HEWLETT hp PACKARD

1000 N.E. Circle Blvd., Corvallis, Oregon 97330

00097-90147

● B C D E

HEWLETT-PACKARD

HP-67/HP-97

Civil Engineering Pac I

VE6WT

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.

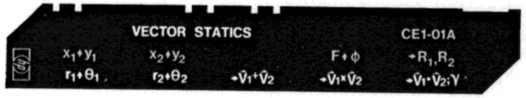
HP-97 users may also want to keep a permanent record of the values input to a certain program. A convenient way to do this is to set the Print Mode switch to NORMAL before running the program. In this mode all input values and their corresponding user-definable keys will be listed on the printer, thus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

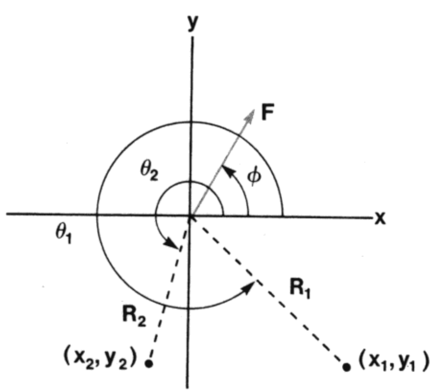
x_1 is the x component of $\vec{V}_1$ $(x_1 = r_1 \cos \theta_1)$;

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.

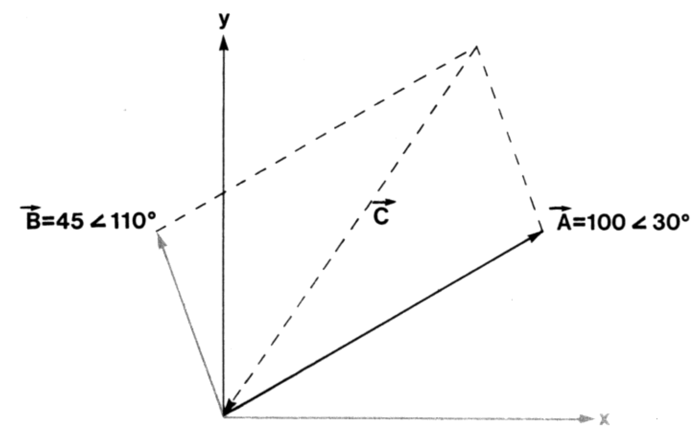
STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	To resolve a force in two			
	known directions, go to step 6.			
	For vector addition, cross			
	product, or dot product con-			
	tinue with step 3.			
3	Input $\vec{V}_1$ and $\vec{V}_2$:			
	$\vec{V}_1$ in polar 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:**

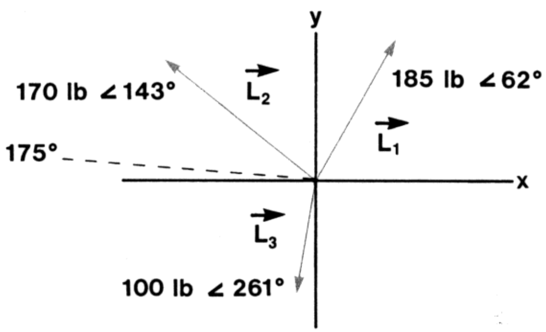
To obtain $\vec{C}$, add $\vec{A}$ and $\vec{B}$ using negative magnitudes for both.

45 CHS ENTER↑ 110 A 100 CHS
ENTER↑ 30 B C → 116.57 ***
−127.66 ***

$\vec{C} = 116.57\angle -127.66°$

Example 2:

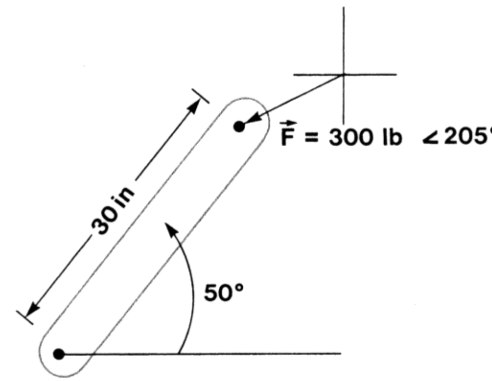
Resolve the following three loads along a 175 degree line.



