HEWLETT-PACKARD

HP-67/HP-97

Civil Engineering Pac I

Printed in Singapore

Introduction

The 18 programs of CE Pac I have been drawn from the fields of statics and stress analysis.

Each program in this pac is represented by one or more magnetic cards and a section in this manual. The manual provides a description of the program with relevant equations, a set of instructions for using the program, and one or more example problems, each of which includes a list of the actual keystrokes required for its solution. Program listings for all the programs in the pac appear at the back of this manual. Explanatory comments have been incorporated in the listings to facilitate your understanding of the actual working of each program. Thorough study of a commented listing can help you to expand your programming repertoire since interesting techniques can often be found in this way.

On the face of each magnetic card are various mnemonic symbols which provide shorthand instructions to the use of the program. You should first familiarize yourself with a program by running it once or twice while following the complete User Instructions in the manual. Thereafter, the mnemonics on the cards themselves should provide the necessary instructions, including what variables are to be input, which user-definable keys are to be pressed, and what values will be output. A full explanation of the mnemonic symbols for magnetic cards may be found in appendix A.

If you have already worked through a few programs in Standard Pac, you will understand how to load a program and how to interpret the User Instructions form. If these procedures are not clear to you, take a few minutes to review the sections, Loading a Program and Format of User Instructions, in your Standard Pac.

We hope that CE Pac I will assist you in the solution of numerous problems in your discipline. We would very much appreciate knowing your reactions to the programs in this pac, and to this end we have provided a questionnaire inside the front cover of this manual. Would you please take a few minutes to give us your comments on these programs? It is in the comments we receive from you that we learn how best to increase the usefulness of programs like these.

CONTENTS

A WORD ABOUT PROGRAM USAGE

This application pac has been designed for both the HP-97 Programmable Printing Calculator and the HP-67 Programmable Pocket Calculator. The most significant difference between the HP-67 and the HP-97 calculators is the printing capability of the HP-97. The two calculators also differ in a few minor ways. The purpose of this section is to discuss the ways that the programs in this pac are affected by the difference in the two machines and to suggest how you can make optimal use of your machine, be it an HP-67 or an HP-97.

Many of the computed results in this pac are output by PRINT statements; on the HP-97 these results will be output on the printer. On the HP-67 each PRINT command will be interpreted as a PAUSE: the program will halt, display the result for about five seconds, then continue execution. The term "PRINT/PAUSE" is used to describe this output condition.

If you own an HP-67, you may want more time to copy down the number displayed by a PRINT/PAUSE. All you need to do is press any key on the keyboard. If the command being executed is PRINTx (eight rapid blinks of the decimal point), pressing a key will cause the program to halt. Execution of the halted program may be re-initiated by pressing **R/S**.

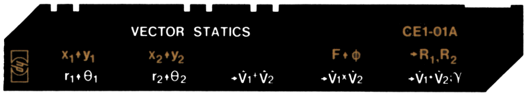
HP-97 users may also want to keep a permanent record of the values input to a certain program. A convenient way to do this is to set the Print Mode switch to NORMAL before running the program. In this mode all input values and their corresponding user-definable keys will be listed on the printer, thus providing a record of the entire operation of the program.

Another area that could reflect differences between the HP-67 and the HP-97 is in the keystroke solutions to example problems. It is sometimes necessary in these solutions to include operations that involve prefix keys, namely, **f** on the HP-97 and **f**, **g**, and **h** on the HP-67. For example, the operation [10^x] is performed on the HP-97 as **f** [10^x] and on the HP-67 as **g** [10^x]. In such cases, the keystroke solution omits the prefix key and indicates only the operation (as here, [10^x]). As you work through the example problems, take care to press the appropriate prefix keys (if any) for your calculator.

Also in keystroke solutions, those values that are output by the PRINT command will be followed by three asterisks (***).

Notes

VECTOR STATICS



Part I of this program performs the basic two dimensional vector operations of addition, cross product and dot, scalar, or inner product. In addition, the angle between vectors may be found. Vectors may be input in polar form (r, θ) or rectangular form (x_1, y_1).

Equations:

for addition: $\vec{V}_1 + \vec{V}_2 = (x_1 + x_2)\,\vec{i} + (y_1 + y_2)\,\vec{j}$

for cross products: $\vec{V}_1 \times \vec{V}_2 = (x_1y_2 - x_2y_1)\,\vec{k}$

for dot, scalar, or inner product: $\vec{V}_1 \cdot \vec{V}_2 = x_1x_2 + y_1y_2$

for the angle between vectors: $\gamma = \cos^{-1}\dfrac{\vec{V}_1 \cdot \vec{V}_2}{|\vec{V}_1|\,|\vec{V}_2|}$

where:

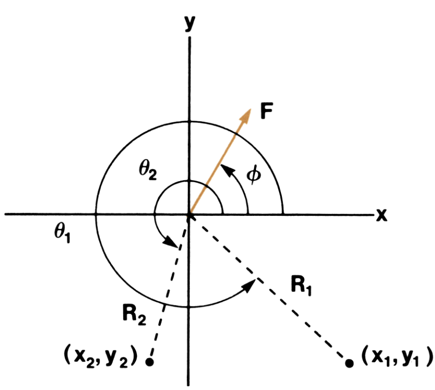
x_1 is the x component of $\vec{V}_1$ $(x_1 = r_1 \cos \theta_1)$;

x_2 is the x component of $\vec{V}_2$ $(x_2 = r_2 \cos \theta_2)$;

y_1 is the y component of $\vec{V}_1$ $(y_1 = r_1 \sin \theta_1)$;

y_2 is the y component of $\vec{V}_2$ $(y_2 = r_2 \sin \theta_2)$;

Part II of this program calculates the two reaction forces necessary to balance a given two-dimensional force vector. The direction of the reaction forces may be specified as a vector of arbitrary length or by Cartesian coordinates using the point of force application as the origin.



Equations:

$$R_1 \cos \theta_1 + R_2 \cos \theta_2 = F \cos \phi$$
$$R_1 \sin \theta_1 + R_2 \sin \theta_2 = F \sin \phi$$

where:

F is the known force;

ϕ is the direction of the known force;

R_1 is one reaction force;

θ_1 is the direction of R_1;

R_2 is the second reaction force;

θ_2 is the direction of R_2.

The coordinates x_1 and y_1 are referenced from the point where F is applied to the end of the member along which R_1 acts; x_2 and y_2 are the coordinates referenced from the point where F is applied to the end of the member along which R_2 acts.

Remarks:

Registers $R_0 - R_3$; $R_{S0} - R_{S9}$ and I are available for user storage.

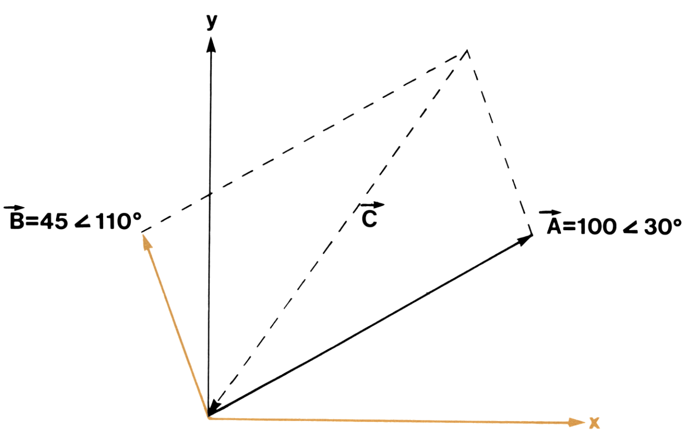
STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	To resolve a force in two			
	known directions, go to step 6.			
	For vector addition, cross			
	product, or dot product con-			
	tinue with step 3.			
3	Input $\vec{V}_1$ and $\vec{V}_2$:			
	$\vec{V}_1$ in polar form	r_1	ENTER↑	r_1
		θ_1	A	y_1
	or			
	$\vec{V}_1$ in rectangular form	x_1	ENTER↑	x_1
		y_1	f A	y_1
	and			
	$\vec{V}_2$ in polar form	r_2	ENTER↑	r_2
		θ_2	B	y_2
	or			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	$\vec{V}_2$ in rectangular form.	x_2	ENTER↑	x_2
		y_2	f B	y_2
4	Perform vector operation:			
	add vectors		C	r, θ
	or			
	take cross product		D	$\vec{V}_1 \times \vec{V}_2$
	or			
	take dot (or scalar) product.		E	$\vec{V}_1 \cdot \vec{V}_2$
	(Optionally, calculate angle			
	between vectors after dot			
	product.)		R/S	γ
5	For a new case, go to step 3			
	and change $\vec{V}_1$ and/or $\vec{V}_2$.			
6	Define reaction directions as			
	Cartesian coordinates or as			
	vectors of arbitrary magnitude.			
	(Use the point of force appli-			
	cations as the origin):			
	define direction one in polar			
	form	1	ENTER↑	1.00
		θ_1	A	sin θ_1
	or			
	in rectangular form	x_1	ENTER↑	x_1
		y_1	f A	y_1
	and			
	define direction two in polar			
	form	1	ENTER↑	1.00
		θ_2	B	sin θ_2
	or			
	in rectangular form.	x_2	ENTER↑	x_2
		y_2	f B	y_2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	Input known force:			
	magnitude	F	ENTER↑	F
	then direction.	ϕ	f D	F sin ϕ
8	Compute reactions		f E	R_1, R_2
9	To change force, go to step 7.			
	To change either or both			
	directions, go to step 6.			

Example 1:

Forces A and B are shown below. If static equilibrium exists, what is force C.



Keystrokes: **Outputs:**

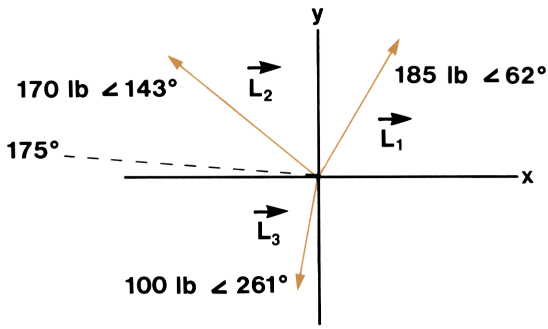
To obtain $\vec{C}$, add $\vec{A}$ and $\vec{B}$ using negative magnitudes for both.

45 CHS ENTER↑ 110 A 100 CHS
ENTER↑ 30 B C ⟶ 116.57 ***
-127.66 ***

$\vec{C}$ = 116.57∠ -127.66°

Example 2:

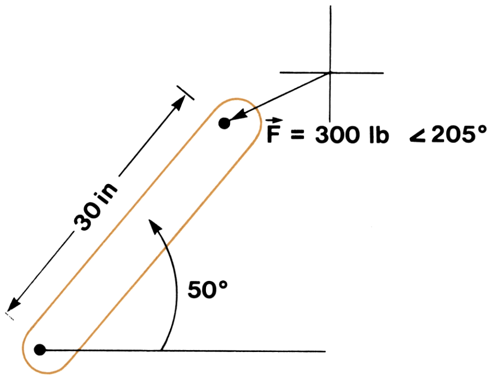
Resolve the following three loads along a 175 degree line.



Keystrokes:	**Outputs:**
First add $\vec{L}_1$ and $\vec{L}_2$.	
185 ENTER↑ 62 A 170 ENTER↑	
143 B C →	270.12 *** (lb)
	100.43 *** (deg)
Define the result as $\vec{V}_1$ and add $\vec{L}_3$.	
A 100 ENTER↑ 261 B C →	178.94 *** (lb)
	111.15 *** (deg)
To resolve the vector, just calculated along the 175° line.	
A 1 ENTER↑ 175 B E →	78.86 *** (lb)
What is the angle between the vector and the line?	
R/S →	63.85 *** (deg)

Example 3:

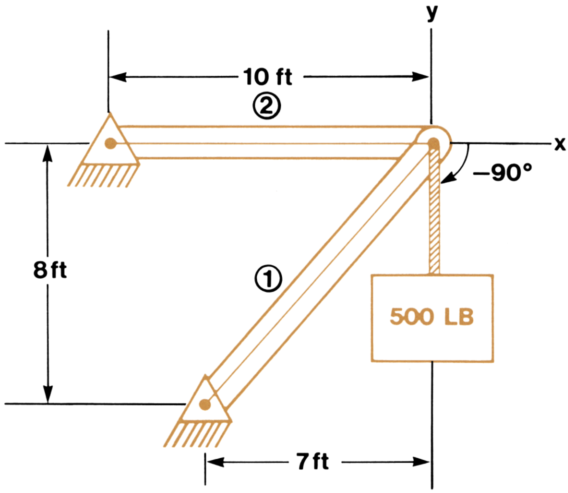
What is the moment at the shaft of the crank pictured below? What is the reaction force transmitted along the member?



Keystrokes:	**Outputs:**	
Moment by cross product ($\vec{V}_1 \times \vec{F}$).		
30 ENTER↑ 50 A 300 ENTER↑		
205 B D ⟶	3803.56	in-lb
Resolution along crank		
1 ENTER↑ 50 A E ⟶	−271.89	lb

Example 4:

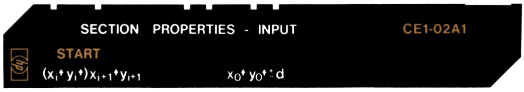
Find the reaction forces in the pin-jointed structure shown below.

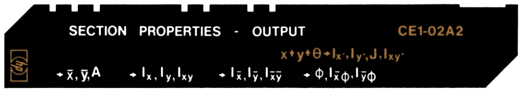


Keystrokes:	Outputs:
7 CHS ENTER↑ 8 CHS f A →	-8.00
10 CHS ENTER↑ 0 f B →	0.00
500 ENTER↑ 90 CHS f D →	-500.00
f E →	-664.38 *** (R_1)
	437.50 *** (R_2)

Notes

SECTION PROPERTIES





The properties of polygonal sections (see figure 1) may be calculated using this program. The (x, y) coordinates of the vertices of the polygon (which must be located entirely within the first quadrant) are input sequentially for a complete, clockwise path around the polygon. Holes in the cross section, which do not intersect the boundary, may be deleted by following a counter-clockwise path.

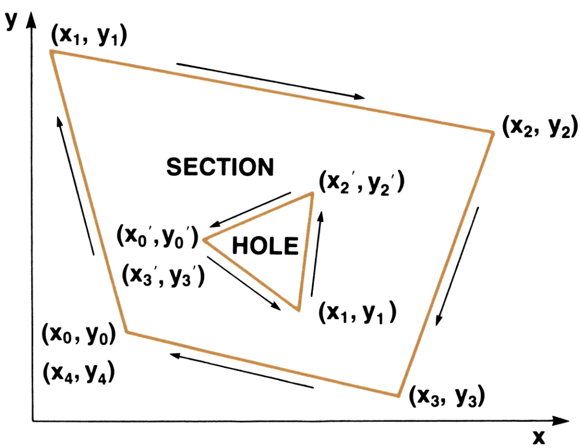


Figure 1 — Polygonal Sections

A special feature allows addition or deletion of circular areas. After the point by point traverse of the section has been completed, circular deletions or additions are specified by the (x,y) coordinates of the circle centers and by the circle diameters. If the diameter is specified as a positive number, the circular areas are added. A negative diameter causes circular areas to be deleted. Example 4 shows an application of this feature.

After all values have been input, the coordinates of the centroid ($\bar{x}$, $\bar{y}$) and the area (A) of the section may be output using card 2, key **A**. The moment of inertia about the x axis (I_x), about the y axis (I_y) and the product of inertia (I_{xy}) are output using **B**. Similar moments, $I_{\bar{x}}$, $I_{\bar{y}}$ and $I_{\bar{x}\bar{y}}$, about an axis translated to the centroid of the section are calculated when **C** is pressed.

Pressing **D** calculates the moments of inertia, $I_{\bar{x}\phi}$ and $I_{\bar{y}\phi}$, about the principal axis. The rotation angle (ϕ) between the principal axis and the axis which was translated to the centroid is also calculated. The moments of inertia I_x', I_y', the polar moment of inertia J and the product of inertia I_{xy}' may be calculated about any arbitrary axis by specifying its location and rotation with respect to the original axis and pressing **f** **D**.

Equations:

$$A = -\sum_{i=0}^{n} (y_{i+1} - y_i)(x_{i+1} + x_i)/2$$

$$\bar{x} = \frac{-1}{A}\sum_{i=0}^{n} \left[(y_{i+1} - y_i)/8\right]\left[(x_{i+1} + x_i)^2 + (x_{i+1} - x_i)^2/3\right]$$

$$\bar{y} = \frac{1}{A}\sum_{i=0}^{n} \left[(x_{i+1} - x_i)/8\right]\left[(y_{i+1} + y_i)^2 + (y_{i+1} - y_i)^2/3\right]$$

$$I_x = \sum_{i=0}^{n} \left[(x_{i+1} - x_i)(y_{i+1} + y_i)/24\right]\left[(y_{i+1} + y_i)^2 + (y_{i+1} - y_i)^2\right]$$

$$I_y = -\sum_{i=0}^{n} \left[(y_{i+1} - y_i)(x_{i+1} + x_i)/24\right]\left[(x_{i+1} + x_i)^2 + (x_{i+1} - x_i)^2\right]$$

$$I_{xy} = \sum_{i=0}^{n} \frac{1}{(x_{i+1} - x_i)}\left[\frac{1}{8}(y_{i+1} - y_i)^2(x_{i+1} + x_i)(x_{i+1}^2 + x_i^2) + \frac{1}{3}(y_{i+1} - y_i)(x_{i+1}y_i - x_i y_{i+1})(x_{i+1}^2 + x_{i+1}x_i + x_i^2) + \frac{1}{4}(x_{i+1}y_i - x_i y_{i+1})^2(x_{i+1} + x_i)\right]$$

$$I_{\bar{x}} = I_x - A\bar{y}^2$$

$$I_{\bar{y}} = I_y - A\bar{x}^2$$

$$I_{\bar{x}\bar{y}} = I_{xy} - A\bar{x}\bar{y}$$

$$\phi = \frac{1}{2}\tan^{-1}\left(\frac{-2I_{\bar{x}\bar{y}}}{I_{\bar{x}} - I_{\bar{y}}}\right)$$

$$I_x{}' = I_{\bar{x}}\cos^2\theta + I_{\bar{y}}\sin^2\theta - I_{\bar{x}\bar{y}}\sin 2\theta$$

$$I_y{}' = I_{\bar{y}}\cos^2\theta + I_{\bar{x}}\sin^2\theta + I_{\bar{x}\bar{y}}\sin 2\theta$$

$$J = I_x{}' + I_y{}'$$

$$I_{xy}{}' = \frac{(I_{\bar{x}} - I_{\bar{y}})}{2}\sin 2\theta + I_{\bar{x}\bar{y}}\cos 2\theta$$

$$A_{circle} = \frac{\pi d^2}{4}$$

$$I_{circle} = \frac{\pi d^4}{64}$$

where:

x_{i+1} is the x coordinate of the current vertex point;

y_{i+1} is the y coordinate of the current vertex point;

x_i is the x coordinate of the previous vertex point;

y_i is the y coordinate of the previous vertex point;

A is the area;

$\bar{x}$ is the x coordinate of the centroid;

$\bar{y}$ is the y coordinate of the centroid;

I_x is the moment of inertia about the x-axis;

I_y is the moment of inertia about the y-axis;

I_{xy} is the product of inertia;

$I_{\bar{x}}$ is the moment of inertia about the x-axis translated to the centroid;

$I_{\bar{y}}$ is the moment of inertia about the y-axis translated to the centroid;

$I_{\bar{x}\bar{y}}$ is the product of inertia about the translated axis;

ϕ is the angle between the translated axis and the principal axis;

$I_{\bar{x}\phi}$ is the moment of inertia about the translated, rotated, principal x-axis;

$I_{\bar{y}\phi}$ is the moment of inertia about the translated, rotated, principal y-axis;

θ is the angle between the original axis and an arbitrary axis.

$I_x{}'$ is the x moment of inertia about the arbitrary axis;

$I_y{}'$ is the y moment of inertia about the arbitrary axis;

J is the polar moment of inertia about the arbitrary axis;

I_{xy}' is the product of inertia about the arbitrary axis;

d is the diameter of a circular area.

Reference:

Wojciechowski, Felix; *Properties of Plane Cross Sections; Machine Design;* p. 105, Jan. 22, 1976.

Remarks:

Registers $R_{S0} - R_{S9}$ are available for user storage.

The polygon must be entirely contained in the first quadrant.

Rounding errors will accumulate if the centroid of the section is a large distance from the origin of the coordinate system.

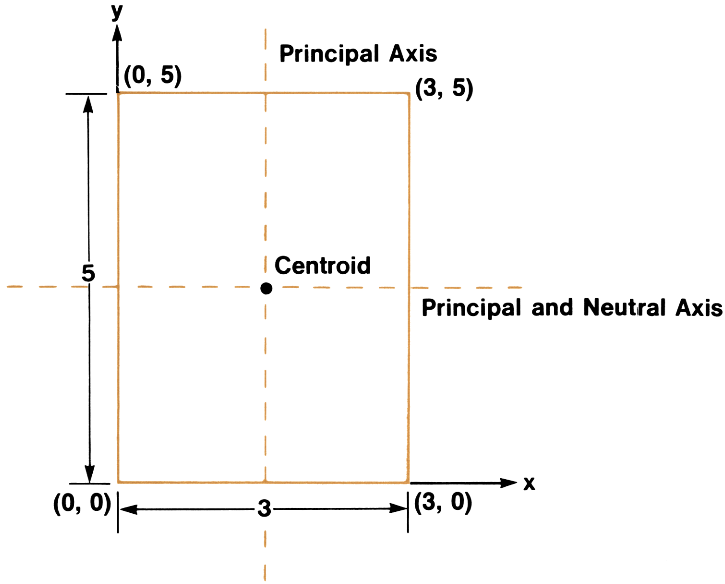
Curved boundaries may be approximated by straight line segments.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2 of			
	card 1.			
2	Initialize.		f A	
3	Key in (x, y) coordinates of			
	first vertex.	x_i	ENTER↑	y_i
		y_i	ENTER↑	y_i
4	Key in (x, y) coordinates of			
	next clockwise vertex.	x_{i+1}	ENTER↑	x_{i+1}
		y_{i+1}	A	y_{i+1}
5	Wait for execution to end, then			
	repeat step 4 for next point.			
	Go to step 6 after you have			
	reinput the starting point.			
6	To delete subsections within			
	the section just traversed,			
	return to step 3, but traverse in			
	a counter-clockwise direction.			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	Optional: Add circular areas,	x	ENTER↑	x
		y	ENTER↑	y
		d	C	0.00
	or delete circular areas.	x	ENTER↑	x
		y	ENTER↑	y
		d	CHS C	0.00
8	Load side 1 and side 2 of			
	card 2.			
9	Calculate any or all of the			
	following:			
	Centroid and area;		A	$\bar{x}$, $\bar{y}$, A
	Properties about original			
	axis;		B	I_x, I_y, I_{xy}
	Properties about axis trans-			
	lated to centroid;		C	$I_{\bar{x}}$, $I_{\bar{y}}$, $I_{\overline{xy}}$
	Angular orientation of			
	principal axis and properties			
	about principal axis;		D	ϕ, $I_{\bar{x}\phi}$, $I_{\bar{y}\phi}$
	or			
	Specify arbitrary axis and			
	rotation and calculate			
	properties.	x′	ENTER↑	
		y′	ENTER↑	
		θ	f D	I_x', I_y', J, I_{xy}'
10	To modify the section, go to			
	step 1, but skip step 2. For a			
	new case, go to step 1.			

Example 1:

What is the moment of inertia about the x-axis (I_x) for the rectangular section shown? What is the moment of inertia about the neutral axis through the centroid of the section ($I_{\bar{x}\phi}$)?



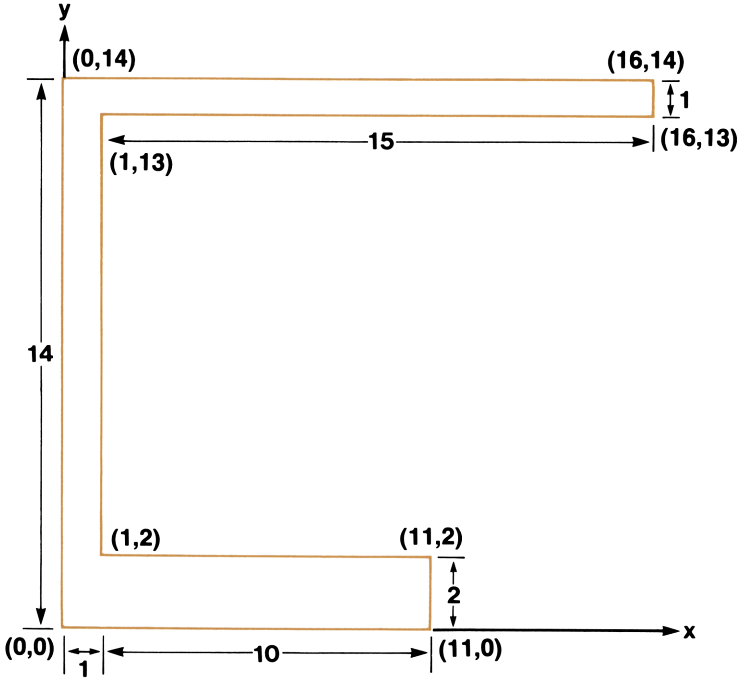
Keystrokes:	**Outputs:**
Load side 1 and side 2 of card 1.	
f A 0 ENTER↑ 0 ENTER↑	
0 ENTER↑ 5 A →	5.00
3 ENTER↑ 5 A →	5.00
3 ENTER↑ 0 A →	0.00
0 ENTER↑ 0 A →	0.00
Load side 1 and side 2 of card 2.	
B →	125.00 *** (I_x)
	45.00 *** (I_y)
	56.25 *** (I_{xy})
D →	0.00 *** (ϕ)
	31.25 *** ($I_{\bar{x}\phi}$)
	11.25 *** ($I_{\bar{y}\phi}$)

Since $\phi = 0$ we would expect $I_{\bar{x}\phi}$ to equal $I_{\bar{x}}$. Press **C** to calculate $I_{\bar{x}}$, $I_{\bar{y}}$ and $I_{\bar{x}\bar{y}}$ and you will see that this prediction is correct. Also, $I_{\bar{x}\bar{y}}$ is zero about the principal axis.

