[ENTER]**



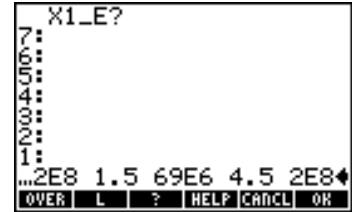
- 5) Select Variable E & I.
[▲] **OK**



- 6) Input the start location X1 and modulus of elasticity E for each of the three material sections.

0 [SPC] 2 [EEX] 8 [SPC] 1.5 [SPC] 69 [EEX] 6 [SPC]
4.5 [SPC] 2 [EEX] 8

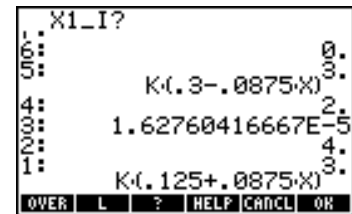
OK



- 7) Input the previously stored moment of inertia data.

ALPHA I [ENTER]

OK



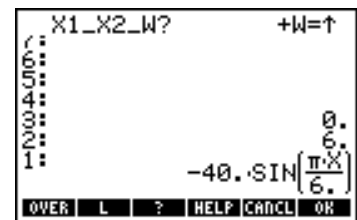
- 8) Press **NO** at the Concentrated Loads? prompt.
9) Press **NO** at the Applied Moments? prompt.
10) Press **YES** at the Uniform or Nonlinear Distributed Loads? prompt.
11) Input the load data.

Enter the start and end locations: 0 **L**

Assemble the load expression:

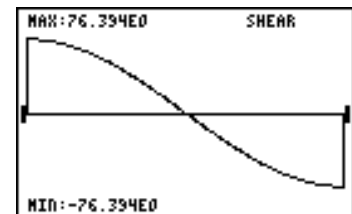
40 [+/-] [←] π [SPC] [X] [X] 6 [÷] [SIN] [X]

OK



- 12) Press **NO** at the Linear Distributed Loads? prompt.
13) Press **NO** at the Review Loads Input? prompt when ready to compute the results.

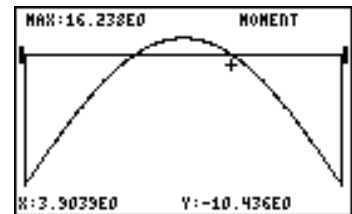
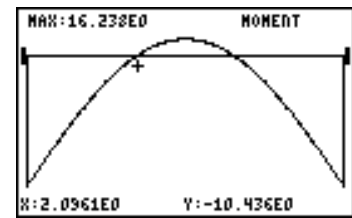
Once the program finishes computing, press **PLOTD** **OK** to plot the shear diagram.



Find the locations where the bending moment is zero:

Plot the diagram, then press to enter the PICTURE environment and activate the graphics cursor. Press or to turn on the cursor coordinate display and use the arrow keys to move the cursor. The moment diagram crosses the x -axis at approximately $X = 2.1$ and $X = 3.9$ m.

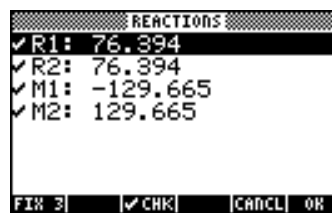
Press to exit.



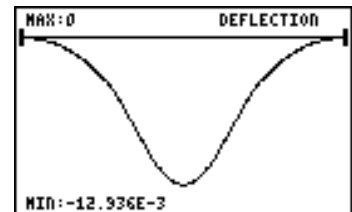
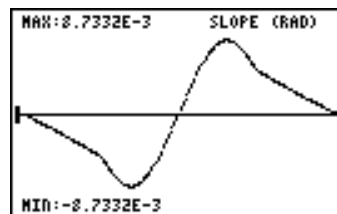
BROWS displays the reactions (kN and kN-m).

CHK checks all and

exits and copies the reaction values to the stack.



Press **YES** to compute the slope and deflection, then plot the diagrams with **PLOTD**.



Display the maximum and minimum slope in degrees:

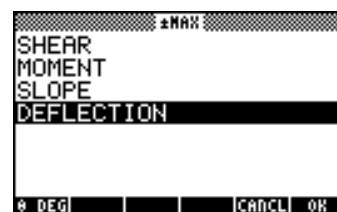
Press to display the other menu page. Press **EXTRM** and highlight **SLOPE**.

If necessary, press to toggle slope output to degrees **0 DEG**.



The maximum slope is ± 0.5 degrees at $X = 2.1$ and $X = 3.9$ m.

returns the max deflection (m).