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:

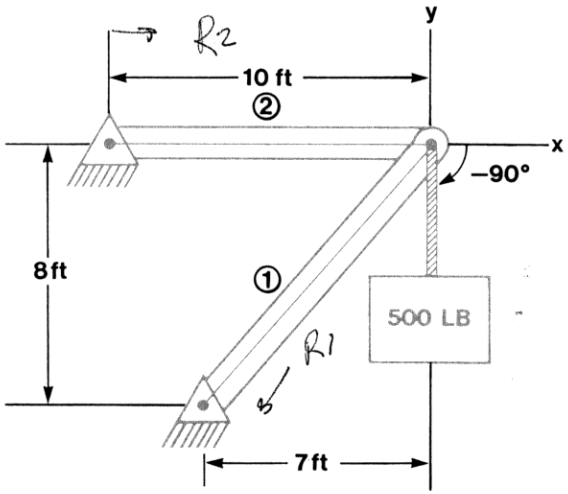
What is the moment at the shaft of the crank pictured below? What is the reaction force transmitted along the member?



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

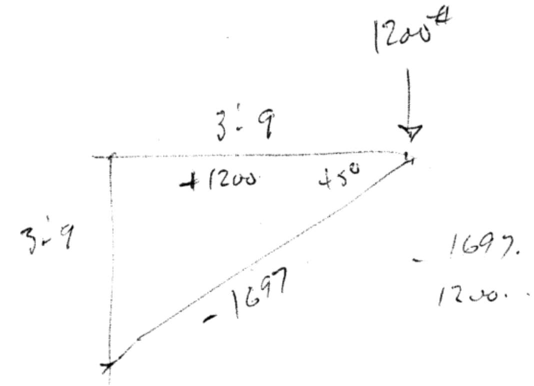
Example 4:

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

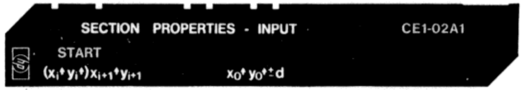


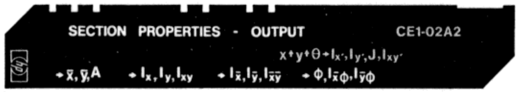
Keystrokes:	Outputs:
7 CHS ENTER↑ 8 CHS f A →	−8.00
10 CHS ENTER↑ 0 f B →	0.00
500 ENTER↑ 90 CHS f D →	−500.00
f E →	−664.38 *** (R_1)
	437.50 *** (R_2)

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.

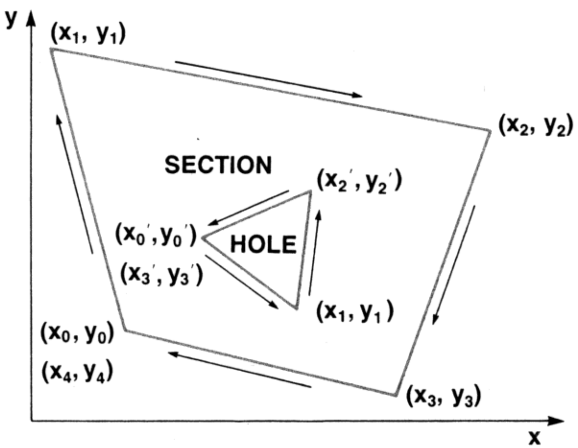


Figure 1 — Polygonal Sections

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:

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

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

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

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

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

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

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

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

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

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

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

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

$$J = I_x' + I_y'$$

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

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

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

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.

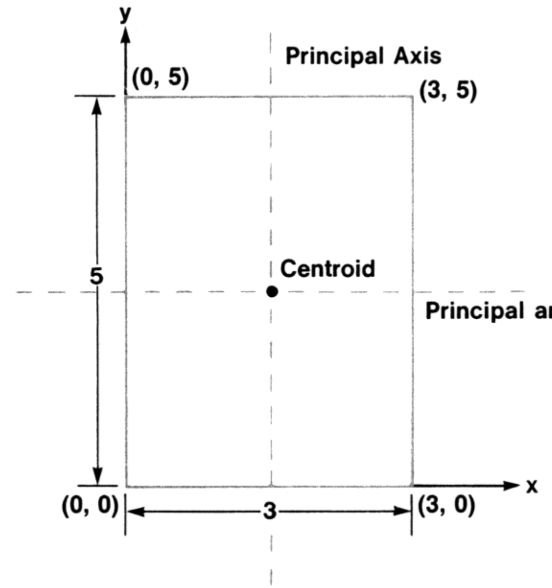
Curved boundaries may be approximated by straight line segments.