C →	31.25 *** ($I_{\bar{x}}$)
	11.25 *** ($I_{\bar{y}}$)
	0.00 *** ($I_{\bar{x}\bar{y}}$)

Example 2:

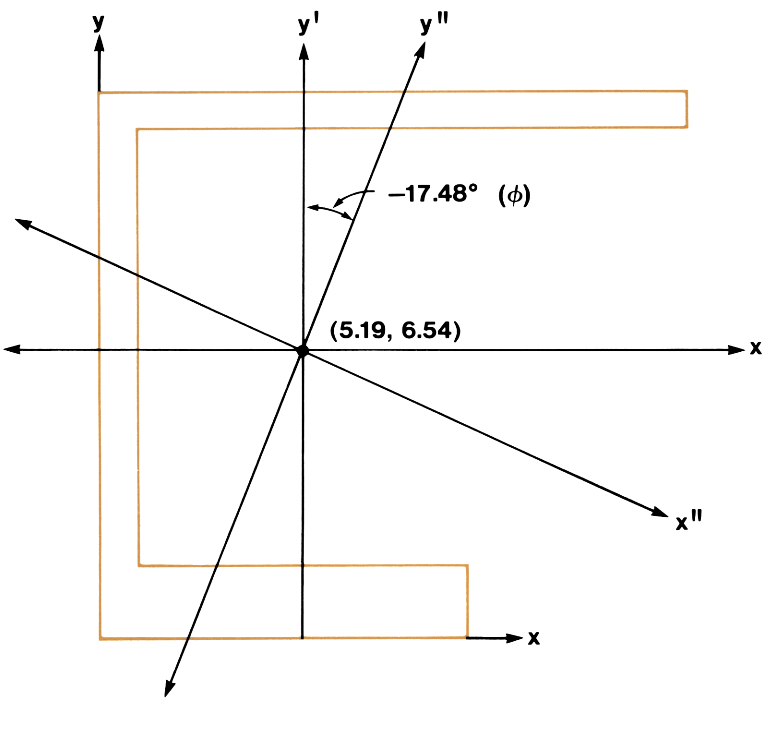
Calculate the section properties for the beam shown below.



Keystrokes:	**Outputs:**
Load side 1 and side 2 of card 1.	
f **A** 0 **ENTER↑** 0 **ENTER↑**	
0 **ENTER↑** 14 **A** →	14.00
16 **ENTER↑** 14 **A** →	14.00
16 **ENTER↑** 13 **A** →	13.00
1 **ENTER↑** 13 **A** →	13.00
1 **ENTER↑** 2 **A** →	2.00
11 **ENTER↑** 2 **A** →	2.00
11 **ENTER↑** 0 **A** →	0.00

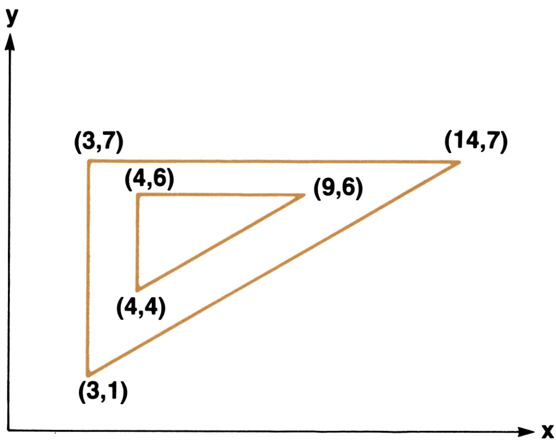
0 ENTER↑ 0 A ⟶	0.00
Load side 1 and side 2 of card 2.	
A ⟶	5.19 *** ($\bar{x}$)
	6.54 *** ($\bar{y}$)
	49.00 *** (A)
B ⟶	3676.33 *** (I_x)
	2256.33 *** (I_y)
	1890.25 *** (I_{xy})
C ⟶	1580.00 *** ($I_{\bar{x}}$)
	934.49 *** ($I_{\bar{y}}$)
	225.61 *** ($I_{\bar{x}\bar{y}}$)
D ⟶	−17.48 *** (ϕ)
	1651.04 *** ($I_{\bar{x}\phi}$)
	863.46 *** ($I_{\bar{y}\phi}$)

Below is a figure showing the translated axis and the rotated, principal axis of example 2.



Example 3:

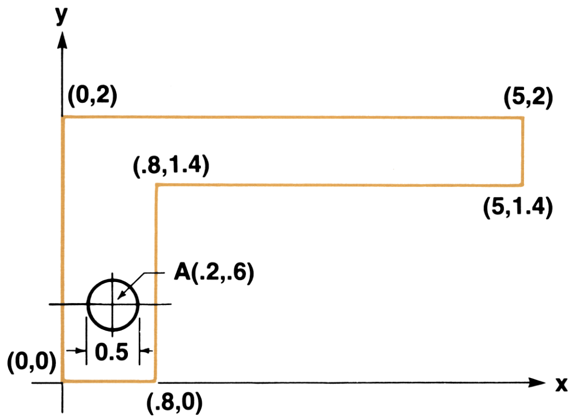
What is the centroid of the section below? The inner triangular boundary denotes an area to be deleted.



Keystrokes:	**Outputs:**
Load side 1 and side 2 of card 1.	
f A 3 ENTER↑ 1 ENTER↑	
3 ENTER↑ 7 A ⟶	7.00
14 ENTER↑ 7 A ⟶	7.00
3 ENTER↑ 1 A ⟶	1.00
Delete inner triangle:	
4 ENTER↑ 4 ENTER↑ 9 ENTER↑	
6 A ⟶	6.00
4 ENTER↑ 6 A ⟶	6.00
4 ENTER↑ 4 A ⟶	4.00
Load side 1 and side 2 of card 2.	
Compute Centroid	
A ⟶	6.85 *** ($\bar{x}$)
	4.94 *** ($\bar{y}$)
	28.00 *** (A)

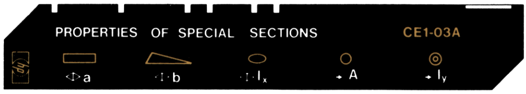
Example 4:

For the part below, compute the polar moment of inertia about point A. Point A denotes the center of a hole about which the part rotates. The area of the hole must be deleted from the cross section.



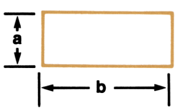
Keystrokes:	**Outputs:**
Load side 1 and side 2 of card 1.	
f A 0 ENTER↑ 0 ENTER↑ 0 ENTER↑	
2 A 5 ENTER↑ 2 A 5 ENTER↑	
1.4 A .8 ENTER↑ 1.4 A .8 ENTER↑	
0 A 0 ENTER↑ 0 A ⟶	0.00
Delete the hole.	
.2 ENTER↑ .6 ENTER↑	
.5 CHS C ⟶	0.00
Load side 1 and side 2 of card 2. Compute J about point (.2, .6) with θ of zero.	
.2 ENTER↑ .6 ENTER↑	
0 f D ⟶	3.91 *** ($I_{x'}$)
	22.22 *** ($I_{y'}$)
	26.13 *** (J)
	7.61 *** ($I_{xy'}$)

PROPERTIES OF SPECIAL SECTIONS



For rectangles, triangles, ellipses, circles, and concentric circles, this program performs an interchangeable solution between the section dimensions and the principle moment of inertia about the x axis. The section area and the principle moment of inertia about the y axis may also be calculated.

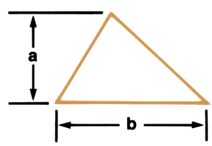
Sections and Equations:



$$I_x = a^3b/12$$

$$I_y = ab^3/12$$

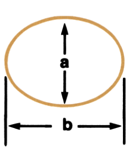
$$A = ab$$



$$I_x = a^3b/36$$

$$I_y = ab^3/36$$

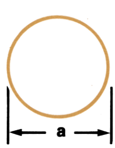
$$A = ab/2$$



$$I_x = \pi a^3b/64$$

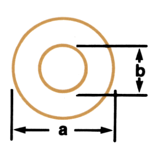
$$I_y = \pi ab^3/64$$

$$A = \pi ab/4$$



$$I_x = \pi a^4/4 = I_y$$

$$A = \pi a^2/4$$



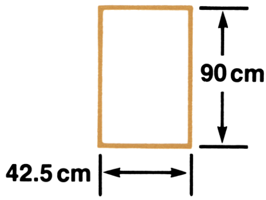
$$I_x = \frac{\pi(a^4 - b^4)}{64} = I_y$$

$$A = \frac{\pi(a^2 - b^2)}{4}$$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Select cross section shape.			
	Rectangle		f A	1.000 00
	Triangle		f B	2.000 00
	Ellipse		f C	3.000 00
	Circle		f D	4.000 00
	Concentric Circles		f E	5.000 00
3	Input two of the following:*	a	A	a
		b	B	b
		I_x	C	I_x
4	Compute unknown value:*		A	a
			B	b
			C	I_x
5	Optional: Compute area		D	A
6	Optional: Compute I_y		E	I_y
7	For a new case, go to step 3			
	and change inputs			
	*For circles, only one input or			
	output is allowed.			
	Input I_x or a only.			

Example 1:

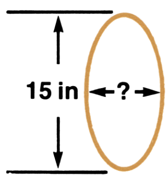
For the rectangular section below, what is the moment of inertia about the x axis? What is the moment of inertia about the y axis?



Keystrokes:	Outputs:	
f **A** →	1.000 00	(Select) (rectangles)
42.5 **B** 90 **A** **C** →	2.582 06	cm^4 (I_x)
E →	575.7 03	cm^4 (I_y)

Example 2:

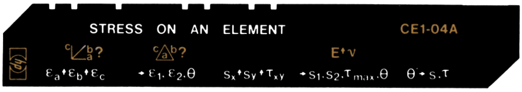
For the elliptical section below, what is the required value of b to make I_x = 1000? What is the area of the section?



Keystrokes:	Outputs:	
f **C** 15 **A** 1000 **C** **B** →	6.036 00	in (b)
D →	71.11 00	in^2 (A)

Notes

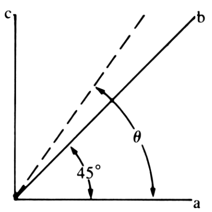
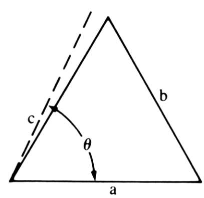
STRESS ON AN ELEMENT



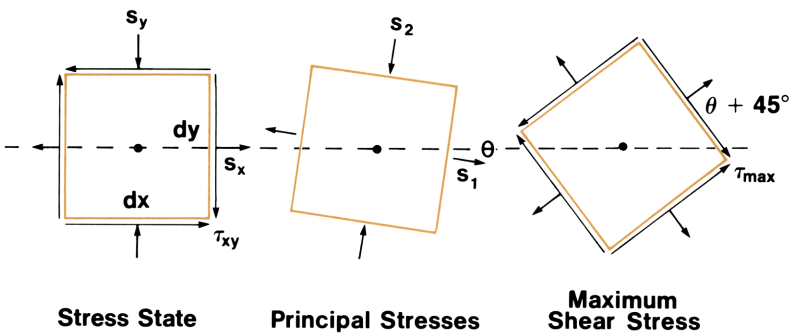
This program reduces data from rosette strain gage measurements and/or performs Mohr circle stress analysis calculations.

Correlations for rectangular and equiangular rosette configurations are included.

Strain Gage Equations:

CONFIGURATION CODE	1	2
TYPE OF ROSETTE	RECTANGULAR	DELTA (EQUIANGULAR)
		
PRINCIPAL STRAINS: $\epsilon_1,\ \epsilon_2$	$\frac{1}{2}\left[\epsilon_a+\epsilon_c \pm \sqrt{2(\epsilon_a-\epsilon_b)^2+2(\epsilon_b-\epsilon_c)^2}\right]$	$\frac{1}{3}\left[\epsilon_a+\epsilon_b+\epsilon_c \pm \sqrt{2(\epsilon_a-\epsilon_b)^2+2(\epsilon_b-\epsilon_c)^2+2(\epsilon_c-\epsilon_a)^2}\right]$
CENTER OF MOHR CIRCLE: $\frac{s_1+s_2}{2}$	$\frac{E(\epsilon_a+\epsilon_c)}{2(1-\nu)}$	$\frac{E(\epsilon_a+\epsilon_b+\epsilon_c)}{3(1-\nu)}$
MAXIMUM SHEAR STRESS: τ_{max}	$\frac{E}{2(1+\nu)}\sqrt{2(\epsilon_a-\epsilon_b)^2+2(\epsilon_b-\epsilon_c)^2}$	$\frac{E}{3(1+\nu)}\sqrt{2(\epsilon_a-\epsilon_b)^2+2(\epsilon_b-\epsilon_c)^2+2(\epsilon_c-\epsilon_a)^2}$
ORIENTATION OF PRINCIPAL STRESSES	$\tan^{-1}\left[\frac{2\epsilon_b-\epsilon_a-\epsilon_c}{\epsilon_a-\epsilon_c}\right]$	$\tan^{-1}\left[\frac{\sqrt{3}\,(\epsilon_c-\epsilon_b)}{(2\epsilon_a-\epsilon_b-\epsilon_c)}\right]$

The Mohr circle portion of the program converts an arbitrary stress configuration to principal stresses, maximum shear stress and rotation angle. It is then possible to calculate the state of stress for an arbitrary orientation θ'.



Mohr Circle Equations:

$$\tau_{max} = \sqrt{\left(\frac{s_x - s_y}{2}\right)^2 + \tau_{xy}^2}$$

$$s_1 = \frac{s_x + s_y}{2} + \tau_{max}$$

$$s_2 = \frac{s_x + s_y}{2} - \tau_{max}$$

$$\theta = ½ \tan^{-1}\left(\frac{2\tau_{xy}}{s_x - s_y}\right)$$

$$s = \frac{s_1 + s_2}{2} + \tau_{max} \cos 2\theta'$$

$$\tau = \tau_{max} \sin 2\theta'$$

where:

s is the normal stress, and τ is the shear stress.

ϵ_a, ϵ_b, and ϵ_c are the strains measured using rosette gages;

s_x is the stress in the x direction for Mohr circle input;

s_y is the stress in the y direction for Mohr circle input;

τ_{xy} is the shear stress on the element for Mohr circle input;

ϵ_1 and ϵ_2 are the principal strains;

s_1 and s_2 are the principal normal stresses;

τ_{max} is the maximum shear stress;

ν is Poisson's ratio;

θ is the counterclockwise angle of rotation from the specified axis to the principal axis. Note that this is opposite to the normal Mohr circle convention.

θ' is an arbitrary rotation angle from the original (x, y) axis;

E is modulus of elasticity.

Reference:

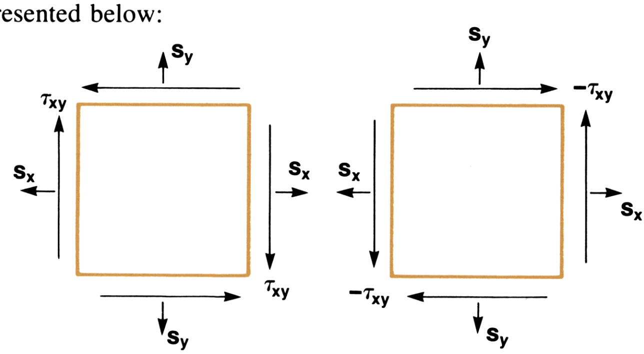
Spotts, M.F., *Design of Machine Elements,* Prentice-Hall, 1971.

Beckwith, T. G., Buck, N. L., *Mechanical Measurements,* Addison-Wesley, 1969

Remarks:

R_0, R_1, R_7, R_8, R_D and R_{S0}–R_{S9} are available for user storage.

Negative stresses and strains indicate compression. Positive and negative shear are represented below:

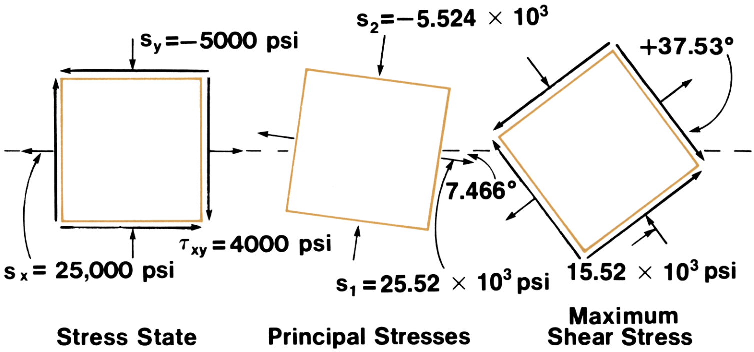


STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	If a stress configuration is			
	known, go to step 8 for Mohr			
	circle evaluation. Continue			
	with step 3 for strain gage			
	data reduction.			
3	Select strain gage			
	configuration:			
	Rectangular		f A	1.000 00
	or Delta.		f B	2.000 00

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
4	Input modulus of elasticity,	E	ENTER↑	E
	then Poisson's ratio.	ν	f D	E
5	Input strains:			
		ϵ_a	ENTER↑	ϵ_a
		ϵ_b	ENTER↑	ϵ_b
		ϵ_c	A	ϵ_a
6	Calculate principal strains			
	and rotation angle.		B	ϵ_1, ϵ_2, θ
7	Skip to step 9 for Mohr circle			
	applications of calculations			
	just completed.			
8	Input stress on element in x			
	direction	s_x	ENTER↑	s_x
	then stress in y direction	s_y	ENTER↑	s_y
	then shear stress.	τ_{xy}	C	0.000 00
9	Calculate principal stresses.		D	s_1, s_2, τ_{max},
				θ
10	Optional: Calculate stress			
	configuration at a specified			
	angle.	θ'	E	s, τ
11	To specify another angle go			
	to step 10. For a new case go			
	to step 2.			

Example 1:

If $s_x = 25000$ psi, $s_y = -5000$ psi, and $\tau_{xy} = 4000$ psi, compute the principal stresses and the maximum shear stress. Compute the normal stresses, where shear stress is maximum ($\theta + 45°$).



Keystrokes: **Outputs:**

Keystrokes	Outputs
25000 ENTER↑ 5000 CHS ENTER↑	
4000 C D →	25.52 03 *** (s_1)
	-5.524 03 *** (s_2)
	15.52 03 *** (τ_{max})
	-7.466 00 *** (θ)
45 + →	37.53 00
E →	10.00 03 *** (s)
	15.52 03 *** (τ_1)

Example 2:

A rectangular rosette measures the strains below. What are the principal strains and principal stresses?

$\epsilon_a = 90 \times 10^{-6}$ $\epsilon_b = 137 \times 10^{-6}$ $\epsilon_c = 305 \times 10^{-6}$

$\nu = 0.3$ $E = 30 \times 10^6$ psi

Keystrokes: **Outputs:**

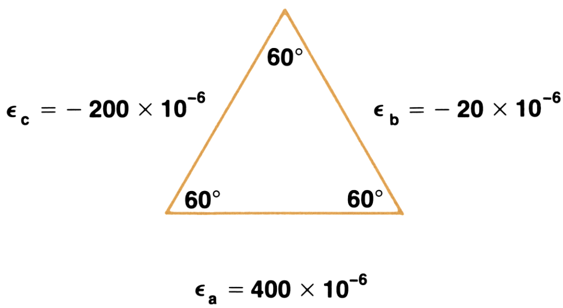
Keystrokes	Outputs
f A →	1.000 00
30 EEX 6 ENTER↑ .3 f D →	30.00 06
90 EEX CHS 6 ENTER↑ 137	
EEX CHS 6 ENTER↑ 305 EEX CHS	
6 A →	90.00-06
B →	320.9-06 *** (ϵ_1)
	74.14-06 *** (ϵ_2)
	14.69 00 *** (θ)
D →	11.31 03 *** (s_1)
	5.618 03 *** (s_2)
	2.847 03 *** (τ_{max})
	14.69 00 *** (θ)

Example 3:

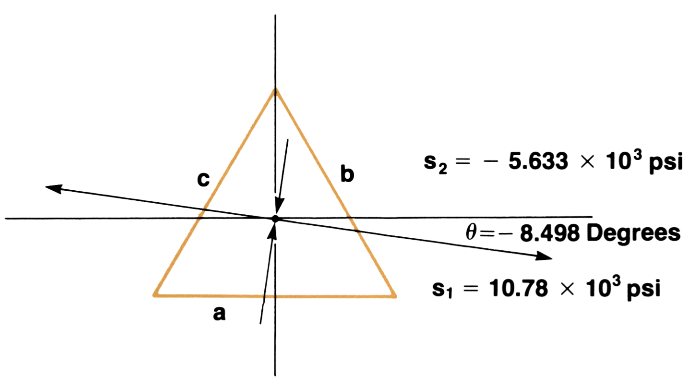
An equiangular rosette measures the strains below. What are the principal strains and stresses?

$E = 30 \times 10^6$ psi

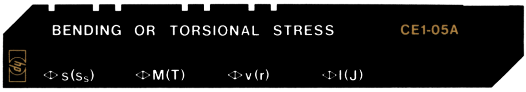
$\nu = 0.3$



Keystrokes:	Outputs:
f B →	2.000 00
400 EEX CHS 6 ENTER↑ 20	
CHS EEX CHS 6 ENTER↑ 200	
CHS EEX CHS 6 A →	400.0–06
B →	415.5–06 *** (ϵ_1)
	–295.5–06 *** (ϵ_2)
	–8.498 00 *** (θ)
D →	10.78 03 *** (s_1)
	–5.633 03 *** (s_2)
	8.204 03 *** (τ_{max})
	–8.498 00 *** (θ)



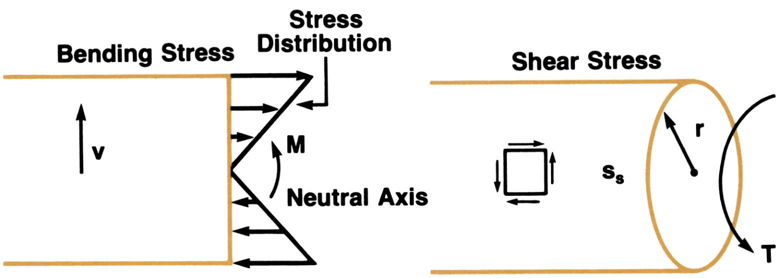
BENDING OR TORSIONAL STRESS



This card solves either the bending stress equation or the analogous torsional shear stress equation, using an interchangeable solution. Given three known values, the remaining unknown value is calculated.

Variables involved in torsional shear stress calculations are shown in parentheses on the magnetic card.

Equations:



$$s = \frac{Mv}{I} \qquad s_s = \frac{Tr}{J}$$

where:

- s is the normal stress at v;
- M is the moment applied to the beam;
- v is the distance from the neutral axis of the beam;
- I is the moment of inertia of the beam;
- s_s is the shear stress at r;
- T is the applied torque;
- r is the distance from the shaft center to the point of interest;
- J is the polar moment of inertia.

Remarks:

This program is not applicable for non-elastic media or elastic media where stresses exceed the elastic limit. Materials must be isotropic.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 or side 2.			
2	Input 3 of the following:			
	Bending stress (or shear			
	stress)	s (s_s)	A	s (s_s)
	Bending moment (or applied			
	torque)	M (T)	B	M (T)
	Distance from neutral axis			
	(or radius)	v (r)	C	v (r)
	Moment of inertia (or polar			
	moment)	I (J)	D	I (J)
3	Calculate the remaining value:			
	Bending stress (or shear			
	stress)		A	s (s_s)
	Bending moment (or torque)		B	M (T)
	Distance from neutral axis			
	(or radius)		C	v (r)
	Moment of inertia (or polar			
	moment)		D	I (J)
4	For a new case, go to step 2			
	and change appropriate inputs.			

Example 1:

If the maximum stress allowed in a beam is 10,000 pounds per square inch, the moment of inertia is 4.80 in^4, and the maximum distance from the neutral axis to the surface is 2 inches, what is the maximum applied moment?

Keystrokes:	**Outputs:**	
10000 A 4.8 D 2 C B ⟶	24.00 03	in-lb (M)

Example 2:

What torque will result in a stress of 12000 pounds per square inch at a radius of 1 inch for a 2 inch diameter shaft?

Keystrokes:	Outputs:	
2 [x^2] [x^2] [π] [×] 32 [÷] ⟶	1.571 00	in^4 (J)
[D] 1 [C] 12000 [A] [B] ⟶	18.85 03	in-lb (T)

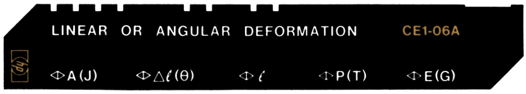
Example 3:

A moment of 30,000 in-lb is applied to a beam with a moment of inertia of 3.8 in^4. If the neutral axis is 1 inch from the surface, what is the stress at the surface?