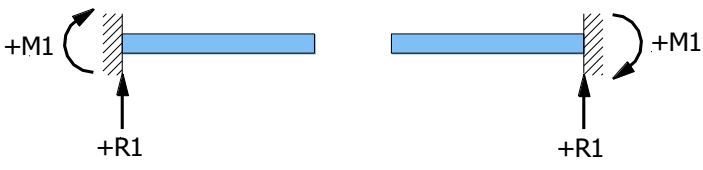
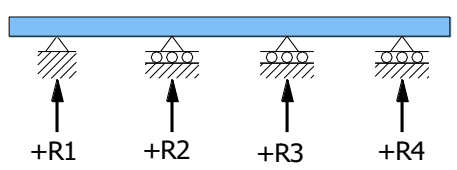
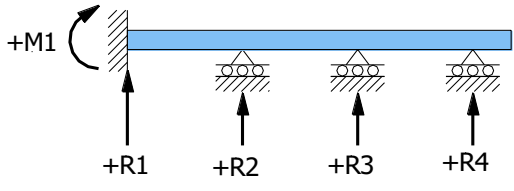
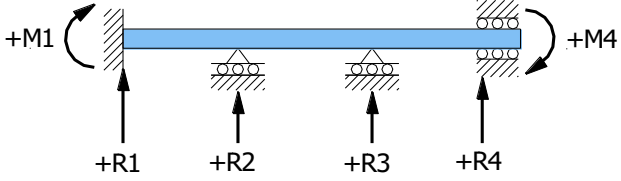
A

Symbols

E	Modulus of elasticity
I	Moment of inertia
L	Length of the beam
M	Applied moment or Bending moment
M1, M2,...	Moment reactions at fixed end supports
N	Number of increments
P	Concentrated load (Point load)
R1, R2,...	Force reactions at the supports
V	Vertical shear
W	Uniform or nonlinear distributed load
W1	Linear distributed load start value
W2	Linear distributed load end value
X	Location—distance from the left end of the beam. X is also used as the independent variable in algebraic expressions for distributed loads and moments of inertia, where: X = Distance from the start location X_1 .
X_1	Start location
X_2	End location
ΔX	Increment
Y	Deflection
θ	Slope in radians
θ°	Slope in degrees

B

Sign Convention

Symbol	Description	Sign Convention
Input:		
P	Concentrated load	+P = Upward
M	Applied moment	+M = Clockwise
W, W1 & W2	Distributed load	+W = Upward
Output:		
V	Shear	+V = 
M	Bending moment	+M = 
θ or θ°	Slope (radians or degrees)	+ θ = Counterclockwise rotation
Y	Deflection	+Y = Upward
Support Type	Reaction Notation & Sign Convention	
Cantilever		
All Supports Pinned		
Left End Fixed		
Both Ends Fixed		

C

Output Browser Keys

The commands BROWS, QUERY, and EXTRM display results in the output browser. The active keys for this browser are described in following table.

DEFLECTION		
3.725:	-9.5441E-3	↑
✓3.750:	-9.3366E-3	
3.775:	-9.1263E-3	
✓3.800:	-8.9135E-3	
3.825:	-8.6987E-3	
3.850:	-8.4824E-3	
3.875:	-8.2649E-3	↓
SCI	4	✓CHK
		CANCL OK

Key	Description
(F1)	The label of the first menu key indicates the current number display format. Press the key repeatedly to cycle the number display format from FIX to SCI to ENG to STD and back to FIX. (←)(F1) sets the number display format to STD.
✓CHK	Toggles the checkmark on the highlighted line. (←)✓CHK checks all and (→)✓CHK unchecks all.
CANCL	Exits without copying anything to the stack.
OK	Exits and copies any checked values to the stack.
(▲)	Moves the highlight bar up one line. At the top line, wraps around to the bottom line. Press and hold (▲) to scroll up. (←)(▲) jumps to the middle line and (→)(▲) jumps to the top line.
(◀)	Moves up one page. At the top, wraps around to the bottom.
(▼)	Moves the highlight bar down one line. At the bottom line, wraps around to the top line. Press and hold (▼) to scroll down. (←)(▼) jumps to the middle line and (→)(▼) jumps to the bottom line.
(▶)	Moves down one page. At the bottom, wraps around to the top.
(0) thru (6)	Set the number of decimal places or significant digits displayed. The current value is displayed in the second menu label.
(+/-)	Same as (F1) .
(ON) CANCEL	Same as CANCL , except that (→)(ON)^{OFF} turns the calculator off without exiting.
(•)	Same as ✓CHK .
(ENTER)	Same as OK .

D Global Variables

The program stores output data in two variables: Σ DAT (real array) and BDat (library data). These variables may be copied or moved from one directory to another, but both variables must reside in the current directory and they must contain data for the *same* beam or else you will get an error message.

E Assumptions & Limitations

- Slopes and deflections must be small.
- Deflection due to shear is assumed small, relative to the bending deflection, and is neglected.
- Stresses must be within the elastic range.
- The program executes algebraic expressions for distributed loads and moments of inertia in radians mode.

F Acknowledgments

Thanks to Eric Rechlin for providing hpcalc.org and to the following people for their indispensable programming tools:

- Sebastien Carlier and Christoph Gießelink for Emu48
- Eric Rechlin for the 50g KML script
- Mika Heiskanen and Jan Brittonson for the Jazz debugger
- Jurjen Bos for Nosy
- Pierre Tardy for CQIF?
- Eduardo Kalinowski and Carsten Dominik for the *Programming in System RPL* document
- James Donnelly for *An Introduction to HP 48 System RPL and Assembly Language Programming*

G About Beam49

Version	Library ID	Size	Checksum	Language
2.1	1707	25729 bytes	# EDE9h	System RPL

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