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	$I_{\bar{x}}$, $I_{\bar{y}}$, $I_{\bar{x}\bar{y}}$
	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 ($I_{\bar{x}\phi}$)?



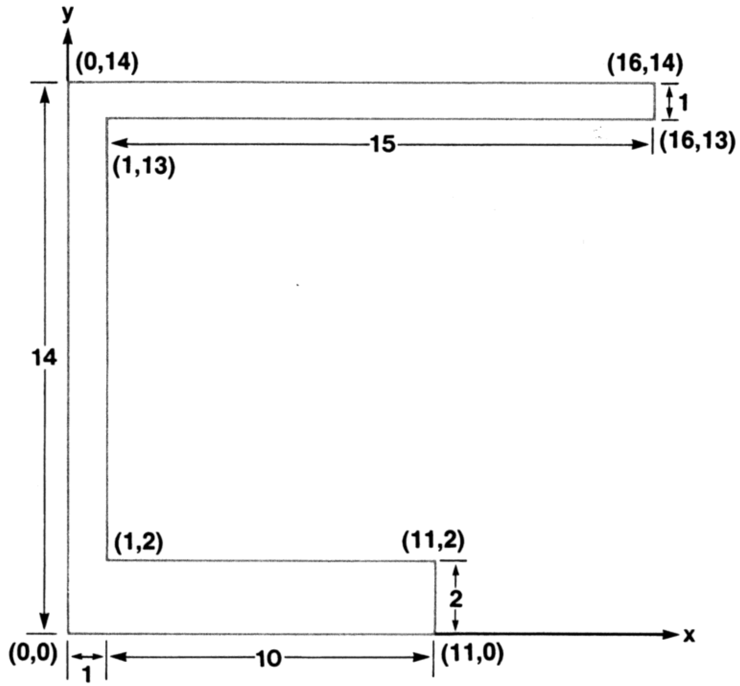
Keystrokes:	Outputs:
Load side 1 and side 2 of card 1.	
f A 0 ENTER↑ 0 ENTER↑	
0 ENTER↑ 5 A →	5.00
3 ENTER↑ 5 A →	5.00
3 ENTER↑ 0 A →	0.00
0 ENTER↑ 0 A →	0.00
Load side 1 and side 2 of card 2.	
B →	125.00 *** (I_x)
	45.00 *** (I_y)
	56.25 *** (I_{xy})
D →	0.00 *** (ϕ)
	31.25 *** ($I_{\bar{x}\phi}$)
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

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

Example 2:

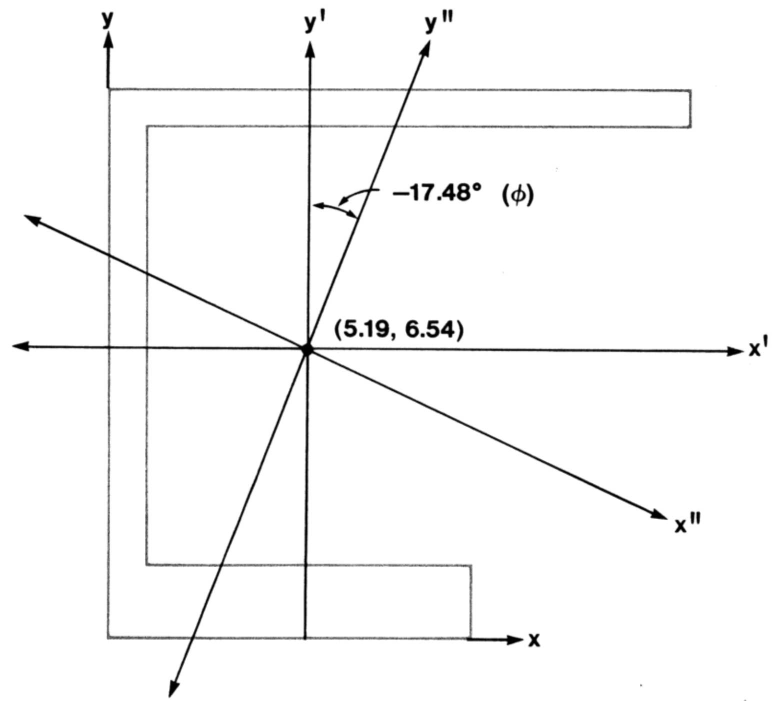
Calculate the section properties for the beam shown below.