Keystrokes:	Outputs:	
30000 [B] 3.8 [D] 1 [C] [A] ⟶	7.895 03	psi (x)

Notes

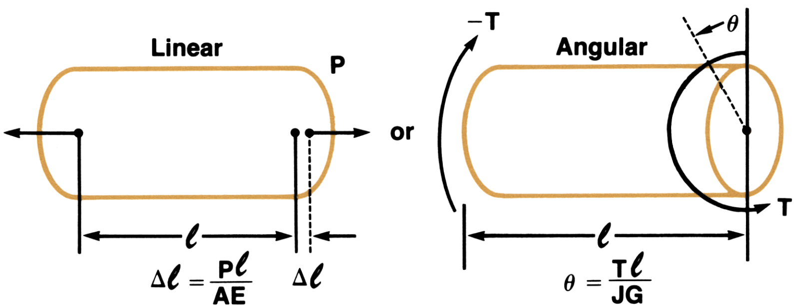
LINEAR OR ANGULAR DEFORMATION



This card solves for linear deflection under tensile load or the analogous angular deflection under torque using an interchangeable solution. Given four of the five variables, the unknown is calculated.

Variables for circular shafts in torsion are shown in parentheses on the magnetic cards.

Equations:



where:

- $\Delta \ell$ is the change in length;
- P is the applied load;
- ℓ is the length;
- A is the cross sectional area;
- E is the modulus of elasticity;
- θ is the deflection angle in radians;
- T is the applied torque;
- J is the polar moment of the section;
- G is the modulus of elasticity in shear.

Remarks:

This program is not applicable for non-elastic media or elastic media where stress exceeds the elastic limit. Materials must be isotropic. The equation for angular deflection is not valid in the neighborhood of the applied torque.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 or side 2.			
2	Input four of the following:			
	Area (or polar moment of			
	inertia)	A (J)	A	A (J)
	Linear deflection (or torsional			
	deflection)	Δ (θ)	B	Δ (θ)
	Length of member	ℓ	C	ℓ
	Applied load (or torque)	P (T)	D	P (T)
	Modulus of elasticity (in shear)	E (G)	E	E (G)
3	Calculate remaining value:			
	Area (or polar moment of			
	inertia)		A	a (J)
	Linear deflection (or torsional			
	deflection		B	Δ (θ)
	Length of member		C	ℓ
	Applied load (or torque)		D	P (T)
	Modulus of elasticity (in			
	shear)		E	E (G)
4	For a new case, go to step 2			
	and change appropriate inputs.			

Example 1:

Steel bars, affixed to the roof are to be used to support the end of a cantilever balcony. The load on each bar will be 50,000 newtons. If the maximum allowable deflection is 0.001 meters, what should the area of the bars be?

ℓ = 10 meters E = 2.068 × 10^{11} N/m^2

Keystrokes: **Outputs:**

50000 D .001 B 10 C
2.068 EEX 11 E A ⟶ 2.418 −03 m^2

For square bars, .05 meters on a side, what will the deflection be?

.05 x^2 A B ⟶ 967.1 −06 m

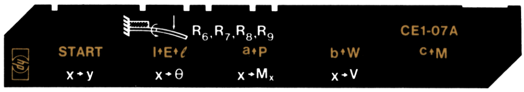
Example 2:

A 6 inch outside/5.5 inch inside diameter steel pipe ($G = 11.5 \times 10^6$ psi) is 15 feet long. How much torque will it resist with an angular deflection of 1.00 degree?

Keystrokes:	**Outputs:**	
First compute $J = \pi(D_o^4 - D_i^4)/32$.		
6 [x²] [x²] 5.5 [x²] [x²] [−] [π] [×]		
32 [÷] ⟶	37.40 00	in⁴ (J)
[A] 15 [ENTER↑] 12 [×] [C] 11.5 [EEX]		
6 [E] 1 [D→R] [B] [D] ⟶	41.70 03	in-lb (T)

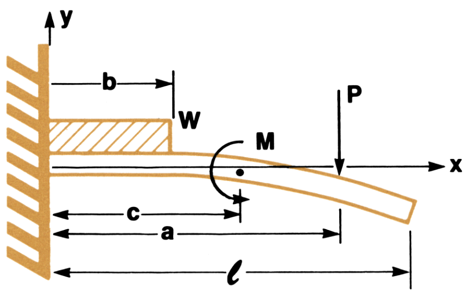
Notes

CANTILEVER BEAMS



This program calculates deflection, slope, moment and shear at any specified point along a rigidly fixed, cantilever beam of uniform cross section. Distributed loads, point loads, applied moments or combinations of all three may be modeled. By using the principle of superposition, complicated beams with multiple point loads, applied moments and combined distributed loads may be analyzed.

Equations:



$$y = y_1 + y_2 + y_3 \qquad \text{(total deflection)}$$

$$y_1 = \frac{PX_1^2}{6EI}(X_1 - 3a) - \frac{Pa^2}{2EI}(x-a)(x>a)^* \qquad \text{(deflection due to point load)}$$

$$y_2 = \frac{-WX_2^2}{6EI}\left[X_2\left(\frac{X_2}{4} - b\right) + 1.5\,b^2\right]$$

$$- \frac{Wb^3}{6EI}(x-b)(x>b) \qquad \text{(distributed load)}$$

$$y_3 = \frac{MX_3^2}{2EI} + \frac{Mc}{EI}(x-c)(x>c) \qquad \text{(applied moment)}$$

$$\theta = \theta_1 + \theta_2 + \theta_3 \qquad \text{(total slope)}$$

$$\theta_1 = \frac{PX_1}{2EI}(X_1 - 2a) \qquad \text{(slope due to point load)}$$

$$\theta_2 = \frac{WX_2}{EI}\left[X_2\left(\frac{X_2}{6} - \frac{b}{2}\right) + \frac{b^2}{2}\right] \qquad \text{(distributed load)}$$

$$\theta_3 = \frac{MX_3}{EI} \qquad \text{(applied moment)}$$

$$M_x = M_{x1} + M_{x2} + M_{x3} \qquad \text{(total moment)}$$

$$M_{x1} = P(X_1 - a) \qquad \text{(moment due to point load)}$$

$$M_{x2} = -W\,(X_2\,(X_2/2 - b) + b^2/2) \qquad \text{(distributed load)}$$

$$M_{x3} = M\ (x \leqslant c) \qquad \text{(applied moment)}$$

$$V = V_1 + V_2 + V_3 \qquad \text{(total shear)}$$

$$V_1 = P\ (x \leqslant a) \qquad \text{(shear due to point load)}$$

$$V_2 = W\,(b - X_2) \qquad \text{(distributed load)}$$

$$V_3 = 0 \qquad \text{(applied moment)}$$

where:

y is the deflection at a distance x from the wall;

θ is the slope (change in y per change in x) at x;

M_x is the moment at x;

V is the shear at x;

I is the moment of inertia of the beam;

E is the modulus of elasticity of the beam;

ℓ is the length of the beam;

P is a concentrated load;

W is a uniformly distributed load with dimensions of force per unit length.

M is an applied moment;

a is the distance from the foundation to the point load;

b is the distance to the end of the distributed load;

c is the distance to the applied moment;

$X_1 = x$ if $x \leqslant a$ or a if $x > a$;

$X_2 = x$ if $x \leqslant b$ or b if $x > b$

$X_3 = x$ if $x \leqslant c$ or c if $x > c$.

*The notation $(x > a)$ is interpreted as 1.00 if x is greater than a and as 0.00 if x is less than or equal to a.

Remarks:

Deflections must not significantly alter the geometry of the problem. Beams must be of constant cross section for deflection and slope equations to be valid. Stresses must be in the elastic region.

Registers R_{S0}–R_{S9} are available for user storage.

SIGN CONVENTIONS FOR BEAMS

NAME	VARIABLE	SENSE	SIGN
DEFLECTION	y	↑	+
SLOPE	θ	↑	+
INTERNAL MOMENT	M_x	↺▬↻	+
SHEAR	V	↑▬↓	+
EXTERNAL FORCE OR LOAD	P or W	↓	+
EXTERNAL MOMENT	M	↻	+

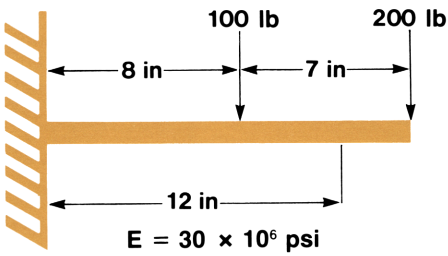
Sums of y, θ, M_x and V may be stored in R_6, R_7, R_8, and R_9, respectively. Note that these registers are indicated on the magnetic card.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Initialize.		f A	0.000 00
3	Input moment of inertia	I	ENTER↑	I
	then modulus of elasticity	E	ENTER↑	E
	then beam length.	ℓ	f B	EI
4	Input load(s):			
	Location of point load	a	ENTER↑	a
	Point load	P	f C	a
	Length of distributed load	b	ENTER↑	b
	Distributed load (force/length)	W	f D	b
	Location of applied moment	c	ENTER↑	c
	Applied moment	M	f E	c
5	Key in x to specify the point			
	of interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	or moment	x	C	M_x
	or shear.	x	D	V
6	For a new calculation with the			
	same loading, go to step 5.			
	For new loads, go to step 4.			
	Be sure to set obsolete			
	loadings to zero. For new			
	beam properties, go to step 3.			
	To restart, go to step 2.			

Example 1:

What is the deflection at x = 12? Neglect the weight of the beam.



$E = 30 \times 10^6$ psi
$I = 4.7$ in^4

Keystrokes: **Outputs:**

f A 4.7 ENTER↑ 30 EEX
6 ENTER↑ 15 f B ⟶ 141.0 06

Compute deflection at 12 inches due to 100 lb weight:
8 ENTER↑ 100 f C 12 A ⟶ −211.8 −06

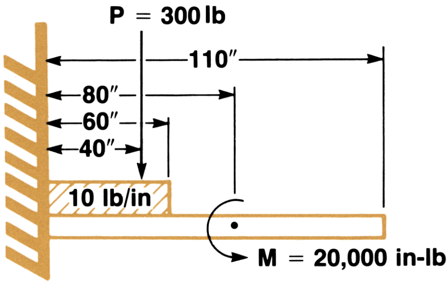
Store deflection due to 100 lb load for addition to deflection due to 200 lb load:
STO 9 ⟶ −211.8−06

Compute deflection at 12 inches due to 200 lb load:
15 ENTER↑ 200 f C 12 A ⟶ −1.123−03

Compute total deflection:
RCL 9 + ⟶ −1.335−03

Example 2:

For the beam below, compute deflection, slope, moment and shear at 0, 50, and 90 inches. Neglect the weight of the beam.



$I = 23\ in^4$
$E = 30 \times 10^6$ psi

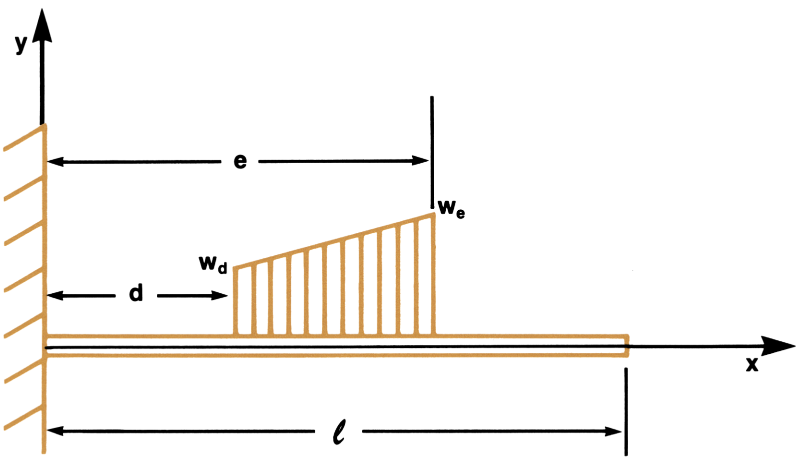
Keystrokes:	**Outputs:**
[f] [A] 23 [ENTER↑] 30 [EEX]	
6 [ENTER↑] 110 [f] [B] 40 [ENTER↑]	
300 [f] [C] 60 [ENTER↑] 10 [f] [D]	
80 [ENTER↑] 20000 [f] [E]	
0 [A] →	0.000 00 (y)
0 [B] →	0.000 00 (θ)
0 [C] →	-10.00 03 (M_x)
0 [D] →	900.0 00 (V)
50 [A] →	5.211 -03
50 [B] →	582.1 -06
50 [C] →	19.50 03
50 [D] →	100.0 00
90 [A] →	50.14 -03
90 [B] →	1.449 -03
90 [C] →	0.000 00
90 [D] →	0.000 00

Notes

CANTILEVER BEAMS—TRAPEZOIDAL LOADING

This program calculates deflection, slope, moment, and shear at any specified point along a cantilever beam of uniform cross section with a distributed trapezoidal load. By using the principle of superposition, complicated distribted loads may be analyzed.

Equations:



$$y = y_d - y_e$$

$$y_d = \theta_0 x + y_0 - \langle x - d \rangle^4 {}^* \left[\frac{w_d}{24EI} + \frac{(w_\ell - w_d)}{120EI(\ell - d)} \langle x - d \rangle \right]$$

$$\theta_0 = \frac{(\ell - d)^3}{6EI} \left[w_d + \frac{(w_\ell - w_d)}{4} \right]$$

$$y_0 = -\frac{(\ell - d)^3}{24EI} \left[w_d(3\ell + d) + \frac{(w_\ell - w_d)}{5} (4\ell + d) \right]$$

$$w_\ell = w_e + \frac{(w_e - w_d)}{(e - d)}(\ell - d)$$

y_e is analogous to y_d except w_d is replaced by w_e and d is replaced by e.

Equations for slope, moment, and shear are the first, second, and third x derivitives of the equations above.

*If $x - d < 0$, $\langle x - d \rangle = 0$.

Definitions:

I is the moment of inertia of the section;

E is the modulus of elasticity of the material;

ℓ is the length of the beam;

d is the distance to the beginning of the load;

w_d is the initial value of the load with units of force per unit length;

e is the distance to the end of the load;

w_e is the final value of the load;

x is the point of interest along the beam;

y is the deflection at x;

θ is the slope at x;

M_x is the internal bending moment at x;

V is the shear at x.

Reference:

Roark, Raymond J., Young, Warren C., Formulas for Stress and Strain, McGraw-Hill Book Company, 1975.

Remarks:

Deflections must not significantly alter the geometry of the problem.

Beams must be of constant cross section for deflection and slope equations to be valid

Stresses must be in the elastic region.

Registers R_6–R_9 are available for problems involving superposition.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input the moment of inertia	I	ENTER↑	I
	then the modulus of elasticity	E	ENTER↑	E
	then the length of the beam.	ℓ	f B	IE
3	Input distance to load	d	ENTER↑	d
	then initial value of load	w_d	ENTER↑	w_d
	then distance to end of load	e	ENTER↑	e
	then final value of loading.	w_e	f C	w_e
4	Key in x to specify points of			
	interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V
5	For a new calculation with the			
	same loading, go to step 4. For			
	new loads, go to step 3.			

Example:

Calculate deflection, slope, moment and shear for the beam above using the following values:

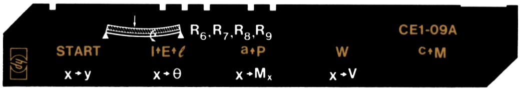
d = 23 inches	w_d = 35 lb/in	e = 47 inches	w_e = 27 lb/in
I = 5 in^4	E = 30 × 10^6 psi	ℓ = 75 in	x = 40 in

What is the deflection at x = 55?

Keystrokes:	**Outputs:**
23 ENTER↑ 35 ENTER↑ 47 ENTER↑	
27 f C 5 ENTER↑ 30 EEX	
6 ENTER↑ 75 f B ⟶	150.0 06
40 A ⟶	−84.71−03
40 B ⟶	−3.057−03
40 C ⟶	−680.6 00
40 D ⟶	197.2 00
55 A ⟶	−130.7−03

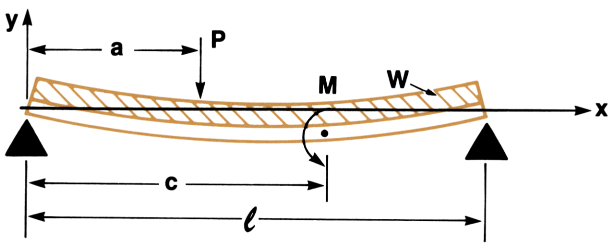
Notes

SIMPLY SUPPORTED BEAMS



This program calculates deflection, slope, moment and shear at any specified point along a simply supported beam of uniform cross section. Distributed loads, point loads, applied moments or combinations of all three may be modeled. By using the principle of superposition, complicated beams with multiple point loads, and multiple applied moments can be analyzed.

Equations:



$$y = y_1 + y_2 + y_3 \qquad \text{(total deflection)}$$

$$y_1 = \frac{P(\ell - a)x}{6EI}\left[x^2 + (\ell - a)^2 - \ell^2\right]^* \qquad \text{(deflection due to point load)}$$

$$y_2 = \frac{-Wx}{24EI}\left[\ell^3 + x^2(x - 2\ell)\right] \qquad \text{(distributed load)}$$

$$y_3 = \frac{-Mx}{EI}\left[c - \frac{x^2}{6\ell} - \frac{\ell}{3} - \frac{c^2}{2\ell}\right]^{**} \qquad \text{(applied moment)}$$

$$\theta = \theta_1 + \theta_2 + \theta_3 \qquad \text{(total moment)}$$

$$\theta_1 = \frac{P(\ell - a)}{6EI}\left[3x^2 + (\ell - a)^2 - \ell^2\right]^* \qquad \text{(slope due to point load)}$$

$$\theta_2 = -\frac{W}{24EI}\left[\ell^3 + x^2(4x - 6\ell)\right] \qquad \text{(distributed load)}$$

$$\theta_3 = \frac{-M}{EI}\left[c - \frac{x^2}{2\ell} - \frac{\ell}{3} - \frac{c^2}{2\ell}\right]^{**} \qquad \text{(applied moment)}$$

$$M_x = M_{x1} + M_{x2} + M_{x3} \qquad \text{(total moment)}$$

$$M_{x1} = \frac{P(\ell - a)x^{*}}{\ell} \qquad \text{(moment due to point load)}$$

$$M_{x2} = -\frac{Wx}{2}\left[x - \ell\right] \qquad \text{(distributed load)}$$

$$M_{x3} = \frac{Mx^{**}}{\ell} \qquad \text{(applied moment)}$$

$$V = V_1 + V_2 + V_3 \qquad \text{(total shear)}$$

$$V_1 = \frac{P(\ell - a)^{*}}{\ell} \qquad \text{(shear due to point load)}$$

$$V_2 = W\left(\frac{\ell}{2} - x\right) \qquad \text{(distributed load)}$$

$$V_3 = \frac{M}{\ell} \qquad \text{(applied moment)}$$

where:

y is the deflection at a distance x from the left support;

θ is the slope (change in y per change in x) at x;

M_x is the moment at x;

V is the shear at x;

I is the moment of intertia of the beam;

E is the modulus of elasticity of the beam;

ℓ is the length of the beam;

P is a concentrated load;

W is a uniformly distributed load with dimensions of force per unit length;

M is an applied moment;

a is the distance from the left support to the point load;

c is the distance to the applied moment.

*If x is greater than a, $(\ell - a)$ is replaced by $-a$ and x is replaced by $(x - \ell)$.

**If x is greater than c, x is replaced by $(x - \ell)$ and c is replaced by $(\ell - c)$.

Remarks:

Deflections must not significantly alter the geometry of the problem. Beams must be of constant cross section for deflection and slope equations to be valid. Stresses must be in the elastic region.

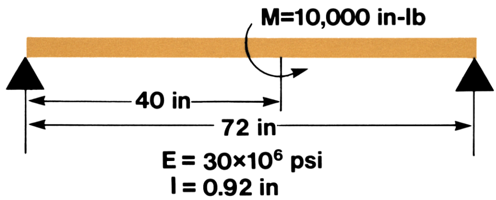
Registers R_{S0}–R_{S9} are available for user storage.

Sums of y, θ, M_x and V may be stored in R_6, R_7, R_8, and R_9, respectively. Note that these registers are indicated on the magnetic card.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Initialize.		f A	0.000 00
3	Input moment of inertia	I	ENTER↑	I
	then modulus of elasticity	E	ENTER↑	E
	then beam length.	*l*	f B	EI
4	Input load(s):			
	Location of point load	a	ENTER↑	a
	Point load	P	f C	a
	Distributed load (force/length)	W	f D	W
	Location of applied moment	c	ENTER↑	c
	Applied moment	M	f E	c
5	Key in x to specify the point of			
	interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V
6	For a new calculation with the			
	same loading, go to step 5.			
	For new loads, go to step 4. Be			
	sure to set obsolete loadings			
	to zero. For new beam			
	properties, go to step 3. To			
	restart, go to step 2.			

Example 1:

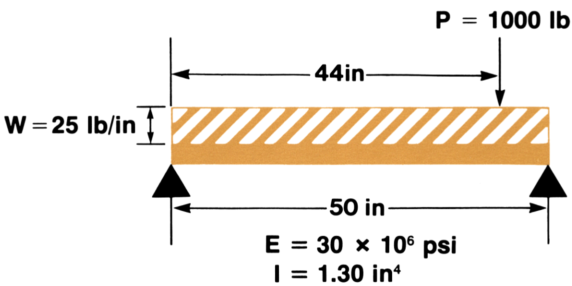
Find the deflection, slope, internal moment and shear at distances of 0, 24 and 60 inches for the beam below. Neglect the weight of the beam.



Keystrokes:	Outputs:	
f A .92 ENTER↑ 30 EEX		
6 ENTER↑ 72 f B →	27.60 06	
40 ENTER↑ 10000 f E →	40.00 00	
0 A →	0.000 00	(y_0)
0 B →	-1.771 -03	(θ_0)
0 C →	0.000 00	(M_0)
0 D →	138.9 00	(V_0)
24 A →	-30.92 -03	(y_{24})
24 B →	-322.1 -06	(θ_{24})
24 C →	3.333 03	(M_{24})
24 D →	138.9 00	(V_{24})
60 A →	2.415 -03	(y_{60})
60 B →	40.26 -06	(θ_{60})
60 C →	-1.667 03	(M_{60})
60 D →	138.9 00	(V_{60})

Example 2:

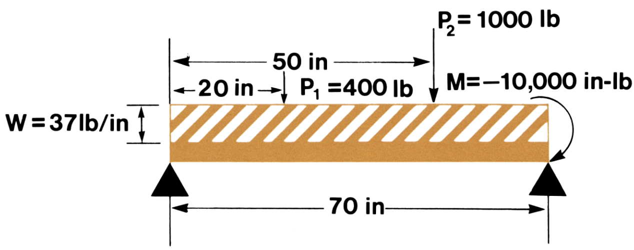
What is the slope of the beam below at x = 38 inches?



Keystrokes:	**Outputs:**	
f A 1.30 ENTER↑ 30 EEX		
6 ENTER↑ 50 f B →	39.00 06	
44 ENTER↑ 1000 f C →	44.00 00	
25 f D →	25.00 00	
38 B →	3.327 –03	(in/in)

Example 3:

What is the total moment at the center of the beam below? (It is not necessary to know the values of E or I to solve the problem. Simply key in 70 and press f B.)



First solve for the effect of the distributed load, P_1, and M.

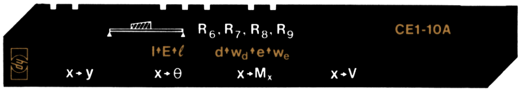
Keystrokes:	**Outputs:**	
f A 70 f B 20 ENTER↑		
400 f C →	20.00 00	
37 f D 70 ENTER↑		
10000 CHS f E →	70.00 00	
70 ENTER↑ 2 ÷ C →	21.66 03	
Store values in R_6.		
STO 6 →	21.66 03	(in-lb)

Now solve for the effect of P_2 and add it to the content of R_6. This is the final answer assuming superposition is valid.

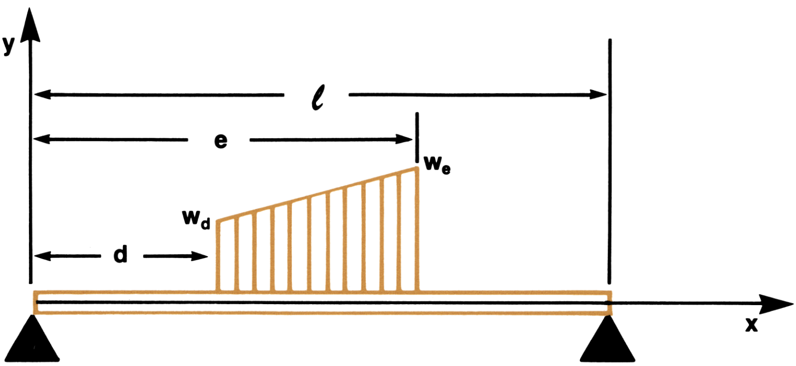
f A 50 ENTER↑ 1000 f C →	50.00 00	
35 C →	10.00 03	(in-lb)
RCL 6 + →	31.66 03	(in-lb)

Notes

SIMPLY SUPPORTED BEAMS—TRAPEZOIDAL LOADING



This program calculates deflection, slope, moment, and shear at any specified point along a simply supported beam of uniform cross section with a distributed trapezoidal load. By using the principle of superposition, complicated distributed loads may be analyzed.



Equations:

$$y = y_d - y_e$$

$$y_d = \theta_0 x + \frac{R_0 x^3}{6EI} - \langle x - d \rangle^4 \left[\frac{w_d}{24EI} + \frac{w_\ell - w_d}{120EI\,(\ell - d)} \langle x - d \rangle \right]$$

$$\theta_0 = \frac{(\ell - d)^2}{24\ell EI} \left[- w_d(\ell^2 + 2d\ell - d^2) - \frac{w_\ell - w_d}{15} (7\ell^2 + 6d\ell - 3d^2) \right]$$

$$R_0 = \frac{(\ell - d)^2}{2\ell} \left[w_d + \frac{w_\ell - w_d}{3\ell} \right]$$

$$w_\ell = w_e + \frac{(w_e - w_d)}{(e - d)} (\ell - e)$$

y_e is analogous to y_d except w_d is replaced by w_e and d is replaced by e.

Equations for slope, moment, and shear are the first, second and third x derivitives of the equations above.

Definitions:

I is the moment of inertia of the section;

E is the modulous of elasticity of the material;

ℓ is the length of the beam;

d is the distance to the beginning of the load;

w_d is the initial value of the load with units of force per unit length;

e is the distance to the end of the load;

w_e is the final value of the load;

x is the point of interest along the beam;

y is the deflection at x;

θ is the slope at x;

M_x is the internal bending moment at x;

V is the shear at x.

Reference:

Roark, Raymond J., Young, Warren C., Formulas for Stress and Strain, McGraw-Hill Book Company, 1975.

Remarks:

Deflections must not significantly alter the geometry of the problem.

Beams must be of constant cross section for deflection and slope equations to be valid.

Stresses must be in the elastic region.

Registers R_6, R_7, R_8, and R_9 are available for problems involving superposition.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input the moment of inertia	I	ENTER↑	I
	then the modulus of elasticity	E	ENTER↑	E
	then the length of the beam.	ℓ	f B	IE
3	Input distance to load	d	ENTER↑	d
	then initial value of load	w_d	ENTER↑	w_d
	then distance to end of load	e	ENTER↑	e
	then final value of loading.	w_e	f C	w_e
4	Key in x to specify point of			
	interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V
5	For a new calculation with the			
	same loading, go to step 4. For			
	new loads, go to step 3.			

Example:

Calculate deflection, slope, moment and shear for the beam above using the following values:

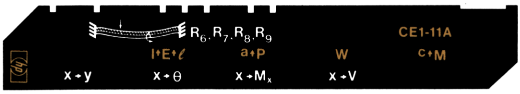
d = 23 inches	w_d = 35 lb/in	e = 47 inches	w_e = 27 lb/in
I = 5 in^4	E = 30×10^6 psi	ℓ = 75 in	x = 55 in

What is the deflection at x = 40?

Keystrokes:	Outputs:
23 ENTER↑ 35 ENTER↑ 47 ENTER↑	
27 f C 5 ENTER↑ 30 EEX	
6 ENTER↑ 75 f B →	150.0 06
55 A →	−29.58−03
55 B →	1.175−03
55 C →	6.842 03
55 D →	−342.1 00
40 A →	−40.82−03

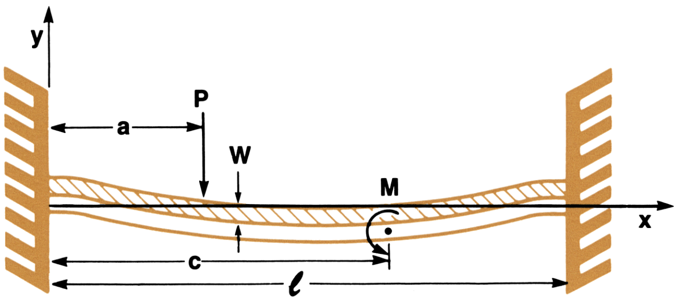
Notes

BEAMS FIXED AT BOTH ENDS



This program calculates deflection, slope, moment and shear at any specified point along a beam of uniform cross section, fixed at both ends. Distributed loads, point loads, applied moments or combinations of all three may be modeled. By using the principle of superposition, complicated beams with multiple point loads, and multiple applied moments can be analyzed.

Equations:



$$y = y_1 + y_2 + y_3 \qquad \text{(total deflection)}$$

$$y_1 = \frac{P(\ell - a)^2 x^2}{6EI\ ^3}\left[x(\ell + 2a) - 3a\ell\right)^* \qquad \text{(deflection due to point load)}$$

$$y_2 = \frac{Wx^2}{24EI}\left[x(2\ell - x) - \ell^2\right] \qquad \text{(distributed load)}$$

$$y_3 = \frac{M(\ell - c)x^2}{\ell^2 EI}\left[\frac{cx}{\ell} + \frac{\ell - 3c}{2}\right]^{**} \qquad \text{(applied moment)}$$

$$\theta = \theta_1 + \theta_2 + \theta_3 \qquad \text{(total slope)}$$

$$\theta_1 = \frac{P(\ell - a)^2 x}{2EI\ ^3}\left[x(\ell + 2a) - 2a\ell\right]^* \qquad \text{(slope due to point load)}$$

$$\theta_2 = \frac{Wx}{12EI}\left[x(3\ell - 2x) - \ell^2\right] \qquad \text{(distributed load)}$$

$$\theta_3 = \frac{M(\ell - c)x}{\ell^2 EI}\left[\frac{3cx}{\ell} + \ell - 3c\right]^{**} \qquad \text{(applied moment)}$$

$$M_x = M_{x1} + M_{x2} + M_{x3} \qquad \text{(total moment)}$$

$$M_{x1} = \frac{P(\ell - a)^2}{\ell^3}\left[x(\ell + 2a) - a\ell\right]^* \qquad \text{(moment due to point load)}$$

$$M_{x2} = \frac{W}{12}\left[6x(\ell - x) - \ell^2\right] \qquad \text{(distributed load)}$$

$$M_{x3} = \frac{M(\ell - c)}{\ell^2}\left[\frac{6cx}{\ell} + \ell - 3c\right]^{**} \qquad \text{(applied moment)}$$

$$V = V_1 + V_2 + V_3 \qquad \text{(total shear)}$$

$$V_1 = \frac{P(\ell - a)^2}{\ell^3}(\ell + 2a) \qquad \text{(shear due to point load)}$$

$$V_2 = \frac{-W}{2}(2x - \ell) \qquad \text{(distributed load)}$$

$$V_3 = \frac{-6M(\ell - c)\,c^{**}}{\ell^3} \qquad \text{(applied moment)}$$

where:

- y is the deflection at a distance x from the left support;
- θ is the slope (change in y per change in x) at x;
- M_x is the moment at x;
- V is the shear at x;
- I is the moment of inertia of the beam;
- E is the modulus of elasticity of the beam;
- ℓ is the length of the beam;
- P is a concentrated load;
- W is a uniformly distributed load with dimensions of force per unit length;
- M is an applied moment;
- a is the distance from the left support to the point load;
- c is the distance to the applied moment.

*If x is greater than a, a is replaced by $(\ell - a)$ and x is replaced by $(\ell - x)$. The signs of θ_1 and V_1 are also changed.

**If x is greater than c, x is replaced by $(\ell - x)$ and c is replaced by $(\ell - c)$. The signs of y_3 and M_{x3} are also changed.

Remarks:

This card differs from other beam cards. The "start" function is not included on LBL f A. You must manually perform the "start" function by storing zero when P, W or M are not included in the problem.

Deflections must not significantly alter the geometry of the problem. Beams must be of constant cross section for deflection and slope equations to be valid. Stresses must be in the elastic region.

Registers R_{S0}–R_{S9} are available for user storage.

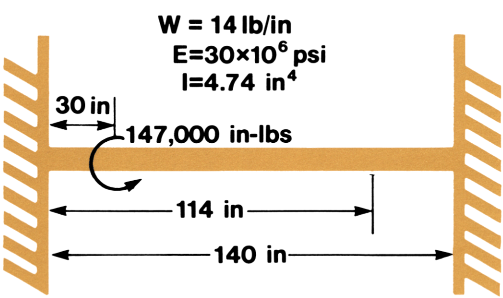
Sums of y, θ, M_x and V may be stored in R_6, R_7, R_8, R_9, respectively. Note that these registers are indicated on the magnetic card.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input moment of inertia	I	ENTER↑	I
	then modulus of elasticity	E	ENTER↑	E
	then beam length.	ℓ	f B	EI
3	Input load(s):*			
	Location of point load	a	ENTER↑	a
	Point load	P	f C	a
	Distributed load (force/length)	W	f D	W
	Location of applied moment	c	ENTER↑	c
	Applied moment	M	f E	c
4	Key in x to specify the point			
	of interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	For a new calculation with the			
	same loading, go to step 4. For			
	new loads, go to step 3. Be			
	sure to set obsolete loadings to			
	zero. For new beam properties,			
	go to step 2.			
	*Loads must be input, even if			
	zero.			

Example 1:

For the beam below, what are the values of deflection, slope, moment, and shear at an x of 114 inches?

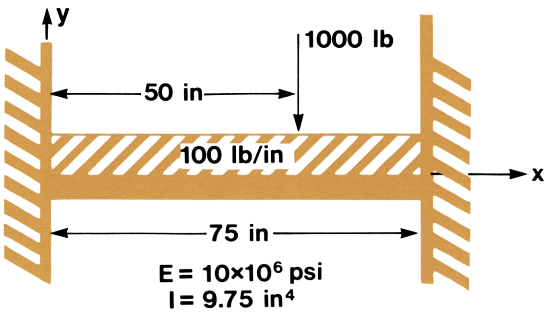


Keystrokes: | **Outputs:**

Keystrokes	Outputs	
4.74 ENTER↑ 30 EEX 6 ENTER↑		
140 f B →	142.2 06	
0 f C 30 ENTER↑ 147000 f E		
14 f D →	14.00 00	
114 A →	43.72 -03	(y)
RCL 0 B →	-3.155-03	(θ)
RCL 0 C →	13.05 03	(M_x)
RCL 0 D →	444.7 00	(V)

Example 2:

Find the internal moment at x = 0 for the configuration below.



Keystrokes:	**Outputs:**
9.75 ENTER↑ 10 EEX 6 ENTER↑	
75 f B ——→	97.50 06
0 f E 100 f D 50 ENTER↑	
1000 f C ——→	50.00 00
0 C ——→	–52.43 03 (M_0)

Also, find the deflection at x = 40.

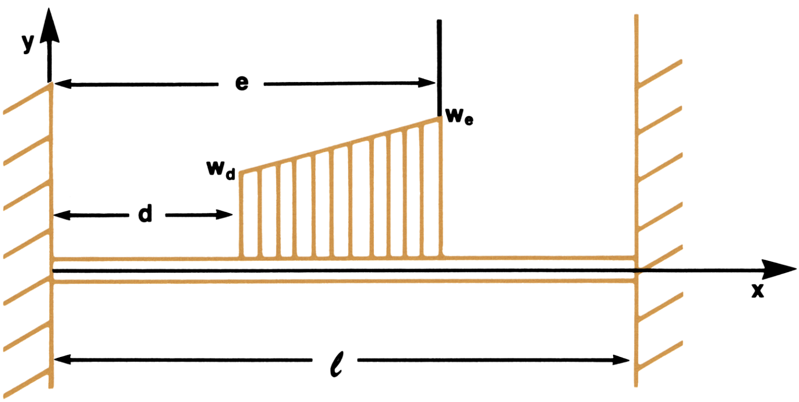
40 A ——→	–101.0 –03 (Y_{40})

Notes

BEAMS FIXED AT BOTH ENDS—TRAPEZOIDAL LOADING

This program calculates deflection, slope, moment, and shear at any specified point along a beam fixed at both ends, of uniform cross section, supporting a distributed trapezoidal load. By using the principle of superposition, complicated distributed loads may be analyzed.

Equations:



$$y = y_d - y_e$$

$$y_d = \frac{M_0 x^2}{2EI} + \frac{R_0 x^3}{6EI} - \langle x - d \rangle \left[\frac{w_d}{24EI} + \frac{(w_\ell - w_d)\langle x - d \rangle}{120EI(\ell - d)} \right]$$

$$M_0 = -\frac{(\ell - d)}{12\ell^2} \left[w_d(\ell + 3d) - \frac{(w_\ell - w_d)}{5} (2\ell + 3d) \right]$$

$$R_0 = \frac{(\ell - d)}{2\ell^3} \left[w_d(\ell + d) + \frac{(w_\ell - w_d)}{10} (3\ell + 2d) \right]$$

$$w_\ell = w_e + \frac{(w_e - w_d)}{(e - d)} (\ell - e)$$

y_e is analogous to y_d except w_e replaces w_d and e replaces d.

Equations for slope, moment and shear are the first, second, and third x derivitives of the equations above.

Definitions:

I is the moment of inertia of the section;

E is the modulus of elasticity of the material;

ℓ is the length of the beam;

d is the distance to the beginning of the load;

w_d is the initial value of the load with units of force per unit length;

e is the distance to the end of the load;

w_e is the final value of the load;

x is the point of interest along the beam;

y is the deflection at x;

θ is the slope at x;

M_x is the internal bending moment at x;

V is the shear at x.

Reference:

Roark, Raymond J., Young, Warren C., Formulas for Stress and Strain, McGraw-Hill Book Company, 1975.

Remarks:

Deflections must not significantly alter the geometry of the problem.

Beams must be of constant cross section for deflection and slope equations to be valid.

Stresses must be in the elastic region.

Registers R_6–R_9 are available for problem involving superposition.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input the moment of inertia	I	ENTER↑	I
	then the modulus of elasticity	E	ENTER↑	E
	then the length of the beam.	ℓ	f B	IE
3	Input distance to load	d	ENTER↑	d
	then initial value of load	w_d	ENTER↑	w_d
	then distance to end of load	e	ENTER↑	e
	then final value of loading.	w_e	f C	w_e
4	Key in x to specify point of			
	interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V
5	For a new calculation with the			
	same loading, go to step 4. For			
	new loads, go to step 3.			

Example:

Calculate deflection, slope, moment and shear for the beam above using the following values:

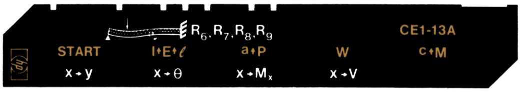
d = 23 inches	w_d = 35 lb/in	e = 47 inches	w_e = 27 lb/in
I = 5 in^4	E = 30 × 10^6 psi	ℓ = 75 in	x = 55 in

What is the deflection at x = 40?

Keystrokes:	Outputs:
23 ENTER↑ 35 ENTER↑ 47 ENTER↑	
27 f C 5 ENTER↑ 30 EEX	
6 ENTER↑ 75 f B →	150.0 06
55 A →	–5.331–03
55 B →	387.0–06
55 C →	383.7 00
55 D →	–328.6 00
40 A →	–9.634–03

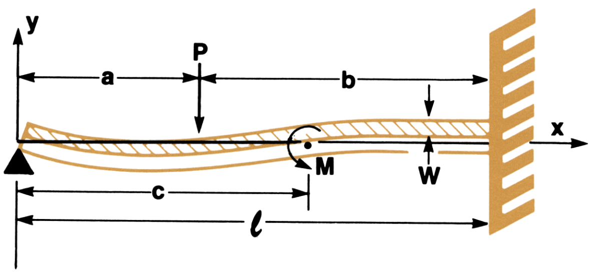
Notes

PROPPED CANTILEVER BEAMS



This program calculates deflection, slope, moment and shear at any specified point along a propped cantilever beam of uniform cross section. Distributed loads, point loads, applied moments or combinations of all three may be modeled. By using the principle of superposition, complicated beams with multiple point loads, and multiple applied moments can be analyzed.

Equations:



$$y = y_1 + y_2 + y_3 \qquad \text{(total deflection)}$$

$$y_1 = \frac{P}{6EI}\left[F(x^3 - 3\ell^2 x) + 3b^2x\right]; \quad x \leq a \qquad \text{(deflection due to point load)}$$

$$y_2 = \frac{W}{48EI}(3\ell x^3 - 2x^4 - \ell^3 x) \qquad \text{(distributed load)}$$

$$y_3 = \frac{M}{EI}G(x^3 - 3\ell^2 x) + \ell x - cx; \quad x \leq c \qquad \text{(applied moment)}$$

$$y_3 = \frac{M}{EI}G(x^3 - 3\ell^2 x) + \ell x - \tfrac{1}{2}(x^2 + c^2); \quad x > c$$

$$\theta = \theta_1 + \theta_2 + \theta_3 \qquad \text{(total slope)}$$

$$\theta_1 = \frac{P}{6EI}\left[F(3x^2 - 3\ell^2) + 3b^2\right]; \quad x \leq a \qquad \text{(slope due to point load)}$$

$$\theta_1 = \frac{P}{6EI}\left[F(3x^2 - 3\ell^2) - 3(x - a)^2\right];\ x > a$$

$$\theta_2 = \frac{W}{48EI}(9\ x^2 - 8x^3 - \ell^3) \qquad \text{(distributed load)}$$

$$\theta_3 = \frac{M}{EI}\left[G(3x^2 - 3\ell^2) + \ell - c\right];\ x \leqslant c \qquad \text{(applied moment)}$$

$$\theta_3 = \frac{M}{EI}\left[G(3x^2 - 3\ell^2) + \ell - x\right];\ x > c$$

$$M_x = M_{x1} + M_{x2} + M_{x3} \qquad \text{(total moment)}$$

$$M_{x1} = PFx;\ x \leqslant a \qquad \text{(moment due to point load)}$$

$$M_{x1} = PFx - P(x - b);\ x > a$$

$$M_{x2} = W\ (3/8x\ \ell - x^2/2) \qquad \text{(distributed load)}$$

$$M_{x3} = 6MGx;\ x \leqslant c \qquad \text{(applied moment)}$$

$$M_{x3} = 6MGx - M;\ x > c$$

$$V = V_1 + V_2 + V_3 \qquad \text{(total shear)}$$

$$V_1 = PF;\ x \leqslant a \qquad \text{(shear due to point load)}$$

$$V_1 = PF - P;\ x > a$$

$$V_2 = W\left(\frac{3}{8}\ \ell - x\right) \qquad \text{(distributed load)}$$

$$V_3 = 6MG \qquad \text{(applied moment)}$$

$$F = \left[\frac{3b^2\ \ell - b^3}{2\ell^3}\right]$$

$$b = (\ \ell - a)$$

$$G = \frac{\ell^2 - c^2}{4\ell^3}$$

where:

y is the deflection at a distance x from the left support;

θ is the slope (change in y per change in x) at x;

M_x is the moment at x;

V is the shear at x;

I is the moment of inertia of the beam;

E is the modulus of elasticity of the beam;

ℓ is the length of the beam;

P is a concentrated load;

W is a uniformly distributed load with dimensions of force per unit length;

M is an applied moment;

a is the distance from the left support to the point load;

c is the distance to the applied moment.

Remarks;

Deflections must not significantly alter the geometry of the problem. Beams must be of constant cross section for deflection and slope equations to be valid. Stresses must be in the elastic region.

Registers R_{S0}–R_{S9} and R_B are available for user storage.

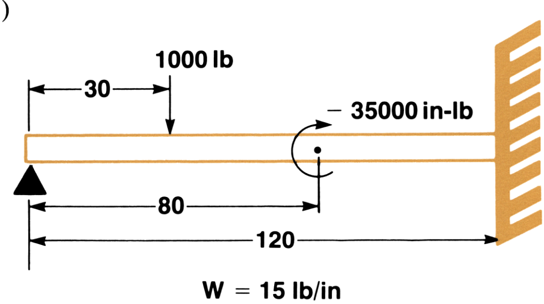
Sums of y, θ, M_X and V may be stored in R_6, R_7, R_8 and R_9, respectively. Note that those registers are indicated on the magnetic card.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Initialize.		f A	0.000 00
3	Input moment of inertia	I	ENTER↑	I
	then modulus of elasticity	E	ENTER↑	E
	then beam length.	ℓ	f B	EI
4	Input load(s):			
	Location of point load	a	ENTER↑	a
	Point load	P	f C	a
	Distributed load (force/length)	W	f D	W
	Location of applied moment	c	ENTER↑	c
	Applied moment.	M	f E	c

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	Key in x to specify the point of			
	interest and calculate			
	deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V
6	For a new calculation with the			
	same loading, go to step 5.			
	For new loads, go to step 4.			
	Be sure to set obsolete			
	loadings to zero. For new			
	beam properties, go to step 3.			
	To restart, go to step 2.			

Example 1:

What are the values of moment and shear at both ends of the beam below? (It is not necessary to know the values of E or I since deflection and slope are not required.)

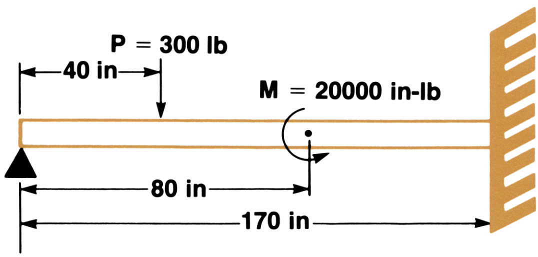


Keystrokes: **Outputs:**

Keystrokes	Outputs	
f A 120 f B 30 ENTER↑		
1000 f C →	30.00 00	
80 ENTER↑ 35000 CHS f E		
15 f D →	15.00 00	
0 C →	0.000 00	(in-lb)
0 D →	1.065 03	(lb)
120 C →	−35.23 03	(in-lb)
120 D →	−1.735 03	(lb)

Example 2:

Calculate the deflection, slope, moment and shear at x = 90 for the beam below.

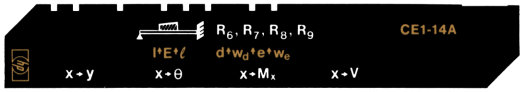


W = 10 lb/in
$E = 30 \times 10^6$ psi
$I = 23$ in^4

Keystrokes:	Outputs:	
f A 23 ENTER↑ 30 EEX 6 ENTER↑		
170 f B →	690.0 06	
40 ENTER↑ 300 f C 10 f D		
80 ENTER↑ 20000 f E →	80.00 00	
90 A →	–75.73 –03	(in)
90 B →	920.8 –06	(in/in)
90 C →	11.89 03	(in-lb)
90 D →	–229.0 00	(lb)

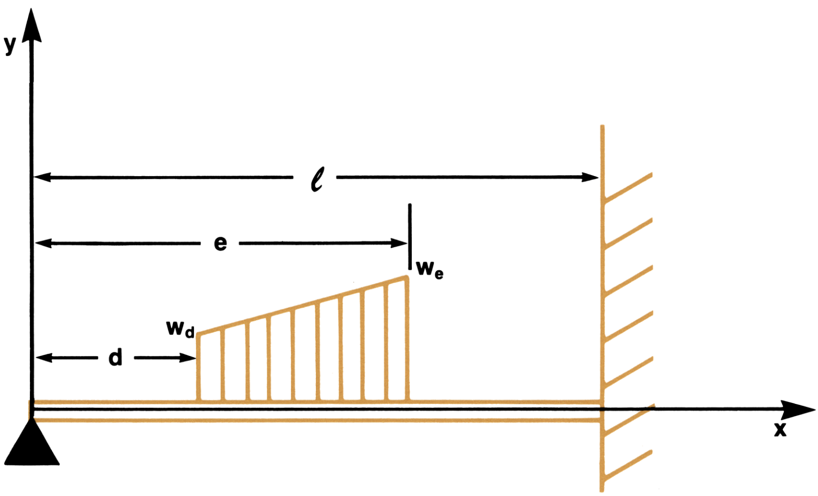
Notes

PROPPED CANTILEVER BEAMS—TRAPEZOIDAL LOADING



This program calculates deflection, slope, moment and shear at any specified point along a propped cantilever beam of uniform cross section with a distributed trapezoidal load. By using the principle of superposition, complicated distributed loads may be analyzed.

Equations:



$$y = y_d + y_e$$

$$y_d = \theta_0 x + R_0 x^3/6EI - \langle x - d\rangle^4 \left[\frac{w_d}{24EI} + \frac{(w_\ell - w_d)\langle x - d\rangle}{120EI} \right]$$

$$R_0 = \frac{(\ell - d)^3}{8\ell^3} \left[w_d(3\ell + d) + \frac{(w_\ell - w_d)}{5}(4\ell + d) \right]$$

$$\theta_0 = -\frac{(\ell - d)^3}{48EI\ell} \left[w_d(\ell + 3d) - \frac{(w_\ell - w_d)}{5}(2\ell + 3d) \right]$$

$$w_\ell = w_e + \frac{(w_e - w_d)}{(e - d)}(\ell - e)$$

y_e is analogous to y_d except w_d is replaced by w_e and d is replaced by e.

Equations for slope moment and shear are the first, second and third x derivatives of the equations above.

Definitions:

I is the moment of inertia of the section;

E is the modulus of elasticity of the material;

ℓ is the length of the beam;

d is the distance to the beginning of the load;

w_d is the initial value of the load with units of force per unit length;

e is the distance to the end of the load;

w_e is the final value of the load;

x is the point of interest along the beam;

y is the deflection at x;

θ is the slope at x;

M_x is the internal bending moment at x;

V is the shear at x.

Reference:

Roark, Raymond J., Young, Warren C., *Formulas for Stress and Strain,* McGraw-Hill Book Company, 1975.

Remarks:

Deflections must not significantly alter the geometry of the problem.

Beams must be of constant cross section for deflection and slope equations to be valid.

Stresses must be in the elastic region.

Registers R_6–R_9 are available for problems involving superposition.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input the moment of inertia	I	ENTER↑	I
	then the modulus of elasticity	E	ENTER↑	E
	then the length of the beam.	ℓ	f B	IE
3	Input distance to load	d	ENTER↑	d
	then initial value of load	w_d	ENTER↑	w_d
	then distance to end of load	e	ENTER↑	e
	then final value of loading.	w_e	f C	w_e
4	Key in x to specify point of in-			
	terest and calculate deflection	x	A	y
	or slope	x	B	θ
	or moment	x	C	M_x
	or shear.	x	D	V
5	For a new calculation with the			
	same loading, go to step 4. For			
	new loads, go to step 3.			

Example:

Calculate deflection, slope, moment and shear for the beam above using the following values:

d = 23 inches	w_d = 35 lb/in	e = 47 inches	w_e = 27 lb/in
I = 5 in^4	E = 30 × 10^6 psi	ℓ = 75 in	x = 55 in

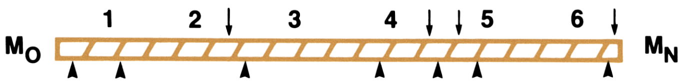
What is the deflection at x = 40?

Keystrokes:	**Outputs:**
23 ENTER↑ 35 ENTER↑ 47 ENTER↑	
27 f C 5 ENTER↑ 30 EEX	
6 ENTER↑ 75 f B ⟶	150.0 06
55 A ⟶	–8.849–03
55 B ⟶	674.9–06
55 C ⟶	–336.0 00
55 D ⟶	–472.6 00
40 A ⟶	–17.47–03

Notes

SIX-SPAN CONTINUOUS BEAMS

This program solves for the intermediate couples present at the support points of a continuous beam. From two to six span beams may be analyzed.



Each span of the beam may have a unique length, cross section, and/or modulus of elasticity but properties may not change within a span.

The first step in using this program is computation of the slope factors at each support of the span. This is best accomplished with programs designed for this purpose such as CE-09 and CE-10. Simply break the continuous beam at each support and calculate the slope at each end assuming no moment is transmitted across supports (it is not necessary to calculate the slope at the left end of the first section or the right end of the last section).

After all slope factors have been calculated for the beam sections, you are ready to use *Six-Span Continuous Beam* to solve for the unknown moments which develop across the intermediate supports of the continuous beam. After loading the program and specifying the number of spans (N), the moment acting at the left end of the beam is specified (M_0), even if zero, then the slope factors from the left side and the right side of the first intermediate support are input. The moment of inertia, modulus of elasticity, and length of the first span are input next.

For subsequent spans (except the last span) input the slope factors and beam properties only. In cases where sections repeat (same load and same properties) the f B keys cause automatic span replication. This saves the effort involved in keying in five pieces of repeated data. If the loadings on successive spans change but beam properties remain constant, input the slope factors but use the automatic property duplication function on the f C keys.

The last span requires input of only the beam properties and the applied moment at the end of the beam (M_N), even if zero. After input of the end moment, calculation begins. About one minute later, the values of the moments acting at each end of each segment of the beam are output. The first output is the left end applied moment M_0, the last output is the right end applied moment M_N. All moments, inputs and outputs, follow the right hand rule sign convention. If you have a HP-67 and you miss the output of the moments it is not necessary to start over. Simply leave M_N in the display and press D, the output routine will be repeated after a few seconds of calculation.

Algorithm:

The program starts by assumming that all internal moments are zero. Based on this assumption it calculates the moment across the first intermediate support using:

$$M_1 = \left\{(\theta_1 - \theta_1') - \frac{M_1 \ell_1}{6E_1I_1} - \frac{M_2 \ell_2}{6E_2I_2}\right\} \Big/ \left(\frac{\ell_1}{3E_1I_1} + \frac{\ell_2}{3E_2I_2}\right)\}$$

It then uses M_1 in an analogous equation for the next support and the next until the end of the beam is reached. The program repeats this procedure until all calculated moments remain unchanged within the specified display setting for one complete cycle of moment calculations.

Reference:

Roark, Raymond J.; Young, Warren C.; *Formulas for Stress and Strain,* McGraw-Hill, 1975.

Remarks:

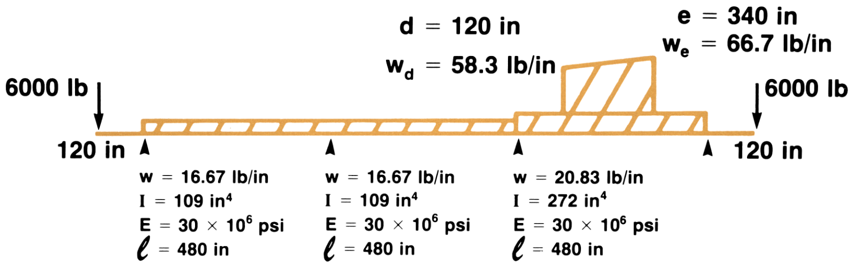
This program uses a trial and error procedure. It is possible that no answer would ever be found for some loadings.

The display setting is used to determine when answers are of satisfactory accuracy. Display of Engineering 3 is recommended for best operation. Larger numbers for display setting will take longer to converge.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Calculate all intermediate			
	slope factors using simply sup-			
	ported beam programs.			
2	Load side 1 and side 2.			
3	Input number of spans in beam			
	$(2 \leq n \leq 6)$	N	f A	0.000 00
4	Input moment applied at left			
	support (even if zero).	M_0	A	M_0
5	Input slope factor from left side			
	of next intermediate support	θ_n	ENTER↑	θ_n
	and from right side of support.*	θ_n'	B	$\theta_n - \theta_n'$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
6	Input properties of the span:**			
	moment of inertia	I		I
	modulus of elasticity	E		E
	and length of span.	ℓ	C	n
7	For next span, go to step 5. For			
	last span, go to step 6 and then			
	skip to step 8.			
8	Input moment at end of last			
	span.	M_N	D	M_0, M_1, M_1',
				$M_2, \ldots, M_N$
9	To change any span, key in			
	number of span	n	f D	n
	Go to step 5 for intermediate			
	spans, step 4 if first span, or			
	step 6 and skip to step 8 if last			
	span.			
10	For a new case, go to step 1.			
	* To duplicate θ_i, θ_i', I, E, and ℓ			
	from previous span to next			
	span press		f B	n
	and go to step 7.			
	**To duplicate I, E, and ℓ from			
	previous span to next span,			
	press		f C	n
	and go to step 7.			

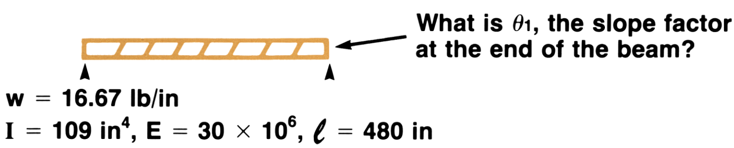
Example:



For the three span beam above, calculate the internal moments transmitted across the two intermediate supports.

Separate the beam into three independent sections and use the *Simply Supported Beam–Trapezoidal Load* program to solve for the slope factors at the points of support.

What is θ_1, the slope factor at the end of the beam?



Keystrokes using CE-10:	Outputs:	
109 ENTER↑ 30 EEX 6 ENTER↑		
480 f B →	3.270 09	
0 ENTER↑ 16.67 ENTER↑		
480 ENTER↑ 16.67 f C →	0.000 00	
480 B →	23.49–03	(θ_1)

Section 2 is loaded the same as section 1. No values change, so compute the slope factors at the two ends of section 2.

0 B →	–23.49–03	(θ_1')
480 B →	23.49–03	(θ_2)

Section 3 requires solution by superposition of the continuous load and the trapezoidal load. First solve for the continuous load and store the result in R_7, then add the result of the trapezoidal load.

Keystrokes using CE-15: **Outputs:**

272 ENTER↑ 30 EEX 6 ENTER↑
480 f B 0 ENTER↑
20.83 ENTER↑ 480 ENTER↑
20.83 f C 0 B ⟶ –11.76–03
STO 7 120 ENTER↑ 58.3 ENTER↑
340 ENTER↑ 66.7 f C 0 B ⟶ –22.74–03
RCL 7 + ⟶ –34.50–03 (θ_2')

Now we have the slopes at the supports. Using the continuous span program, we can compute the internal moments at the intermediate supports.

Summary of Knowns

Span 1	Span 2	Span 3
$M_0 = 6000\,\text{lb} \times 120\,\text{in}$		
$\ell = +720{,}000$ in-lb		
$\theta_1 = 23.49 \times 10^{-3}$	$\theta_1' = -23.49 \times 10^{-3}$	
	$\theta_2 = 23.49 \times 10^{-3}$	$\theta_2' = -34.50 \times 10^{-3}$
$I = 109$	$I = 109$	$I = 272$
$E = 30 \times 10^6$	$E = 30 \times 10^6$	$E = 30 \times 10^6$
$\ell = 480$	$\ell = 480$	$\ell = 480$
		$M_3 = 6000 \times 120$ $= -720{,}000$ in-lb (M_3 is negative by right hand rule)

Keystrokes: **Outputs:**

Span 1
3 f A 720 EEX 3 A 23.49 EEX CHS
3 ENTER↑ 23.49 CHS EEX CHS 3 B
109 ENTER↑ 30 EEX 6 ENTER↑
480 C ⟶ 1.000 00 Input for span 1 complete.

Span 2
23.49 EEX CHS 3 ENTER↑ 34.50 CHS EEX CHS 3 B
Since I, E, and ℓ remain the same between span 1 and span 2, use the automatic section property duplicate function instead of keying the values in again.
f C ⟶ 2.000 00

Span 3

272 ENTER↑ 30 EEX 6 ENTER↑

480 C ⟶	3.000 00	
720 CHS EEX 3 D ⟶	720.0 03	M_0
	−125.5 03	M_1
	125.5 03	M_1'
	−698.3 03	M_2
	698.3 03	M_2'
	−720.0 03	M_3

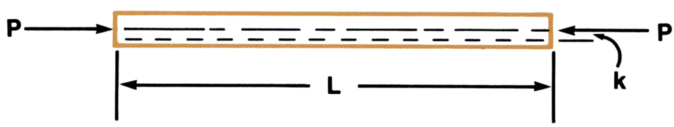
Since we now know all loads and the moments at the ends of each span, we could calculate deflection, moment and shear for any point along the span using program CE-09 and program CE-10.

16-01

STEEL COLUMN FORMULA

This program computes the allowable load and the maximum load for structural steel columns using the American Institute of Steel Construction formula (1961). The column ends must be welded, riveted, or otherwise constrained against deflection and rotation.

Equations:



$$P_{allow} = A\,\sigma_y\left[1 - (\ell/k)^2/2\,C^2\right]/m \qquad \text{for } \ell/k < C$$

$$P_{allow} = A(1.0273 \times 10^{12}\ N/m^2)/(\ell/k)^2 \qquad \text{for } C < \ell/k \leqslant 200$$

$$C^2 = 2\,\pi^2 E/\sigma_y$$

$$m = 5/3 \times 3(\ell/k)/8C - \left[(\ell/k)/2C\right]^3$$

$$P_{max} = P_{allow}\,m$$

Definitions:

P_{allow} is the allowable load;

P_{max} is the maximum load the column could carry;

A is the area of the section;

ℓ is the length of the column;

k is the minimum radius of gyration of the column cross section;

I is the minimum moment of inertia of the cross section;

σ_y is the yield point of the steel.

E is the modulous of elasticity of steel.

Remarks:

Either SI (metric) or English units may be used. For SI units, input the yield point stress of the material using the A key and use meters as the unit of length for all other inputs. For English units, input the yield point stress in pounds per square inch using the B key and use inches as the unit of length in all other inputs.

You may input the minimum moment of inertia I, instead of the minimum radius of gyration k. If I is input it will automatically be converted to k using the relation:

$$k^2 = I/A$$

Reference:

Roark, Raymond J.; Young, Warren C.; *Formulas for Stress and Strain,* McGraw-Hill, 1975.

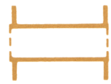
Remarks:

Columns must be nominally straight, homogeneous, and of uniform cross section.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input the following values:			
	Input yield point stress of the			
	material in newtons per square			
	meter	σy (N/m²)	f A	0.00 00
	or pounds per square inch	σy (psi)	f B	0.00 00
	and section area	A	A	A
	and column length	ℓ	B	ℓ
	and minimum radius of gyration	k	C	k
	or minimum moment of inertia	I	f C	I
3	Calculate allowable load		D	P_{allow}
	and/or maximum load		E	P_{max}
4	For a new case, go to step 2			
	and change any or all of the			
	inputs.			

Example 1:

Two steel channels are lased together to form the cross section below:



Calculate the allowable and maximum loads using the following specifications:
$k = 81.0 \times 10^{-3}$m $A = 9.46 \times 10^{-3}$ m² $\sigma_y = 248 \times 10^6$ N/m²
$\ell = 7.5$ m and 12 m

Keystrokes:	Outputs:	
248 [EEX] 6 [f] [A] 9.46 [EEX] [CHS]		
3 [A] 7.5 [B] 81 [EEX] [CHS]		
3 [C] [D] →	918.2 03	P_{allow} (N)
[E] →	1.736 06	P_{max} (N)
12 [B] [D] →	442.8 03	P_{allow} (N)
[E] →	844.5 03	P_{max} (N)

Example 2:

For a column with the properties below, what is the allowable load?

$\sigma_y = 33{,}000$ psi $A = 20$ in² $I = 223$ in⁴ $\ell = 350$ in

Keystrokes:	Outputs:	
33000 [f] [B] 20 [A] 223 [f] [C]		
350 [B] [D] →	241.0 03	P_{allow} (Pounds)

Notes

REINFORCED CONCRETE BEAMS

This program can be used in the design and analysis of rectangular reinforced concrete beams in accordance with the strength design method of the American Concrete Institute Code (ACI 318–71). The program solves interchangeably between the following six variables:

A_s—The area of nonprestressed tension reinforcement (psi or kg/cm²);

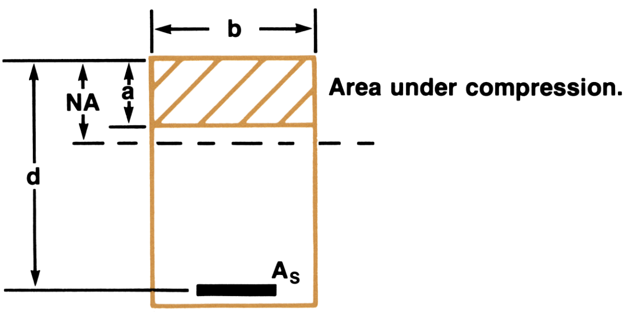
b—The width of the member (in or cm);

M—The maximum internal bending moment (lb-in or kg-cm);

d—The depth to the centroid of the reinforcing steel (in or cm);

f_c—The compressive strength of the concrete (psi or kg/cm²);

f_y—The yield strength of the steel (psi or kg/cm²).



During calculation of the parameters listed above, the calculator checks to be sure that enough reinforcement has been specified to meet the minimum allowable value:

$$\frac{A_s}{bd} > \frac{200}{f_y}$$

If this condition is not met the display will flash 10.50 which signifies that the design does not meet section 10.5 of the ACI code. Stop the flashing by pressing **R/S**. Press **R↓** to see the current value of A_s. Press **R↓** again to see the minimum allowable value of A_s. Pressing **A** at this point stores the minimum value of A_s and readys the calculator for calculation of the desired variable.

The program also checks for too much steel. Code section 10.32 specifies the maximum steel area as:

$$\frac{A_{smax}}{b\ d} = (0.6375)\ \beta_1 \frac{f_c}{f_y} \frac{87000}{87000 + f_y}$$

where

$$\beta_1 = \begin{cases} 0.85 \text{ for } f_c \leqslant 4000 \\ 0.85 - (f_c - 4000)/20000 \text{ for } f_c > 4000 \end{cases}$$

If too much steel has been specified, the calculator flashes 10.32. Stop the flashing by pressing **R/S**, then press **R↓** to see the current steel area. Press **R↓** again to see the maximum allowable tension steel area. Press **A** if you wish to use the maximum amount of steel in subsequent calculations.

If the program halts displaying ''Error,'' the input values are mathematically impossible to satisfy. This may be due to an entry error (you may review the values by recalling R_1 for A_S, R_2 for b, R_3 for M etc....) or the configuration may be mathematically undefined. If this is the case, increase the beam size and/or decrease the moment.

Optionally, the depth of the compression zone (a) may be calculated using the **f** **B** keys and the depth of the neutral axis (NA) may be calculated using **f** **C**. The depth of the neutral axis is important since T-beams may be modeled as rectangular beams if the slab or flange equals or exceedes the depth of the neutral axis.

Equations:

$$M = d\ \phi\ A_s\ f_y - (0.59\ \phi\ A_S^2\ f_y^2)/(b\ f_c)$$

$$\phi = \text{factor of safety} = 0.9$$

Reference:

ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318–71), American Concrete Institute, May 1976 printing.

Remarks:

This program is intended as an aid to computation and cannot replace an understanding of ACI 318–71.

This program does not check for deflection of shear stress modes of failure. Refer to ACI 318–71 for specifics on deflection and shear stress.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Optional: toggle metric units			
	(1 = kilograms and centi-			
	meters) or English units			
	(0 = pounds and inches).		f A	1 or 0
3	Input 5 of the following			
	variables:			
	Area of tension reinforcement	A_s	A	A_s
	Width of beam	b	B	b
	Bending moment	M	C	M
	Depth of section to centroid of			
	steel	d	D	d
	Compressive strength of			
	concrete	f_c	E	f_c
	Yield strength of tension			
	reinforcement	f_y	f E	f_y
4	Calculate remaining unknown			
	value:			
	Area of tension reinforcement		A	A_s
	Width of beam		B	b
	Bending moment		C	M
	Depth of section to centroid			
	of steel		D	d
	Compressive strength of			
	concrete		E	f_c
	Yield strength of tension			
	reinforcement		f E	f_y
5	If step 4 resulted in an "Error"			
	or a flashing display, refer to			
	description for explanation.			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
6	Optional: Calculate depth of			
	compressive stress block		f B	a
	and/or depth of neutral axis		f C	NA
7	For a new case, go to step 3			
	and change any or all of the			
	input values.			

Example 1:

For the specifications below, calculate the amount of reinforcing steel required.

M = 1.2×10^6 in-lb   b = 18 in   d = 26 in f_c = 3500 psi

f_y = 50000 psi

Keystrokes: **Outputs:**

f A f A ⟶ 0.000 00 (Set for English units.)

1.2 EEX 6 C 18 B 26 D

3500 E 50000 f E A ⟶ 10.50 00

(Flashing display indicates that calculated steel area is too small to meet ACI minimum as specified in ACI 10.5. Press R/S to halt the flashing display. Press R↓ to see the calculated value, then press R↓ again to see the minimum value, then use the minimum value to recalculate M.)

R/S R↓ ⟶ 1.045 00 in^2 (calc)

R↓ ⟶ 1.872 00 in^2 (min)

A C ⟶ 2.116 06 in-lb (M)

Example 2:

For the beam specifications below, calculate the area of steel required.

b = 25 cm   d = 30 cm   M = 1.6×10^6 kg-cm f_c = 281 kg/cm^2

f_y = 4219 kg/cm^2

Keystrokes: **Outputs:**

f A ⟶ 1.000 00 (metric units)

25 B 30 D 1.6 EEX 6 C

281 E 4219 f E A ⟶ 10.32 00

(Flashing display indicates that calculated steel area is too large to meet ACI specification 10.32. Press [R/S] to halt flashing display. Press [R↓] to see calculated value, then [R↓] again to see maximum value.)

[R/S] [R↓] ⟶	17.78 00	cm^2
[R↓] ⟶	16.02 00	cm^2

Using 16 cm^2 for A_s, what is the minimum value for d?

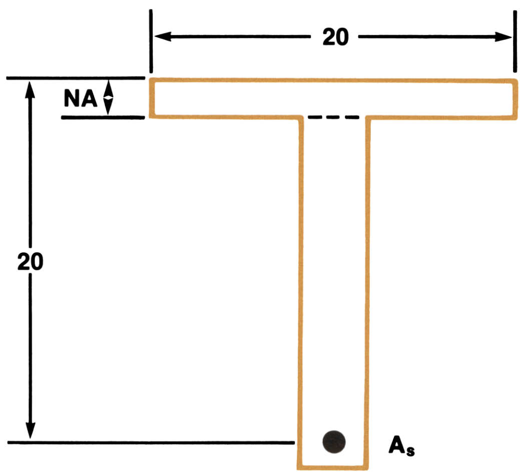
16 [A] [D] ⟶	32.01 00	cm

Example 3:

Calculate the area of the steel and the depth of the slab or flange for the T-beam data below. Use the depth of the neutral axis as the minimum depth of the flange so that the T-beam can be modeled as a rectangular beam.

$M = 2 \times 10^6$ in-lb $b = 20$ in $d = 20$ in $f_c = 4000$ psi

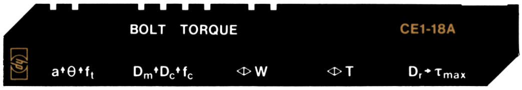
$f_y = 60{,}000$ psi



Keystrokes:	**Outputs:**	
[f] [A] [f] [A] ⟶	0.000 00	(English units)
2 [EEX] 6 [C] 20 [B] 20 [D] 4000 [E]		
60000 [f] [E] [A] ⟶	1.935 00	in^2 (A_s)
[f] [C] ⟶	2.014 00	in (Neutral axis depth and minimum flange depth.)

Notes

BOLT TORQUE



This program may be used to calculate either the torque that will yield a specified bolt load or the load resulting from a specified torque. The maximum shear stress in the body of the screw may also be calculated.

Equations:

$$T = W\frac{D_m}{2}\left[\frac{\tan\alpha + f_t/\cos\theta}{1 - f_t\tan\alpha/\cos\theta}\right] + W f_c \frac{D_c}{2}$$

$$\tau_{max} = \sqrt{(W/2\,A_r)^2 + (16T_t/\pi D_r^3)^2}$$

$$T_t = T - W f_c \frac{D_c}{2}$$

where:

T is the applied torque;

W is the bolt load;

D_m is the mean thread diameter;

α is the helix angle of the thread;

f_t is the coefficient of thread friction;

θ is one-half of the thread angle;

f_c is the collar coefficient of friction;

D_c is the collar diameter;

τ_{max} is the maximum shear stress in the body of the screw;

A_r is the root area;

D_r is the diameter at the root of the thread.

Remarks:

The accuracy with which f_t and f_c are approximated has a significant effect on the applicability of the resulting computations.

Reference;

Hall, Holowenko, Laughlin *Machine Design,* Schaum's Outline Series, McGraw-Hill Co., 1961.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 or side 2.			
2	Input helix angle of thread	α	ENTER↑	α
	then one-half of thread angle	θ	ENTER↑	θ
	then coefficient of thread			
	friction	f_t	A	0.00
	Input mean thread diameter	D_m	ENTER↑	D_m
	then collar diameter	D_c	ENTER↑	D_c
	then collar coefficient of			
	friction	f_c	B	0.00
3	Input one of the following			
	bolt load	W	C	W
	bolt torque	T	D	T
4	Calculate one of the following			
	bolt load		C	W
	bolt torque		D	T
5	Optional: Input diameter of the			
	root of the thread and compute			
	shear stress	D_r	E	τ_{max}
6	For a new load or torque go to			
	step 3. For a new case go to			
	step 2.			

Example:

Some bolts must exert a force of 11,000 pounds each. What torque is necessary to achieve this load assuming the following specifications? What is the shear stress in the bolt?

$D_m = 0.3344$ in $f_c = 0.30$

$\alpha = 3.40°$ $D_c = 0.8750$

$f_t = 0.15$ $D_r = 0.2983$

$\theta = 30°$

Keystrokes:	**Outputs:**	
3.40 ENTER↑ 30 ENTER↑ .15 A		
.3344 ENTER↑ .8750 ENTER↑		
.3 B 11000 C D ——→	1876.03	in-lb
12 ÷ ——→	156.34	ft-lbs
.2983 E ——→	114335.98	psi

If the torque were set at 140 foot-pounds (1680 inch-pounds), what would be the bolt load?

1680 D C ——→	9850.61	lbs

PROGRAM LISTINGS

The following listings are included for your reference. A table of keycodes and keystrokes corresponding to the symbols used in the listings can be found in Appendix E of your Owners Handbook.

Program **Page**

L01-01

VECTOR STATICS

Step	Key	Comment
001	*LBLA	Convert from polar to
002	X⇄Y	rectangular.
003	→R	
004	X⇄Y	
005	*LBLa	Store x, y components of
006	STOB	$\vec{V}_1$.
007	X⇄Y	
008	STOA	
009	X⇄Y	
010	RTN	
011	*LBLB	Convert from polar to
012	X⇄Y	rectangular.
013	→R	
014	X⇄Y	
015	*LBLb	
016	STOD	Store x, y components of
017	X⇄Y	$\vec{V}_2$.
018	STOC	
019	X⇄Y	
020	RTN	
021	*LBLd	
022	X⇄Y	Store F cos ϕ and F sin ϕ.
023	→R	
024	STO8	
025	X⇄Y	
026	STO9	
027	RTN	
028	*LBLC	
029	SPC	$\vec{V}_1 + \vec{V}_2$
030	RCLD	
031	RCLB	
032	+	
033	RCLA	
034	RCLC	
035	+	
036	→P	
037	PRTX	
038	X⇄Y	
039	PRTX	
040	RTN	
041	*LBLD	
042	SPC	$\vec{V}_1 \times \vec{V}_2$
043	RCLA	
044	RCLD	
045	×	
046	RCLC	
047	RCLB	
048	×	
049	-	
050	PRTX	
051	RTN	
052	*LBLE	$\vec{V}_1 \cdot \vec{V}_2$
053	SPC	
054	RCLA	
055	RCLC	
056	×	
057	RCLB	
058	RCLD	
059	×	
060	+	
061	STOE	
062	PRTX	
063	RTN	
064	RCLE	
065	RCLA	
066	RCLB	
067	→P	Calculate angle between
068	X⇄Y	vectors.
069	CLX	
070	RCLC	
071	RCLD	
072	→P	
073	X⇄Y	
074	R↓	
075	×	
076	÷	
077	COS⁻¹	
078	RCLE	
079	X⇄Y	
080	PRTX	
081	RTN	
082	*LBLe	
083	SPC	
084	RCLB	
085	RCLA	Calculate R_1.
086	→P	
087	CLX	
088	1	
089	→R	
090	STO4	
091	X⇄Y	
092	STO5	
093	RCLD	
094	RCLC	
095	→P	
096	CLX	
097	1	
098	→R	
099	STO6	
100	X⇄Y	
101	STO7	
102	R↑	
103	×	
104	R↓	
105	×	
106	R↑	
107	-	
108	STOE	
109	RCL8	
110	RCL7	
111	×	
112	RCL9	

REGISTERS

0	1	2	3	4	5	6	7	8	9
				$\cos\theta_1$	$\sin\theta_1$	$\cos\theta_2$	$\sin\theta_2$	F cos ϕ	F sin ϕ

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
x_1	y_1	x_2	y_2	used	

113 RCL6			
114 ×			
115 -			
116 RCLE			
117 ÷			
118 PRTX			
119 RCL9			
120 RCL4	Calculate R_2.		
121 ×			
122 RCL8			
123 RCL5			
124 ×			
125 -			
126 RCLE			
127 ÷			
128 PRTX			
129 RTN			

LABELS

A $r_1 \uparrow \theta_1$	B $r_2 \uparrow \theta_2$	C $\rightarrow \vec{V}_1 + \vec{V}_2$	D $\rightarrow \vec{V}_1 \times \vec{V}_2$	E $\rightarrow V_1 \cdot V_2 ; \gamma$
a $x_1 \uparrow y_1$	b $x_2 \uparrow y_2$	c	d $F \uparrow \phi$	e $\rightarrow R_1 ; R_2$
0	1	2	3	4
5	6	7	8	9

FLAGS

0
1
2
3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

SECTION PROPERTIES

Step	Key	Comment
001	*LBLa	Clear registers.
002	CLRG	
003	RTN	
004	*LBLA	Store coordinates.
005	STOD	
006	R↑	
007	STOA	
008	R↑	
009	STOB	
010	R↑	
011	STOC	Sum ΔA.
012	RCLA	
013	+	
014	STO8	
015	RCLD	
016	RCLB	
017	-	
018	STO7	
019	×	
020	2	
021	÷	
022	ST-0	Sum ΔI_y.
023	1	
024	2	
025	÷	
026	RCLC	
027	RCLA	
028	-	
029	STO6	
030	X²	
031	RCL8	
032	GSB4	
033	ST-4	Sum ΔI_x.
034	RCL6	
035	RCLB	
036	RCLD	
037	+	
038	STO9	
039	×	
040	2	
041	4	
042	÷	
043	RCL9	
044	X²	
045	RCL7	
046	GSB4	
047	ST+3	Sum ΔM_x.
048	RCL6	
049	RCL9	
050	RCL7	
051	GSB1	
052	ST+2	Sum ΔM_y.
053	RCL7	
054	RCL8	
055	RCL6	
056	GSB1	
057	ST-1	Sum ΔI_{xy}.
058	RCLC	
059	RCLB	
060	×	
061	RCLA	
062	RCLD	
063	×	
064	-	
065	ENT↑	
066	ENT↑	
067	4	
068	÷	
069	RCL8	
070	×	
071	RCLA	
072	RCLC	
073	×	
074	RCLC	
075	X²	
076	STO9	
077	+	
078	RCLA	
079	X²	
080	ST+9	
081	+	
082	RCL7	
083	×	
084	3	
085	÷	
086	+	
087	×	
088	RCL9	
089	8	
090	÷	
091	RCL8	
092	×	
093	RCL7	
094	X²	
095	×	
096	+	
097	RCL6	
098	X≠0?	
099	÷	
100	ST+5	
101	RCLC	Recall x_i and y_i for next segment.
102	RCLD	
103	RTN	
104	*LBL1	Calculate ΔM_x and ΔM_y.
105	X²	
106	3	
107	÷	
108	X⇄Y	
109	GSB4	
110	8	
111	÷	
112	RTN	

REGISTERS

0	1	2	3	4	5	6	7	8	9
ΣA	ΣM_y	ΣM_x	ΣI_x	ΣI_y	ΣI_{xy}	$(x_{i+1} - x_i)$	$(y_{i+1} - y_i)$	$(x_{i+1} + x_i)$	$(y_{i+1} + y_i)$
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
x_i	y_i	x_{i+1}	y_{i+1}		

113 *LBL4	Calculation subroutine.		
114 X²			
115 +			
116 x			
117 RTN	Add to sums for circular regions.		
118 *LBLC			
119 ENT↑			
120 ABS			
121 x			
122 Pi			
123 x			
124 4			
125 ÷			
126 STOA			
127 ST+0			
128 ENT↑			
129 ABS			
130 x			
131 Pi			
132 ÷			
133 4			
134 ÷			
135 STOB			
136 R↓			
137 STOC			
138 R↓			
139 STOD			
140 R↑			
141 x			
142 RCLA			
143 x			
144 ST+5			
145 RCLB			
146 RCLA			
147 RCLC			
148 X²			
149 x			
150 +			
151 ST+3			
152 RCLB			
153 RCLA			
154 RCLD			
155 X²			
156 x			
157 +			
158 ST+4			
159 RCLA			
160 RCLD			
161 x			
162 ST+1			
163 RCLA			
164 RCLC			
165 x			
166 ST+2			
167 CLX			
168 RTN			

LABELS

A x_{i+1} ↑ y_{i+1}	B	C x ↑ y ↑ ± d	D	E
a	b	c	d	e
0	1 Calculate	2	3	4 Calculate
5	6	7	8	9

FLAGS

0
1
2
3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

L02-03

(CARD 2)

Step	Key	Comment
001	*LBLA	Output $\overline{x}$, $\overline{y}$ and A.
002	GSB2	
003	PRTX	
004	X⇄Y	
005	PRTX	
006	RCL0	
007	PRTX	
008	RTN	
009	*LBL2	Calculate $\overline{x}$ and $\overline{y}$.
010	SPC	
011	RCL2	
012	RCL0	
013	÷	
014	STOA	
015	RCL1	
016	RCL0	
017	÷	
018	STOB	
019	RTN	
020	*LBLB	Output Ix, Iy and Ixy.
021	SPC	
022	RCL3	
023	PRTX	
024	RCL4	
025	PRTX	
026	RCL5	
027	PRTX	
028	RTN	
029	*LBLC	Calculate $I\overline{x}$, $I\overline{y}$ and $I\overline{x}\overline{y}$ and ϕ.
030	GSB3	
031	RCLC	
032	PRTX	
033	RCLD	
034	PRTX	
035	RCLE	
036	PRTX	
037	RTN	
038	*LBL3	
039	GSB2	
040	RCL5	
041	RCL0	
042	RCLA	
043	RCLB	
044	×	
045	×	
046	-	
047	STOE	
048	ENT↑	
049	+	
050	RCL4	
051	RCLB	
052	X²	
053	RCL0	
054	×	
055	-	
056	STOD	
057	RCLA	
058	X²	
059	RCL0	
060	×	
061	CHS	
062	RCL3	
063	+	
064	STOC	
065	-	
066	X≠0?	
067	÷	
068	TAN⁻¹	
069	RTN	
070	*LBLD	Calculate $I\overline{x}$, $I\overline{y}$, $I\overline{x}\overline{y}$ and output ϕ.
071	GSB3	
072	STOI	
073	2	
074	÷	
075	PRTX	
076	*LBL6	Rotate to principal axis values.
077	1	
078	→R	
079	X²	
080	STOA	
081	RCLC	
082	×	
083	X⇄Y	
084	X²	
085	STOB	
086	RCLD	
087	×	
088	+	
089	RCLI	
090	SIN	
091	RCLE	
092	×	
093	-	
094	PRTX	
095	LSTX	
096	RCLA	
097	RCLD	
098	×	
099	+	
100	RCLB	
101	RCLC	
102	×	
103	+	
104	PRTX	
105	RTN	
106	*LBLd	Calculate Ix′, Iy′, J and Ixy′.
107	ENT↑	
108	+	
109	STOI	
110	R↓	
111	STOC	
112	R↓	

REGISTERS

0	1	2	3	4	5	6	7	8	9
ΣA	ΣM_y	ΣM_x	ΣI_x	ΣI_y	ΣI_{xy}	$(x_{i+1}-x_i)$	$(y_{i+1}-y_i)$	$(x_{i+1}+x_i)$	$(y_{i+1}+y_i)$
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
x_i, $\overline{y}$, $\cos^2\phi$	y_i, $\overline{x}$, $\sin^2\phi$	x_{i+1}, $I\overline{y}$	y_{i+1}, $I\overline{y}$	$I\overline{x}\,\overline{y}$	2ϕ

```
113  STOD
114  GSB2
115  x
116  RCL0
117  x
118  CHS
119  RCL5
120  +
121  RCLD
122  RCLB
123  -
124  RCLC
125  RCLA
126  -
127  x
128  RCL0
129  x
130  +
131  STOE
132  RCLC
133  X²
134  RCLC
135  RCLA
136  x
137  2
138  x
139  -
140  RCL0
141  x
142  RCL3
143  +
144  STOC
145  RCLD
146  X²
147  RCLD
148  RCLB
149  x
150  2
151  x
152  -
153  RCL0
154  x
155  RCL4
156  +
157  STOD
158  RCLI
159  2
160  ÷
161  GSB6
162  +
163  PRTX
164  RCLC
165  RCLD
166  -
167  2
168  ÷
169  RCLI
170  SIN
171  x
172  RCLE
173  RCLI
174  COS
175  x
176  +
177  PRTX
178  RTN
```

LABELS				
A →$\bar{x}, \bar{y}, \phi$	B →Ix, Iy, Ixy	C →$I\bar{x}, I\bar{y}, I\bar{x}\bar{y}$	D →$I\bar{x}\phi I\bar{y}\phi I\bar{x}\bar{y}\phi$	E
a	b	c	d →Ix′, Iy′, Ixy′	e
0	1 $\tan^{-1}$	2 $\bar{x}, \bar{y}$	3 Ix, Iy, Ixy	4
5	6 Rotate	7	8	9

FLAGS	
0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

PROPERTIES OF SPECIAL SECTIONS

Rectangle Code.

```
*LBLa
1
GTO0
```

Triangle Code.

```
*LBLb
2
GTO0
```

Ellipse Code.

```
*LBLc
3
GTO0
```

Circle Code.

```
*LBLd
.4
GTO0
```

Concentric Circle Code.

```
*LBLe
5
```

Store Code.

```
*LBL0
STOI
RTN
```

Store a.

```
*LBLA
STOA
GTOi
*LBL4
0
STOB
X⇄Y
*LBL1
*LBL2
*LBL3
*LBL5
F3?
RTN
```

Calculate a for selected geometry.

```
RCLC
RCLB
X≠0?
÷
GTOi
*LBL1
1
2
GTO0
*LBL2
3
6
GTO0
*LBL3
Pi
÷
6
4
*LBL0
x
3
1/X
Yˣ
STOA
RTN
*LBL4
*LBL5
RCLC
6
4
x
Pi
÷
RCLB
X²
X²
+
√X
√X
STOA
RTN
```

Store b and check for circle geometry user error.

```
*LBLB
GTOi
*LBL4
RCLI
SIN⁻¹
*LBL1
*LBL2
*LBL3
*LBL5
STOB
F3?
RTN
```

Calculate for selected geometry.

```
GTOi
*LBL1
*LBL2
*LBL3
RCLC
1
2
x
RCLA
X²
LSTX
x
÷
GSBi
STOB
RTN
*LBL2
3
x
*LBL1
RTN
*LBL3
3
÷
1
6
x
Pi
÷
```

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a	b	I_x			

```
113  RTN
114  *LBL5
115  RCLA
116  X²
117  X²
118  RCLC
119  6
120  4
121  x
122  Pi
123  ÷
124  -
125  √X
126  √X
127  STOB
128  RTN
```

Store Ix.

```
129  *LBLC
130  STOC
131  F3?
132  RTN
```

Calculate Ix.

```
133  RCLB
134  RCLA
135  GSB9
136  STOC
137  RTN
```

Calculate Ix or Iy.

```
138  *LBLE
139  RCLA
140  RCLB
141  *LBL9
142  ENT↑
143  X²
144  GTOi
145  *LBL1
146  x
147  x
148  1
149  2
150  ÷
151  RTN
152  *LBL2
153  x
154  x
155  3
156  6
157  ÷
158  RTN
159  *LBL3
160  x
161  x
162  Pi
163  x
164  6
165  4
166  ÷
167  RTN
168  *LBL4
169  *LBL5
170  X⇄Y
171  X²
172  x
173  X⇄Y
174  X²
175  X²
176  -
177  ABS
178  Pi
179  x
180  6
181  4
182  ÷
183  RTN
```

Calculate Area.

```
184  *LBLD
185  RCLA
186  RCLB
187  x
188  GTOi
189  *LBL2
190  2
191  ÷
192  *LBL1
193  RTN
194  *LBL3
195  Pi
196  x
197  4
198  ÷
199  RTN
200  *LBL4
201  *LBL5
202  RCLA
203  X²
204  RCLB
205  X²
206  -
207  Pi
208  x
209  4
210  ÷
211  RTN
```

LABELS					FLAGS
A $\epsilon_a \uparrow \epsilon_b \uparrow \epsilon_c$	B b	C ↔Ix	D →A	E →Iy	0
a Rect.	b Triang.	c Ellipse	d Circle	e	1
0	1	2 Ix	3 A	4 Iy	2
5	6	7	8	9	3

SET STATUS		
FLAGS (ON / OFF)	TRIG	DISP
0 ☐ ☒	DEG ☒	FIX ☐
1 ☐ ☒	GRAD ☐	SCI ☐
2 ☐ ☒	RAD ☐	ENG ☒
3 ☐ ☒		n 3

STRESS ON AN ELEMENT

Store code:
1 = rectangular
2 = equiangular

```
001  *LBLa
002       1
003    GTO0
004  *LBLb
005       2
006  *LBL0
007    STOI
008     RTN
```

Store ν and E.

```
009  *LBLd
010    STO9
011      R↓
012    STOE
013     RTN
```

Store ϵ_a, ϵ_b and ϵ_c.

```
014  *LBLA
015    STOC
016      R↓
017    STOB
018      R↓
019    STOA
020     RTN
```

Calculate ϵ_1 and ϵ_2.

```
021  *LBLB
022    RCLA
023    GTOi
024  *LBL2
025    RCLB
026       +
027  *LBL1
028    RCLC
029       +
030    STO6
031       0
032    GTOi
033  *LBL2
034    RCLC
035    RCLA
036       -
037  *LBL1
038    RCLB
039    RCLC
040       -
041      →P
042    RCLA
043    RCLB
044       -
045      →P
046       2
047      √X
048       x
049    STO5
050       2
051    GTOi
052  *LBL2
053       1
054       +
055  *LBL1
056    ST÷5
057    ST÷6
058    GSB5
059    RCLE
060    RCL9
061       1
062       +
063       ÷
064    ST×5
065    RCLE
066       1
067    RCL9
068       -
069       ÷
070    ST×6
071    RCLC
072    RCLB
073       -
074       3
075      √X
076    GTOi
077  *LBL1
078       2
079    RCLB
080       x
081    RCLA
082       -
083    RCLC
084       -
085    RCLA
086    RCLC
087    GTO4
088  *LBL2
089       x
090       2
091    RCLA
092       x
093    RCLB
094       -
095    RCLC
```

Calculate τ_{max} and $\frac{s_1 + s_2}{2}$ from strains. (steps 057–095)

Output θ.

```
096  *LBL4
097       -
098    GSB6
099      R↓
100    PRTX
101     RTN
```

Calculate τ_{max} and $(s_1 + s_2)/2$ from s_x, s_y and τ_{xy}.

```
102  *LBLC
103      R↑
104      R↑
105    STO3
106    STO6
107      R↑
108    ST+6
109       -
110    STO4
111       2
112    ST÷6
```

REGISTERS

0	1	2	3	4	5	6	7	8	9
		2θ	s_x	$s_x - s_y$	τ_{max}	$(s_1 + s_2)/2$			ν
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
ϵ_a	ϵ_b	ϵ_c		E	Control

Step	Key	Comments
113	÷	
114	R↑	
115	STO2	
116	ST+2	
117	→P	
118	STO5	
119	RCL2	
120	CHS	
121	RCL4	
122	*LBL6	Calculate θ and 2θ.
123	X≠0?	
124	÷	
125	TAN⁻¹	
126	STO2	
127	2	
128	÷	
129	θ	
130	RTN	
131	*LBLD	Output s_1, s_2 and τ_{max} and θ.
132	GSB5	
133	RCL5	
134	PRTX	
135	RCL2	
136	2	
137	÷	
138	PRTX	
139	RTN	
140	*LBLE	
141	SPC	Calculate s and t from θ'.
142	ENT↑	
143	+	
144	RCL2	
145	-	
146	RCL5	
147	→R	
148	RCL6	
149	+	
150	PRTX	
151	X⇄Y	
152	PRTX	
153	RTN	
154	*LBL5	Calculate ϵ_1 and ϵ_2 or s_1 and s_2.
155	SPC	
156	RCL6	
157	RCL5	
158	+	
159	PRTX	
160	RCL6	
161	RCL5	
162	-	
163	PRTX	
164	RTN	

LABELS					FLAGS	SET STATUS
A $\epsilon_a \uparrow \epsilon_b \uparrow \epsilon_c$	B $\rightarrow \epsilon_1, \epsilon_2, \theta$	C $s_x \uparrow s_y \uparrow \tau_{xy}$	D $\rightarrow s_1, s_2, \tau_{max}, \theta$	E $\theta' \rightarrow s, \tau$	0	FLAGS: ON / OFF — 0 OFF x; 1 OFF x; 2 OFF x; 3 OFF x
a Rectangular	b Equiangular	c	d E↑ν	e	1	TRIG: DEG x; GRAD; RAD
0 Store code	1 Rectangular	2 Equiangular	3	4 Output	2	DISP: FIX; SCI; ENG x; n 3
5 Calc	6 θ	7	8	9	3	

BENDING OR TORSIONAL STRESS

Step	Key	Comments
001	*LBLA	s code.
002	1	
003	GTO0	
004	*LBLB	M code.
005	2	
006	GTO0	
007	*LBLC	v code.
008	3	
009	GTO0	
010	*LBLD	I code.
011	4	
012	*LBL0	Store code and input and stop if input.
013	STOI	
014	R↓	
015	STOi	
016	F3?	
017	RTN	
018	1	Calculate result.
019	STOi	
020	RCL2	
021	RCL3	
022	×	
023	RCL4	
024	÷	
025	RCL1	
026	÷	
027	GTOi	
028	*LBL2	Reciprocate result to get M or v.
029	*LBL3	
030	1/X	
031	*LBL1	Store result and stop.
032	*LBL4	
033	STOi	
034	RTN	

REGISTERS

0	1 s (s_s)	2 M (T)	3 v (r)	4 I (J)	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I Control

LABELS					FLAGS
A s (s_s)	B M (T)	C v (r0	D I (J)	E	0
a	b	c	d	e	1
0	1 s	2 M	3 v	4 I	2
5	6	7	8	9	3 Input

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

L06-01

LINEAR OR ANGULAR DEFORMATION

*LBLA 1 GTO0	A code.
*LBLB 2 GTO0	Δℓ code.
*LBLC 3 GTO0	ℓ code.
*LBLD 4 GTO0	P code.
*LBLE 5	E code.
*LBL0 STOI R↓ STOi F3? RTN	Store code and input and stop if input.
1 STOi RCL4 RCL3 x RCL1 ÷ RCL5 ÷ RCL2 ÷ GTOi	Calculate result.
*LBL4 *LBL3 1/X	Reciprocate for ℓ and P.
*LBL1 *LBL2 *LBL5 STOi RTN	Store result and stop.

REGISTERS

0	1	2	3	4	5	6	7	8	9
	A (J)	Δℓ (θ)	ℓ	P (T)	E (G)				
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
					Control

LABELS					FLAGS
A →A (J)	B →Δℓ (θ)	C →ℓ	D →P (T)	E →E (G)	0
a	b	c	d	e	1
0	1 A	2 Δℓ	3 ℓ	4 P	2
5 E	6	7	8	9	3 Input

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

CANTILEVER BEAMS

Step	Key	Comment
001	*LBLa	Initialize
002	0	
003	STO3	
004	STO4	
005	STO5	
006	RTN	
007	*LBLb	Store ℓ and EI.
008	STO2	
009	R↓	
010	x	
011	STOE	
012	RTN	
013	*LBLc	Store P and a.
014	STO3	
015	X⇄Y	
016	STOA	
017	RTN	
018	*LBLd	Store W and b.
019	STO4	
020	X⇄Y	
021	STOB	
022	RTN	
023	*LBLe	Store M and c.
024	STO5	
025	X⇄Y	
026	STOC	
027	RTN	
028	*LBLA	y_1'
029	STO0	
030	RCLA	
031	GSB4	
032	LSTX	
033	x	
034	CHS	
035	3	
036	x	
037	F2?	
038	0	
039	RCL1	
040	RCLA	
041	3	
042	x	
043	-	
044	RCL1	
045	x	
046	+	
047	RCL3	
048	x	
049	RCL1	
050	x	
051	RCLB	
052	GSB4	
053	RCLB	
054	3	
055	Y^x	
056	x	
057	F2?	
058	CLX	
059	STOD	y_2'
060	R↓	
061	RCL1	
062	4	
063	÷	
064	RCLB	
065	-	
066	RCL1	
067	x	
068	RCLB	
069	X²	
070	1	
071	.	
072	5	
073	x	
074	+	
075	RCL1	
076	X²	
077	x	
078	RCLD	
079	+	
080	RCL4	
081	x	$y' + y_2'$
082	-	
083	RCLC	
084	GSB4	
085	6	
086	x	
087	RCL1	
088	3	
089	x	
090	X⇄Y	y_3'
091	F2?	
092	CLX	
093	+	
094	RCL5	
095	x	
096	RCL1	
097	x	$y_1' + y_2' + y_2'$
098	+	
099	6	
100	÷	
101	RCLE	y
102	÷	
103	RTN	
104	*LBLB	
105	STO0	
106	RCLA	
107	GSB4	
108	RCL1	θ_1'
109	2	
110	÷	
111	RCLA	
112	-	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	x'(a)	ℓ	P	W	M				

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a	b	c		EI	

Step	Key	Comments
113	RCL3	
114	×	
115	RCL1	
116	×	
117	RCLB	
118	GSB4	
119	R↓	
120	RCL1	
121	6	θ_2'
122	÷	
123	RCLB	
124	2	
125	÷	
126	-	
127	RCL1	
128	×	
129	RCLB	
130	X²	
131	2	
132	÷	
133	+	
134	RCL4	
135	×	
136	RCL1	
137	×	
138	-	
139	RCLC	
140	GSB4	
141	R↓	θ_3'
142	RCL5	
143	RCL1	
144	×	
145	+	
146	RCLE	$\theta_1' + \theta_2' + \theta_3'$
147	÷	
148	RTN	θ
149	*LBLC	
150	STO0	
151	RCLA	M_1
152	GSB4	
153	RCL1	
154	RCLA	
155	-	
156	RCL3	
157	×	
158	RCLE	
159	GSB4	
160	CLX	
161	RCL1	M_2
162	2	
163	÷	
164	RCLB	
165	-	
166	RCL1	
167	×	
168	RCLB	
169	X²	
170	2	
171	÷	
172	+	
173	RCL4	
174	×	
175	-	$M_1 + M_2$
176	RCLC	
177	GSB4	
178	CLX	M_3
179	RCL5	
180	X⇄Y	
181	F2?	
182	+	$M_1 + M_2 + M_3$
183	RTN	
184	*LBLD	
185	STO0	
186	RCLA	V_1
187	GSB4	
188	0	
189	F2?	
190	RCL3	
191	RCLB	
192	GSB4	
193	CLX	
194	RCL1	
195	RCLB	V_2
196	-	
197	RCL4	
198	×	
199	-	
200	RTN	V
201	*LBL4	
202	CF2	Select smaller of x and a (or b or c) and store as x'.
203	RCL0	
204	STO1	
205	X⇄Y	
206	X≤Y?	
207	STO1	
208	X>Y?	If x > a set flag.
209	SF2	
210	-	
211	RTN	

LABELS

A x→y	B x→θ	C x→M_x	D x→V	E
a Start	b l↑E↑ℓ	c a↑P	d b↑W	e c↑M
0	1	2	3	4 Store x'
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☐
SCI	☐
ENG	☒
n	3

L08-01

CANTILEVER BEAMS—TRAPEZIODAL LOAD

Step	Key	Comments	Step	Key	Comments
001	*LBLa	Store EI and ℓ.	057	÷	
002	STO2		058	RCL4	
003	R↓		059	6	
004	x		060	÷	
005	STOE		061	+	
006	RTN		062	RCLI	
007	*LBLc	Store w_e, e, w_d and d	063	X^2	
008	P⇄S		064	LSTX	
009	STO1		065	x	
010	R↓		066	x	
011	STO2		067	CHS	
012	R↓		068	RCL1	
013	STO3		069	+	
014	R↓		070	RCLE	
015	STO4		071	÷	
016	P⇄S		072	CHS	
017	RTN		073	RTN	
018	*LBLA	Calculate y.	074	*LBLC	Calculate M_x.
019	GSB9		075	GSB9	
020	GSB1		076	GSB1	
021	GSB7		077	GSB7	
022	GSB1		078	GSB1	
023	GTO6		079	GTO6	
024	*LBL1		080	*LBL1	
025	1		081	6	
026	2		082	÷	
027	0		083	RCL4	
028	÷		084	2	
029	RCL4		085	÷	
030	2		086	+	
031	4		087	RCLI	
032	÷		088	X^2	
033	+		089	x	
034	RCLI		090	CHS	
035	X^2		091	RTN	
036	X^2		092	*LBLD	Calculate V.
037	x		093	GSB9	
038	-		094	GSB1	
039	RCL1		095	GSB7	
040	RCL2		096	GSB1	
041	RCL0		097	*LBL6	Sum loading effect and stop for display.
042	-		098	CHS	
043	x		099	P⇄S	
044	+		100	RCL0	
045	RCLE		101	P⇄S	
046	÷		102	+	
047	RTN		103	R/S	
048	*LBLB	Calculate slope.	104	*LBL1	
049	GSB9		105	2	
050	GSB1		106	÷	
051	GSB7		107	RCL4	
052	GSB1		108	+	
053	GTO6		109	RCLI	
054	*LBL1		110	x	
055	2		111	RTN	
056	4		112	*LBL9	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	θ_0	ℓ		w_d or w_e					

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
Sum	w_e	e	w_d	d					

A	B	C	D	E	I
	w_L		d or e	EI	(x − d) or 0

Step	Key	Comments
113	STO0	Store x and calculate w_L.
114	P⇄S	
115	RCL3	
116	RCL1	
117	RCL3	
118	-	
119	RCL2	
120	RCL4	
121	-	
122	÷	
123	RCL4	
124	×	
125	-	
126	STOB	Put d and w_d in the stack.
127	RCL2	
128	RCL1	
129	GTO8	
130	*LBL7	Store sum and put e and w_e in stack.
131	P⇄S	
132	STO0	
133	RCL4	
134	RCL3	
135	*LBL8	(x – d) If (x – d) is greater than 0, (x – d) → I, otherwise 0 → I.
136	P⇄S	
137	STO4	
138	R↓	
139	STOD	
140	RCL0	
141	-	
142	X<0?	
143	CLX	
144	STOI	
145	RCLB	Calculate y_0 in the stack and θ_0 in R_1.
146	RCL4	
147	STO1	
148	-	
149	6	
150	ST÷1	
151	R↓	
152	2	
153	4	
154	÷	
155	ST+1	
156	5	
157	÷	
158	RCL2	
159	5	
160	×	
161	RCLD	
162	-	
163	×	
164	LSTX	
165	RCL2	
166	-	
167	RCL4	
168	×	
169	2	
170	4	
171	÷	
172	+	
173	RCLD	
174	X²	
175	LSTX	
176	×	
177	ST×1	
178	×	
179	CHS	
180	RCLB	Calculate $\frac{(w_d \text{ or } w_e - w_L)\,I}{(\ell - d)}$
181	RCL4	
182	-	
183	RCLD	
184	X≠0?	
185	÷	
186	RCLI	
187	×	
188	RTN	

LABELS

A x → y	B x → θ	C x → M_x	D x → V	E
a	b I↑E↑ℓ	c d↑w_d↑e↑w_e	d	e
0	1 Used	2	3	4
5 ÷ EI	6 Sum	7 e, w_e	8 R_0, θ_0	9 d, w_d

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

SIMPLY SUPPORTED BEAMS

Step	Key	Comment
001	*LBLa	Store zeros for P, W, and M.
002	0	
003	STO3	
004	STO4	
005	STO5	
006	RTN	
007	*LBLb	Store ℓ and EI.
008	STO2	
009	R↓	
010	×	
011	STOE	
012	RTN	
013	*LBLc	Store P and a.
014	STO3	
015	X⇄Y	
016	STOA	
017	RTN	
018	*LBLd	Store W.
019	STO4	
020	RTN	
021	*LBLe	Store M and c.
022	STO5	
023	X⇄Y	
024	STOC	
025	RTN	
026	*LBLB	Set derivative flag.
027	SF0	
028	GTO0	
029	*LBLA	Clear derivative flag.
030	CF0	
031	*LBL0	
032	STO0	
033	RCL2	Compute
034	ENT↑	
035	×	y_2 (EI) or θ_2 (EI).
036	LSTX	
037	×	
038	RCL0	
039	F0?	
040	4	
041	F0?	
042	×	
043	RCL2	
044	2	
045	×	
046	F0?	
047	3	
048	F0?	
049	×	
050	-	
051	RCL0	
052	X²	
053	×	
054	+	
055	RCL4	
056	×	

Step	Key	Comment
057	2	
058	4	
059	÷	
060	RCL0	
061	X⇄Y	
062	×	
063	F0?	
064	LSTX	
065	CHS	
066	GSB1	
067	RCL1	Compute
068	X²	y_1 (EI)
069	F0?	or
070	3	θ_1 (EI).
071	F0?	
072	×	
073	RCLD	
074	X²	
075	+	
076	RCL2	
077	X²	
078	-	
079	×	
080	6	
081	÷	
082	GSB2	
083	RCL1	Compute
084	X²	y_3 (EI)
085	RCL2	or
086	÷	θ_3 (EI).
087	6	
088	÷	
089	F0?	
090	3	
091	F0?	
092	×	
093	RCL2	
094	3	
095	÷	
096	+	
097	RCLD	
098	X²	
099	2	
100	÷	
101	RCL2	
102	÷	
103	+	
104	RCLD	
105	-	
106	×	
107	RCL2	
108	×	
109	RCLI	
110	+	$y = y_1 + y_2 + y_3$
111	RCLE	or
112	÷	$\theta = \theta_1 + \theta_2 + \theta_3$

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	x,(x − ℓ)	ℓ	P	W	M				

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a		c	(ℓ−a), − a; c, ℓ−c	EI	SUM

Step	Key	Comment
113	RTN	
114	*LBLD	Set derivative flag.
115	SF0	
116	GTO0	
117	*LBLC	Clear derivative flag.
118	CF0	
119	*LBL0	Compute M_{x2} or V_2
120	STO0	
121	2	
122	÷	
123	RCL2	
124	F0?	
125	2	
126	F0?	
127	÷	
128	RCL0	
129	-	
130	RCL4	
131	x	
132	x	
133	F0?	
134	LSTX	
135	GSB1	M_{x1} or V_1
136	GSB2	M_{x3} or V_3
137	RCLI	$M = M_{x1} + M_{x2} + M_{x3}$ or $V = V_1 + V_2 + V_3$
138	+	
139	RTN	
140	*LBL1	Store first results.
141	STOI	
142	RCL2	Store ℓ − a and x
143	RCLA	
144	-	
145	STOD	
146	RCL0	
147	STO1	
148	RCLA	If a > x GTO 0
149	X>Y?	
150	GTO0	
151	RCLA	Otherwise store −a for ℓ − a and x − ℓ for x.
152	CHS	
153	STOD	
154	RCL2	
155	ST-1	
156	*LBL0	$\frac{P(\ell - a)}{\ell}$
157	RCL3	
158	RCLD	
159	x	
160	RCL2	
161	÷	
162	F0?	
163	RTN	$\frac{P(\ell - a)x}{\ell}$
164	RCL1	
165	x	
166	RTN	
167	*LBL2	Add first result to second.
168	RCLI	
169	+	
170	STOI	Store x and c.
171	RCL0	
172	STO1	
173	RCLC	
174	STOD	
175	X>Y?	If c > x GTO 0.
176	GTO0	
177	RCL0	Otherwise store x − ℓ for x and ℓ − c for c.
178	RCL2	
179	-	
180	STO1	
181	RCL2	
182	RCLC	
183	-	
184	STOD	
185	*LBL0	$\frac{M}{\ell}$
186	RCL5	
187	RCL2	
188	÷	
189	F0?	
190	RTN	$\frac{M_x}{\ell}$
191	RCL1	
192	x	
193	RTN	Recall x.

LABELS

A x→y	B x→θ	C x→M_x	D x→V	E RCL x
a Start	b I↑E↑ℓ	c a↑P	d W	e c↑M
0 Used	1 Con	2 Mom	3	4
5	6	7	8	9

FLAGS

0	Derivative
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

L10-01

SIMPLY SUPPORTED BEAMS—TRAPEZIODAL LOAD

Step	Key	Comment	Step	Key	Comment
001	*LBLa	Store EI and ℓ.	057	6	
002	STO2		058	÷	
003	R↓		059	RCLI	
004	×		060	X²	
005	STOE		061	×	
006	RTN		062	RCLI	
007	*LBLc	Store w_e, e, w_d, and d.	063	×	
008	P⇄S		064	+	
009	STO1		065	RCL1	
010	R↓		066	2	
011	STO2		067	÷	
012	R↓		068	RCL0	
013	STO3		069	X²	
014	R↓		070	*LBL5	
015	STO4		071	×	
016	P⇄S		072	+	
017	RTN		073	RCLE	
018	*LBLA	Calculate y.	074	÷	
019	GSB9		075	RTN	
020	GSB1		076	*LBLC	
021	GSB7		077	GSB9	Calculate M_x.
022	GSB1		078	GSB1	
023	GTO6		079	GSB7	
024	*LBL1		080	GSB1	
025	5		081	GTO6	
026	÷		082	*LBL1	
027	RCL4		083	6	
028	-		084	÷	
029	2		085	RCL4	
030	4		086	2	
031	÷		087	÷	
032	RCLI		088	-	
033	X²		089	RCLI	
034	X²		090	X²	
035	×		091	×	
036	X⇄Y		092	RCL1	
037	RCL0		093	RCL0	
038	X²		094	×	
039	RCL1		095	+	
040	×		096	RTN	
041	6		097	*LBLD	
042	÷		098	GSB9	Calculate V.
043	+		099	GSB1	
044	RCL0		100	GSB7	
045	GTO5		101	GSB1	
046	*LBLB		102	*LBL6	
047	GSB9		103	CHS	Sum loading effect and stop for display.
048	GSB1	Calculate slope.	104	P⇄S	
049	GSB7		105	RCL0	
050	GSB1		106	P⇄S	
051	GTO6		107	+	
052	*LBL1		108	R/S	
053	4		109	*LBL1	
054	÷		110	2	
055	RCL4		111.	÷	
056	-		112	RCL4	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	R_0	ℓ		w_d or w_e					

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
Sum	w_e	e	w_d	d					

A	B	C	D	E	I
	$w_ℓ$		d or e	EI	(x – d) or 0

Step	Key Entry	Comments
113	-	
114	RCLI	
115	x	
116	RCL1	
117	+	
118	RTN	
119	*LBL9	------------
120	STO0	Store x and calculate w_ℓ.
121	RCL2	
122	P⇄S	
123	RCL2	
124	-	
125	RCL1	
126	RCL3	
127	-	
128	x	
129	RCL2	
130	RCL4	
131	-	
132	÷	
133	RCL1	
134	+	
135	STOB	
136	RCL4	
137	RCL3	Put d and w_d in stack.
138	GTO8	
139	*LBL7	------------
140	P⇄S	Store sum and put e and
141	STO0	w_e in stack.
142	RCL2	
143	RCL1	
144	*LBL8	------------
145	P⇄S	(x − d)
146	STO4	If (x − d) is greater than 0,
147	R↓	(x − d) → I, otherwise 0 → I.
148	STOD	
149	RCL0	
150	-	
151	CHS	
152	X<0?	
153	CLX	
154	STOI	------------
155	RCLB	Calculate slope in stack and
156	RCL4	R_0 in R_1.
157	-	
158	STO1	
159	3	
160	0	
161	÷	
162	3	
163	RCLD	
164	x	
165	6	
166	ST÷1	
167	RCL2	
168	x	

Step	Key Entry	Comments
169	-	
170	RCLD	
171	x	
172	RCL2	
173	X²	
174	7	
175	x	
176	-	
177	x	
178	RCLD	
179	RCL2	
180	ENT↑	
181	+	
182	-	
183	RCLD	
184	x	
185	RCL2	
186	X²	
187	-	
188	RCL4	
189	2	
190	÷	
191	ST+1	
192	x	
193	+	
194	1	
195	2	
196	÷	
197	RCL2	
198	RCLD	
199	-	
200	X²	
201	RCL2	
202	÷	
203	ST×1	
204	x	------------
205	RCL4	Calculate
206	RCLB	
207	-	$\dfrac{(w_d \text{ or } w_e - W_\ell)I}{(\ell - d)}$
208	RCL2	
209	RCLD	
210	-	
211	X≠0?	
212	÷	
213	RCLI	
214	x	
215	RTN	

LABELS

A x → y	B x → θ	C x → M_x	D x → V	E
a	b I↑E↑ℓ	c d↑w_d↑e↑w_e	d	e
0	1 Used	2	3	4
5 ÷ EI	6 Sum	7 e, w_e	8 R_0, θ_0	9 d, w_d

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

BEAMS FIXED AT BOTH ENDS

Step	Key	Comment
001	*LBLa	Store W.
002	STO4	
003	RTN	
004	*LBLb	Store ℓ and EI.
005	STO2	
006	R↓	
007	×	
008	STOE	
009	RTN	
010	*LBLc	Store P and a.
011	STO3	
012	X⇄Y	
013	STOA	
014	RTN	
015	*LBLe	Store M and c.
016	STO5	
017	X⇄Y	
018	STOC	
019	RTN	
020	*LBLB	Set derivative flag and start θ_2 calculation.
021	SF0	
022	STO0	
023	GSB7	
024	RCL2	
025	3	
026	×	
027	RCL0	
028	GSB7	
029	GTO0	
030	*LBLA	Clear derivative flag and start y_2 calculation.
031	CF0	
032	STO0	
033	X²	
034	RCL2	
035	GSB7	
036	RCL0	
037	*LBL0	Complete calculation of θ_2 EI or y_2 EI.
038	SF1	
039	-	
040	RCL0	
041	×	
042	RCL2	
043	X²	
044	-	
045	×	
046	2	
047	4	
048	÷	
049	RCL4	
050	×	
051	RCLA	Calculate y_1 EI or θ_1 EI.
052	GSB1	
053	RCL1	
054	×	
055	RCLD	
056	RCL2	

Step	Key	Comment
057	×	
058	3	
059	X⇄Y	
060	×	
061	F0?	
062	LSTX	
063	F0?	
064	-	
065	-	
066	GSB6	
067	6	
068	÷	
069	F0?	
070	3	
071	F0?	
072	×	
073	F0?	
074	GSB3	
075	GSB4	
076	RCLC	Calculate y_3 EI and/or θ_3 EI.
077	GSB1	
078	F0?	
079	3	
080	F0?	
081	×	
082	X⇄Y	
083	F0?	
084	GSB7	
085	+	
086	GSB6	
087	GSB8	Calculate y or θ.
088	RCLE	
089	÷	
090	RTN	
091	*LBLD	Set derivative flag and start V_2 calculation.
092	SF0	
093	STO0	
094	RCL2	
095	X⇄Y	
096	GSB7	Clear derivative flag and start M_2 calculation.
097	GTO0	
098	*LBLC	
099	CF0	
100	STO0	
101	RCL2	
102	X⇄Y	
103	-	
104	RCL0	
105	×	
106	RCL2	
107	X²	
108	6	
109	÷	
110	*LBL0	Complete calculation of V_2 or M_2.
111	SF1	
112	-	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	x, (ℓ − x)	ℓ	P	W	M				
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a		c	a, (ℓ−a); c, (ℓ−c)	EI	SUM

Step	Key	Comments	Step	Key	Comments
113	2		169	RCL2	
114	÷		170	RCL0	
115	RCL4		171	-	
116	×		172	STO1	
117	RCLA		173	*LBL0	$\frac{P(\ell - a)^2}{\ell^3}$ or
118	GSB1		174	RCL5	
119	F0?		175	F1?	
120	GTO0	Calculate V_1 or M_1.	176	RCL3	
121	RCL1		177	RCL2	
122	×		178	RCLD	
123	RCLD		179	-	$\frac{M(\ell - a)}{\ell^3}$
124	RCL2		180	F1?	
125	×		181	X²	
126	-		182	×	
127	*LBL0		183	RCL2	
128	×		184	3	
129	F0?		185	Yˣ	
130	GSB3		186	÷	
131	GSB4		187	RCL2	
132	RCLC		188	RCLD	
133	GSB1	Calculate V_3 or M_3.	189	F1?	$\frac{(\ell - 3a)\ell}{2}$
134	F0?		190	GTO0	
135	R↓		191	3	
136	F0?		192	×	
137	CLX		193	-	
138	F0?		194	RCL2	
139	RCLD		195	×	
140	6		196	2	
141	×		197	÷	
142	X⇄Y		198	RCLD	ax
143	GSB7		199	RCL1	
144	+		200	×	
145	×		201	RTN	
146	*LBL8		202	*LBL0	$(\ell + 2a)$
147	F0?	Sign change?	203	GSB7	
148	GTO4		204	+	
149	GSB3		205	CF1	
150	*LBL4	Calculate sum.	206	RTN	
151	RCLI		207	*LBL3	Sign change.
152	+		208	F2?	
153	RTN		209	CHS	
154	*LBL1	Store a or c and sum.	210	RTN	Calculation subroutine.
155	CF2		211	*LBL6	
156	STOD		212	×	
157	R↓		213	RCL1	
158	STOI		214	*LBL5	
159	RCLD		215	X²	
160	RCL0		216	F0?	
161	STO1		217	√X	
162	X≤Y?	Is x beyond loading point?	218	×	
163	GTO0	Yes—set sign change flag and $a = \ell - a$ or $c = \ell - c$ and $x = \ell - x$.	219	RTN	
164	SF2		220	*LBL7	2X subroutine
165	RCL2		221	ENT↑	
166	RCLD		222	+	
167	-		223	RTN	
168	STOD				

LABELS					FLAGS
A x→y	B x→θ	C x→M_x	D x→V	E	0 Derivative
a	b I↑E↑ℓ	c a↑P	d W	e c↑M	1 P
0 Used	1 Calc.	2	3 Sign	4 sum	2 Sign
5 Calc.	6 Calc.	7 2x	8	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

BEAMS FIXED AT BOTH ENDS—TRAPEZOIDAL LOAD

Step	Key	Comment
001	*LBLb	Store EI and ℓ.
002	STO2	
003	R↓	
004	×	
005	STOE	
006	RTN	
007	*LBLc	Store w_e, e, w_d, and d.
008	P⇄S	
009	STO1	
010	R↓	
011	STO2	
012	R↓	
013	STO3	
014	R↓	
015	STO4	
016	P⇄S	
017	RTN	
018	*LBLA	Calculate y.
019	GSB9	
020	GSB1	
021	GSB7	
022	GSB1	
023	GTO6	
024	*LBL1	
025	5	
026	÷	
027	RCL4	
028	-	
029	2	
030	4	
031	÷	
032	RCLI	
033	X²	
034	X²	
035	×	
036	X⇄Y	
037	6	
038	÷	
039	RCL0	
040	×	
041	RCL1	
042	2	
043	÷	
044	-	
045	RCL0	
046	X²	
047	GTO5	
048	*LBLB	Calculate slope.
049	GSB9	
050	GSB1	
051	GSB7	
052	GSB1	
053	GTO6	
054	*LBL1	
055	4	
056	÷	
057	RCL4	
058	-	
059	6	
060	÷	
061	RCLI	
062	X²	
063	LSTX	
064	×	
065	×	
066	X⇄Y	
067	RCL0	
068	×	
069	2	
070	÷	
071	RCL1	
072	-	
073	RCL0	
074	*LBL5	
075	×	
076	+	
077	RCLE	
078	÷	
079	RTN	
080	*LBLC	Calculate M_x.
081	GSB9	
082	GSB1	
083	GSB7	
084	GSB1	
085	GTO6	
086	*LBL1	
087	6	
088	÷	
089	RCL4	
090	2	
091	÷	
092	-	
093	RCLI	
094	X²	
095	×	
096	X⇄Y	
097	RCL0	
098	×	
099	+	
100	RCL1	
101	-	
102	RTN	
103	*LBLD	Calculate V.
104	GSB9	
105	GSB1	
106	GSB7	
107	GSB1	
108	*LBL6	Sum loading effect and stop for display.
109	CHS	
110	P⇄S	
111	RCL0	
112	P⇄S	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	$-M_0$	ℓ		w_d or w_e					

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
Sum	w_e	e	w_d	d					

A	B	C	D	E	I
	$w_ℓ$		d or e	EI	(x − d) or 0

Step	Key	Comments
113	+	
114	R/S	
115	*LBL1	
116	2	
117	÷	
118	RCL4	
119	-	
120	RCLI	
121	x	
122	+	
123	RTN	
124	*LBL9	Store x and calculate w_ℓ.
125	STO0	
126	RCL2	
127	P⇄S	
128	RCL2	
129	-	
130	RCL1	
131	RCL3	
132	-	
133	x	
134	RCL2	
135	RCL4	
136	-	
137	÷	
138	RCL1	
139	+	
140	STOB	
141	RCL4	
142	RCL3	Put d and w_d in stack.
143	GTO8	
144	*LBL7	
145	P⇄S	Store sum and put e and w_e in stack.
146	STO0	
147	RCL2	
148	RCL1	
149	*LBL8	
150	P⇄S	(x − d)
151	STO4	If (x − d) is greater than 0,
152	R↓	(x − d) → I, otherwise 0 → I.
153	STOD	
154	RCL0	
155	-	
156	CHS	
157	X<0?	
158	CLX	
159	STOI	Calculate R_0 in stack and
160	RCLD	$-M_0$ in R_1.
161	STO1	
162	ENT↑	
163	+	
164	3	
165	ST×I	
166	RCL2	
167	ST+1	
168	ST+1	
169	x	
170	+	
171	RCLB	
172	RCL4	
173	-	
174	ST×1	
175	x	
176	2	
177	0	
178	ST÷1	
179	÷	
180	RCLD	
181	3	
182	ST÷1	
183	x	
184	RCL2	
185	+	
186	RCL4	
187	x	
188	1	
189	2	
190	÷	
191	ST+1	
192	CLX	
193	RCL2	
194	RCLD	
195	+	
196	RCL4	
197	x	
198	2	
199	÷	
200	+	
201	RCL2	
202	RCLD	
203	-	
204	RCL2	
205	ST×1	
206	÷	
207	X²	
208	LSTX	
209	x	
210	ST×1	
211	x	
212	RCL4	
213	RCLB	
214	-	Calculate
215	RCL2	$\frac{(w_d \text{ or } w_e - w_\ell)\,I}{(\ell - d)}$
216	RCLD	
217	-	
218	X≠0?	
219	÷	
220	RCLI	
221	x	
222	RTN	

LABELS

A x → y	B x → θ	C x → M	D x → V	E
a	b I↑E↑ℓ	c d↑w_d↑e↑w_e	d	e
0	1 Used	2	3	4
5 ÷ EI	6 Sum	7 e, w_e	8 R_0, θ_0	9 d, w_d

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

PROPPED CANTILEVER BEAMS

Step	Key	Comment
001	*LBLa	
002	0	
003	STO3	Initialize
004	STO5	
005	*LBLd	
006	STO4	Store W.
007	RTN	
008	*LBLb	
009	STO2	Store ℓ and EI.
010	R↓	
011	x	
012	STOE	
013	RTN	
014	*LBLc	
015	STO3	Store P and a.
016	X⇄Y	
017	STOA	
018	RTN	
019	*LBLe	
020	STO5	Store M and c.
021	X⇄Y	
022	STOC	
023	RTN	
024	*LBLB	Store x, clear integral flag, load constants.
025	CF0	
026	STO0	
027	9	
028	ENT↑	
029	8	
030	GTO0	
031	*LBLA	Store x, set integral flag, load constants.
032	SF0	
033	STO0	
034	3	
035	ENT↑	
036	2	
037	*LBL6	
038	RCL0	Calculate 6 y_2 EI or $6\theta_2$ EI.
039	x	
040	RCL2	
041	÷	
042	-	
043	RCL0	
044	X²	
045	x	
046	RCL2	
047	X²	
048	-	
049	RCL2	
050	x	
051	GSB5	Calculate $6y_1$ EI or $6\,\theta_1$ EI.
052	RCL0	
053	X²	
054	F0?	
055	3	
056	F0?	
057	÷	
058	RCL2	
059	X²	
060	-	
061	STOD	
062	x	
063	RCLI	
064	X²	
065	+	
066	GSB4	
067	F2?	
068	GTO0	
069	RCL0	
070	RCLA	
071	-	
072	X²	
073	F0?	
074	LSTX	
075	F0?	
076	x	
077	F0?	
078	3	
079	F0?	
080	÷	
081	-	
082	*LBL0	
083	3	
084	x	
085	RCL3	
086	x	
087	ST+1	EI $(y_1 + y_2)$ EI $(\theta_1 + \theta_2)$
088	6	
089	ST÷1	
090	GSB1	
091	RCLD	Calculate y_3 EI or θ_3 EI.
092	x	
093	3	
094	x	
095	RCL2	
096	+	
097	GSB4	
098	F2?	
099	GTO6	
100	RCL0	
101	GSB4	
102	0	
103	F0?	
104	R↓	
105	F0?	
106	RCLC	
107	X²	
108	+	
109	F0?	
110	2	
111	F0?	
112	÷	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	sum	ℓ	D	W	M				

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a		c	$(x^2/3 - \ell^2)$	EI	$(\ell - a)$; c

Step	Key	Comment
113	GTO0	
114	*LBL6	
115	RCLC	
116	GSB4	
117	*LBL0	
118	-	
119	GSB8	
120	RCLE	$y = y_1 + y_2 + y_3$ or
121	÷	$\theta = \theta_1 + \theta_2 + \theta_3$
122	RTN	
123	*LBLD	Store x, clear integral flag,
124	CF0	multiply by 2.
125	STO0	
126	2	
127	x	
128	GTO0	
129	*LBLC	Store x, set integral flag.
130	SF0	
131	STO0	
132	*LBL0	
133	3	
134	RCL2	Compute M_2 or V_2.
135	x	
136	X⇄Y	
137	4	
138	x	
139	-	
140	GSB5	
141	GSB4	
142	F2?	Compute M_1 or V_1
143	GTO0	
144	1	
145	GSB4	
146	-	
147	F0?	
148	RCLA	
149	F0?	
150	+	
151	*LBL0	
152	RCL3	
153	x	
154	ST+1	
155	GSB1	
156	6	Compute M_3 or V_3
157	x	
158	GSB4	
159	F2?	
160	GTO8	
161	F0?	
162	1	
163	F0?	
164	-	
165	*LBL8	
166	RCL5	
167	x	$M_x = M_1 + M_2 + M_3$
168	ST+1	

Step	Key	Comment
169	RCL1	or
170	RTN	$V = V_1 + V_2 + V_3$
171	*LBL4	Multiply by x if integral
172	F0?	flag is set.
173	RCL0	
174	F0?	
175	x	
176	RTN	
177	*LBL5	Finish y_2, θ_2, M_2 and
178	RCL4	V_2 calculations.
179	x	
180	GSB4	
181	8	
182	÷	
183	STO1	
184	CF1	Store b.
185	RCL2	
186	RCLA	
187	-	
188	STOI	
189	LSTX	
190	GTO0	
191	*LBL1	
192	RCLC	Store c.
193	STOI	
194	*LBL0	Set x ≤ to a or c flag.
195	CF2	
196	RCL0	
197	X≤Y?	
198	SF2	
199	RCLI	Calculate
200	3	
201	x	
202	F1?	$\frac{3a^2\ell - a^3}{2\ell^3}$
203	RCL2	
204	RCL2	
205	x	First pass, then
206	RCLI	
207	X²	
208	-	$\frac{\ell^2 - c^2}{4\ell^3}$ on
209	2	
210	F1?	
211	X²	Second pass.
212	÷	
213	RCL2	
214	3	
215	Yˣ	
216	÷	
217	F1?	
218	RTN	
219	SF1	
220	RCLI	
221	x	
222	RTN	

LABELS					FLAGS
A Start	B I↑E↑ℓ	C a↑P	D W	E c↑M	0 Integral
a x→y	b x→θ	c x→M_x	d x→V	e	1 Moment
0 Used	1 P	2	3	4 x mult	2 x ≤ d or c
5 W − P	6 Used	7	8 Mult & Sum	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

PROPPED CANTILEVER BEAMS—TRAPEZIODAL LOAD

Step	Key	Comments
001	*LBLb	Store EI and ℓ.
002	STO2	
003	R↓	
004	x	
005	STOE	
006	RTN	
007	*LBLc	Store w_e, e, w_d, and d.
008	P⇄S	
009	STO1	
010	R↓	
011	STO2	
012	R↓	
013	STO3	
014	R↓	
015	STO4	
016	P⇄S	
017	RTN	
018	*LBLA	Calculate y.
019	GSB9	
020	GSB1	
021	GSB7	
022	GSB1	
023	GTO6	
024	*LBL1	
025	5	
026	÷	
027	RCL4	
028	-	
029	2	
030	4	
031	÷	
032	RCLI	
033	X²	
034	X²	
035	x	
036	X⇄Y	
037	RCL0	
038	X²	
039	x	
040	6	
041	÷	
042	RCL1	
043	-	
044	RCL0	
045	GTO5	
046	*LBLB	Calculate slope.
047	GSB9	
048	GSB1	
049	GSB7	
050	GSB1	
051	GTO6	
052	*LBL1	
053	4	
054	÷	
055	RCL4	
056	-	
057	6	
058	÷	
059	RCLI	
060	X²	
061	LSTX	
062	x	
063	x	
064	RCL1	
065	-	
066	X⇄Y	
067	2	
068	÷	
069	RCL0	
070	X²	
071	*LBL5	
072	x	
073	+	
074	RCLE	
075	÷	
076	RTN	
077	*LBLC	Calculate M_x.
078	GSB9	
079	GSB1	
080	GSB7	
081	GSB1	
082	GTO6	
083	*LBL1	
084	6	
085	÷	
086	RCL4	
087	2	
088	÷	
089	-	
090	RCLI	
091	X²	
092	x	
093	X⇄Y	
094	RCL0	
095	x	
096	+	
097	RTN	
098	*LBLD	Calculate V.
099	GSB9	
100	GSB1	
101	GSB7	
102	GSB1	
103	*LBL6	Sum loading effect and stop for display.
104	CHS	
105	P⇄S	
106	RCL0	
107	P⇄S	
108	+	
109	R/S	
110	*LBL1	
111	2	
112	÷	

REGISTERS

0	1	2	3	4	5	6	7	8	9
x	$-\theta_0$	ℓ		w_d or w_e					

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
Sum	w_e	e	w_d	d					

A	B	C	D	E	I
	w_ℓ		d or e	EI	(x − d) or 0

Step	Key	Comment
113	RCL4	
114	-	
115	RCLI	
116	x	
117	+	
118	RTN	
119	*LBL5	------------
120	STO0	Store x and calculate w_ℓ.
121	RCL2	
122	P⇄S	
123	RCL2	
124	-	
125	RCL1	
126	RCL3	
127	-	
128	x	
129	RCL2	
130	RCL4	
131	-	
132	÷	
133	RCL1	
134	+	
135	STOB	
136	RCL4	Put d and w_d in stack.
137	RCL3	
138	GTO8	
139	*LBL7	------------
140	P⇄S	Store sum and put e and
141	STO0	w_e in stack.
142	RCL2	
143	RCL1	
144	*LBL8	------------
145	P⇄S	(x – d)
146	STO4	If (x – d) is greater than 0,
147	R↓	(x – d) → I, otherwise 0 → I.
148	STOD	
149	RCL0	
150	-	
151	CHS	
152	X<0?	
153	CLX	
154	STOI	------------
155	RCLD	Calculate R_0 in stack and
156	STO1	$-\theta$ in R_1.
157	3	
158	ST×1	
159	RCL2	
160	ST+1	
161	x	
162	+	
163	RCL4	
164	8	
165	÷	
166	ST×1	
167	x	
168	RCL2	
169	ENT↑	
170	+	
171	RCLD	
172	3	
173	x	
174	+	
175	RCLB	
176	RCL4	
177	-	
178	4	
179	0	
180	÷	
181	x	
182	ST+1	
183	CLX	
184	LSTX	
185	RCL2	
186	4	
187	x	
188	RCLD	
189	+	
190	x	
191	+	
192	RCL2	
193	ST÷1	
194	÷	
195	LSTX	
196	X^2	
197	÷	
198	6	
199	ST÷1	
200	R↓	
201	RCL2	
202	RCLD	
203	-	
204	X^2	
205	LSTX	
206	x	
207	ST×1	
208	x	
209	RCL4	------------
210	RCLB	Calculate
211	-	$\frac{(w_d \text{ or } w_e - w_\ell)\,I}{(\ell - d)}$
212	RCL2	
213	RCLD	
214	-	
215	X=0?	
216	GTO6	
217	÷	
218	RCLI	
219	x	
220	RTN	

LABELS

A $x \rightarrow y$	B $x \rightarrow \theta$	C $x \rightarrow M_x$	D $x \rightarrow V$	E
a	b I↑E↑ℓ	c $d\uparrow w_d \uparrow e \uparrow w_e$	d	e
0	1	2	3	4
5 ÷ EI	6 Sum	7 e, w_e	8 R_0, θ_0	9 d, w_d

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

SIX-SPAN CONTINUOUS BEAMS

Key	Comments
*LBLa	Clear registers.
CLRG	
P⇄S	
CLRG	
6	If N is greater than 6, give error.
X⇄Y	
X>Y?	
GTO9	
4	Calculate 4N + .04N and store in I.
.	
0	
4	
x	
STOI	
CLX	
RTN	
*LBLA	Store M_0.
STOi	
DSZI	
RTN	
*LBLb	Check for error of slope duplicate on last section.
RCLI	
INT	
3	
X=Y?	
GTO9	
ISZI	Recall last slope factor difference and reset index.
ISZI	
ISZI	
ISZI	
RCLi	
0	
DSZI	
DSZI	
DSZI	
DSZI	Store difference.
GSBB	
GTOc	Duplicate I, E, ℓ.
*LBLB	
-	Calculate and store differ- in slope at support.
STOi	
DSZI	
RTN	
*LBLc	Recall last IE product and ℓ.
ISZI	
ISZI	
ISZI	
1	
RCLi	
ISZI	
RCLi	Reset index.
DSZI	
DSZI	
DSZI	
DSZI	
*LBLC	
STOi	Store ℓ and EI.
DSZI	
R↓	
x	
STOi	
DSZI	
DSZI	
*LBL0	Compute span number for display and check to make sure index does not equal 3. If it does, make it 2.
RCLI	
ENT↑	
FRC	
EEX	
2	
x	
X⇄Y	
INT	
3	
X=Y?	
DSZI	
R↓	
-	
4	
÷	
INT	
RTN	
*LBLD	Store M_N and set index to begin span.
CF2	
CHS	
STO0	
RCLI	
FRC	
1	
0	
1	
x	
STOI	
*LBL8	Evaluate individual intermediate moments.
CF1	
RCLi	
2	
÷	
DSZI	
RCLi	
X⇄Y	
DSZI	
RCLi	
DSZI	
RCLi	
÷	
3	
÷	
STO3	
x	
-	
DSZI	
DSZI	

REGISTERS

0	1	2	3	4	5	6	7	8	9
M_N	EI_N	ℓ_N	inter. mom.	M_N	EI_{N-1}	ℓ_{N-1}	$(\theta - \theta')$	M_{N-1}	EI_{N-2}

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
ℓ_{N-2}	$(\theta - \theta')$	M_{N-2}	EI_{N-3}	ℓ_{N-3}	etc ...	...	...	...	...

A	B	C	D	E	I
...	...	...	...	...	Control

Step	Key	Comment
113	DSZI	
114	RCL i	
115	DSZI	
116	RCL i	
117	÷	
118	3	
119	÷	
120	ST+i	
121	DSZI	
122	SF1	
123	RCL i	
124	x	
125	2	
126	÷	
127	-	
128	RCL3	
129	÷	
130	ISZI	
131	ISZI	
132	ISZI	Check new moment against old moment to see if change has occurred.
133	ISZI	
134	RCL i	
135	RND	
136	X⇄Y	
137	STO i	
138	RND	
139	X≠Y?	
140	SF2	
141	F1?	More spans?
142	GTO8	
143	RCLI	Reset index for next cycle or data output.
144	FRC	
145	1	
146	0	
147	1	
148	x	
149	STOI	
150	F2?	Another cycle?
151	GTO8	
152	RCL i	Output moments.
153	*LBL4	
154	SPC	
155	PRTX	
156	DSZI	
157	DSZI	
158	DSZI	
159	DSZI	
160	GTO8	
161	RCL i	
162	CHS	
163	PRTX	
164	RTN	
165	*LBL0	
166	RCL i	
167	CHS	
168	PRTX	
169	CHS	
170	GTO4	
171	*LBLd	Reset input index for a particular span.
172	ENT↑	
173	ENT↑	
174	RCLI	
175	FRC	
176	EEX	
177	2	
178	x	
179	4	
180	÷	
181	X=Y?	
182	GTO0	
183	R↓	
184	1	
185	X=Y?	
186	GTO1	
187	R↓	
188	4	
189	x	
190	1	
191	-	For intermediate spans.
192	RCLI	
193	FRC	
194	+	
195	STOI	
196	R↑	
197	RTN	
198	*LBL0	
199	RCLI	For span N.
200	FRC	
201	2	
202	+	
203	STOI	
204	R↑	
205	RTN	
206	*LBL1	
207	RCLI	For span 1.
208	FRC	
209	1	
210	0	
211	1	
212	x	
213	STOI	
214	R↑	
215	RTN	

LABELS

A M_0	B $\theta_n \uparrow \theta_n'$	C I↑E↑ℓ	D $M_N \rightarrow M_0, M_1 ...$	E
a N	b Dup. all	c Dup. I, E, ℓ	d Set n	e
0 Used	1 span 1	2	3	4 Output
5	6	7	8 Loop	9 Error

FLAGS

0	
1	next span?
2	Output?
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n 3	

STEEL COLUMN FORMULA

Step	Key	Comment
001	*LBLa	
002	STO9	Store yield point stress in N/m² and store other SI constants.
003	2	
004	0	
005	7	
006	EEX	
007	9	
008	X⇄Y	
009	÷	
010	Pi	
011	X²	
012	×	
013	ENT↑	
014	+	
015	√X	
016	STOC	
017	1	
018	0	
019	2	
020	7	
021	3	
022	EEX	
023	8	
024	STO7	
025	CLX	
026	RTN	
027	*LBLb	Store yield point stress in psi and store other English constants.
028	STO9	
029	3	
030	0	
031	EEX	
032	6	
033	X⇄Y	
034	÷	
035	Pi	
036	X²	
037	×	
038	ENT↑	
039	+	
040	√X	
041	STOC	
042	1	
043	4	
044	9	
045	EEX	
046	6	
047	STO7	
048	CLX	
049	RTN	
050	*LBLA	Store area.
051	STOA	
052	RTN	
053	*LBLB	Store length.
054	STOD	
055	RTN	
056	*LBLC	
057	CF0	Clear I flag and store k.
058	STOE	
059	RTN	
060	*LBLD	Calculate P_{allow}.
061	CF1	
062	RCLD	
063	RCLE	
064	F0?	
065	GSB8	
066	÷	
067	STO8	
068	RCLC	
069	X>Y?	
070	GTO1	
071	X⇄Y	
072	2	
073	0	
074	0	
075	X⇄Y	
076	X>Y?	
077	GTO5	
078	SF1	
079	*LBL1	
080	3	
081	RCL8	
082	RCLC	
083	÷	
084	X²	
085	STO8	
086	LSTX	
087	R↓	
088	-	
089	R↑	
090	×	
091	8	
092	÷	
093	5	
094	ENT↑	
095	3	
096	÷	
097	+	
098	STO6	
099	F1?	
100	GTO0	
101	RCL9	
102	X⇄Y	
103	÷	
104	1	
105	RCL8	
106	2	
107	÷	
108	-	
109	×	
110	GTO7	
111	*LBL0	
112	RCL7	

REGISTERS

0	1	2	3	4	5	6	7	8	9
						m	constant	(ℓ/K), "	Used

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
A		C	I	k or I	

113 RCLD 114 RCLE 115 ÷ 116 X² 117 ÷ 118 *LBL7 119 RCLA 120 x 121 RTN			
122 *LBLE 123 GSBD 124 RCL6 125 x 126 RTN	Calculate P_{max}.		
127 *LBL8 128 CF0 129 RCLA 130 ÷ 131 √X 132 STOE 133 RTN	Convert I to k.		
134 *LBLc 135 SF0 136 STOE 137 RTN	Set I flag and store I.		

LABELS					FLAGS	SET STATUS		
A A	B ℓ	C k	D →P_{allow}	E →P_{max}	0 I input?	FLAGS	TRIG	DISP
a σ_y (N/m²)	b σ_y (psi)	c	d	e	1 C < ℓ/k	ON OFF 0 ☐ ☒ 1 ☐ ☒ 2 ☐ ☒ 3 ☐ ☒	DEG ☒ GRAD ☐ RAD ☐	FIX ☐ SCI ☐ ENG ☒ n 3
0 C < ℓ/k	1 m	2	3	4	2			
5 Error	6	7 A x P/A	8 I → k	9	3			

REINFORCED CONCRETE BEAMS

Step	Key	Comments
001	*LBLe	
002	6	
003	GTO0	Input values and store
004	*LBLA	control code.
005	1	
006	GTO0	
007	*LBLB	
008	2	
009	GTO0	
010	*LBLC	
011	3	
012	GTO0	
013	*LBLD	
014	4	
015	GTO0	
016	*LBLE	
017	5	
018	*LBL0	
019	STOI	
020	R↓	
021	STOi	
022	F3?	
023	RTN	------------
024	1	
025	STOi	Calculate for all inter-
026	.	changeable solutions.
027	5	
028	9	
029	RCL5	
030	RCL2	
031	×	
032	÷	
033	RCL1	
034	RCL6	
035	×	
036	×	
037	LSTX	
038	.	
039	9	
040	×	
041	×	
042	LSTX	
043	RCL4	
044	×	
045	GTOi	------------
046	*LBL1	Solve for A_s and f_y.
047	*LBL6	
048	CHS	
049	ENT↑	
050	R↓	
051	X⇄Y	
052	R↑	
053	X²	
054	X⇄Y	
055	STO0	
056	4	
057	×	
058	RCL3	
059	×	
060	-	
061	√X	
062	+	
063	RCL0	
064	÷	
065	2	
066	÷	
067	CHS	
068	GTO0	
069	*LBL3	------------
070	X⇄Y	Compute M.
071	-	
072	GTO0	------------
073	*LBL2	Compute b and f_c.
074	*LBL5	
075	RCL3	
076	-	
077	÷	
078	GTO0	
079	*LBL4	------------
080	X⇄Y	Compute d.
081	RCL3	
082	+	
083	X⇄Y	
084	÷	
085	*LBL8	------------
086	STOi	Store metric constants.
087	2	
088	6	
089	1	
090	STO9	
091	6	
092	1	
093	1	
094	7	
095	STO8	
096	1	
097	4	
098	.	
099	8	
100	6	
101	F0?	------------
102	GTO0	Store English constants if
103	4	flag 0 is not set.
104	EEX	
105	3	
106	STO9	
107	8	
108	7	
109	EEX	
110	3	
111	STO8	
112	2	

REGISTERS

0	1	2	3	4	5	6	7	8	9
Used	A_s	b	M	d	f_c	f_y	β_1	87000, 6117	4000, 281
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
					Control

Step	Key Entry	Comments
113	0	
114	0	
115	*LBL0	
116	RCL6	Check for minimum reinforcing.
117	÷	
118	RCL1	
119	RCL2	
120	RCL4	
121	x	
122	÷	
123	X>Y?	
124	GTO0	
125	R↓	
126	LSTX	Reinforcing below minimum. Display code.
127	x	
128	GSB8	
129	+	
130	RCL1	
131	1	
132	0	
133	.	
134	5	
135	*LBL7	
136	PSE	Pause loop.
137	GTO7	
138	*LBL0	Check for too much steel.
139	.	
140	8	
141	5	
142	RCL5	
143	RCL9	
144	-	
145	2	
146	EEX	
147	4	
148	x	
149	X<0?	
150	CLX	
151	-	
152	STO7	
153	.	
154	6	
155	3	
156	7	
157	5	
158	x	
159	RCL5	
160	x	
161	RCL6	
162	÷	
163	RCL8	
164	RCL6	
165	+	
166	÷	
167	RCL8	
168	x	

Step	Key Entry	Comments
169	X>Y?	
170	GTO0	
171	RCL2	Set display for too much steel code and GTO 7.
172	RCL4	
173	x	
174	x	
175	GSB8	
176	-	
177	RCL1	
178	1	
179	0	
180	.	
181	3	
182	2	
183	GTO7	
184	*LBL0	
185	RCLi	Output answer.
186	RTN	
187	*LBLa	Metric flag toggle.
188	F0?	
189	GTO0	
190	SF0	
191	1	
192	RTN	
193	*LBL0	
194	CF0	
195	0	
196	RTN	
197	*LBLb	Set a calculate flag.
198	SF2	
199	*LBLc	
200	RCL1	Calculate NA or a.
201	1	
202	.	
203	1	
204	8	$NA = \frac{1.18\, f_y\, A_s}{\beta_1\, f_c\, b}$
205	x	
206	RCL2	$a = \beta_1 NA$
207	÷	
208	RCL6	
209	x	
210	RCL5	
211	÷	
212	F2?	
213	RTN	
214	RCL7	
215	÷	
216	RTN	
217	*LBL8	Calculate small delta from A_s to correct for any rounding errors.
218	SF3	
219	EEX	
220	CHS	
221	4	
222	÷	
223	RTN	

LABELS

A A_s	B b	C M	D d	E f_c
a Met?	b →a	c →NA	d	e f_y
0 Used	1 A_s	2 b	3 M	4 d
5 f_c	6 f_y	7 code	8 delta	9

FLAGS

0	Metric
1	
2	a
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

BOLT TORQUE

Store f_t, $\cos\theta$, $\tan\alpha$, and intermediate result.

```
*LBLA
STO1
R↓
COS
STO2
R↓
TAN
STO3
RCL1
RCL2
÷
+
1
RCL1
RCL3
x
RCL2
÷
-
÷
STO1
CF3
CLX
RTN
```

Store diameters.

```
*LBLB
STO4
R↓
2
÷
STO5
R↓
2
÷
STO6
CF3
CLX
RTN
```

Store or calculate load.

```
*LBLC
STO7
F3?
RTN
RCL8
RCL1
RCL6
x
RCL4
RCL5
x
+
÷
STO7
RTN
```

Store or calculate torque.

```
*LBLD
STO8
F3?
RTN
RCL1
RCL6
x
RCL4
RCL5
x
+
RCL7
x
STO8
RTN
```

Calculate shear stress in bolt.

```
*LBLE
2
Pi
÷
X⇄Y
÷
LSTX
÷
8
LSTX
÷
RCL1
RCL6
x
RCL7
x
x
RCL7
→P
X⇄Y
R↓
x
CF3
RTN
```

REGISTERS

0	1 f, Used	2 $\cos\theta$	3 $\tan\alpha$	4 f_c	5 $D_c/2$	6 $D_m/2$	7 W	8 T	9 Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Notes

Appendix A
MAGNETIC CARD SYMBOLS AND CONVENTIONS

SYMBOL OR CONVENTION	INDICATED MEANING
White mnemonic: x [A]	White mnemonics are associated with the user-definable key they are above when the card is inserted in the calculator's window slot. In this case the value of x could be input by keying it in and pressing [A].
Gold mnemonic: y x [f] [E]	Gold mnemonics are similar to white mnemonics except that the gold [f] key must be pressed before the user-definable key. In this case y could be input by pressing [f] [E].
x ↑ y [A]	↑ is the symbol for [ENTER↑]. In this case [ENTER↑] is used to separate the input variables x and y. To input both x and y you would key in x, press [ENTER↑], key in y and press [A].
[x] [A]	The box around the variable x indicates input by pressing [STO] [A].
(x) [A]	Parentheses indicate an option. In this case, x is not a required input but could be input in special cases.
➔x [A]	➔ is the symbol for calculate. This indicates that you may calculate x by pressing key [A].
➔ x, y, z [A]	This indicates that x, y, and z are calculated by pressing [A] once. The values would be printed in x, y, z order.
➔ x; y; z [A]	The semi-colons indicate that after x has been calculated using [A], y and z may be calculated by pressing [R/S].
➔ "x," y [A]	The quote marks indicate that the x value will be "paused" or held in the display for one second. The pause will be followed by the display of y.
⇔ x [A]	The two-way arrow ⇔ indicates that x may be either output or input when the associated user-definable key is pressed. If numeric keys have been pressed between user-definable keys, x is stored. If numeric keys have not been pressed, the program will calculate x.

SYMBOL OR CONVENTION	INDICATED MEANING
P? A	The question mark indicates that this is a mode setting, while the mnemonic indicates the type of mode being set. In this case a print mode is controlled. Mode settings typically have a 1.00 or 0.00 indicator displayed after they are executed. If 1.00 is displayed, the mode is on. If 0.00 is displayed, it is off.
START A	The word START is an example of a command. The start function should be performed to begin or start a program. It is included when initialization is necessary.
DEL A	This special command indicates that the last value or set of values input may be deleted by pressing A.

Notes

Notes

Notes

HEWLETT PACKARD

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B C D E