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

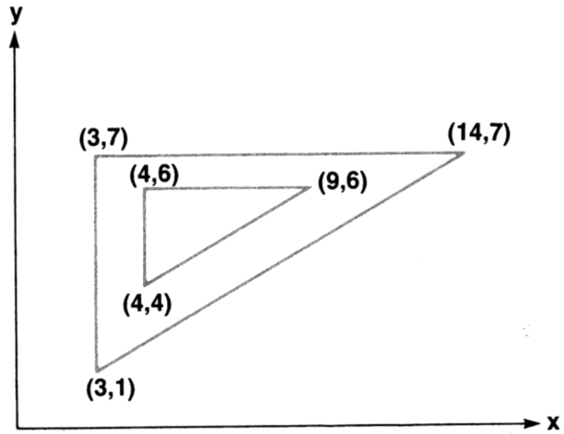
Keystrokes	Outputs
0 ENTER↑ 0 A →	0.00
Load side 1 and side 2 of card 2.	
A →	5.19 *** ($\bar{x}$)
	6.54 *** ($\bar{y}$)
	49.00 *** (A)
B →	3676.33 *** (I_x)
	2256.33 *** (I_y)
	1890.25 *** (I_{xy})
C →	1580.00 *** ($I_{\bar{x}}$)
	934.49 *** ($I_{\bar{y}}$)
	225.61 *** ($I_{\bar{x}\bar{y}}$)
D →	–17.48 *** (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:

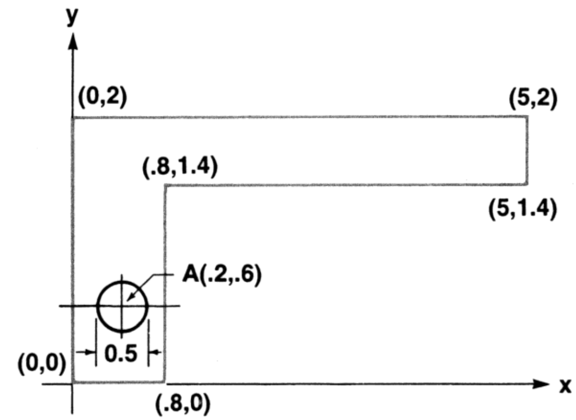
What is the centroid of the section below? The inner triangular boundary denotes an area to be deleted.



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)

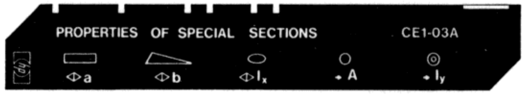
Example 4:

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.



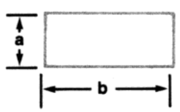
Keystrokes:	Outputs:
Load side 1 and side 2 of card 1.	
f A 0 ENTER↑ 0 ENTER↑ 0 ENTER↑	
2 A 5 ENTER↑ 2 A 5 ENTER↑	
1.4 A .8 ENTER↑ 1.4 A .8 ENTER↑	
0 A 0 ENTER↑ 0 A →	0.00
Delete the hole.	
.2 ENTER↑ .6 ENTER↑	
.5 CHS C →	0.00
Load side 1 and side 2 of card 2. Compute J about point (.2, .6) with θ of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

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.

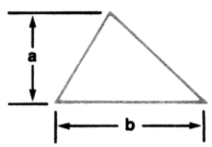
Sections and Equations:



$I_x = a^3b/12$

$I_y = ab^3/12$

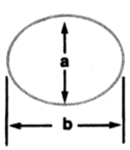
$A = ab$



$I_x = a^3b/36$

$I_y = ab^3/36$

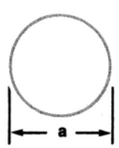
$A = ab/2$



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

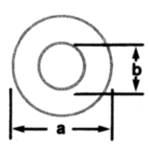
$I_y = \pi ab^3/64$

$A = \pi ab/4$



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

$A = \pi a^2/4$



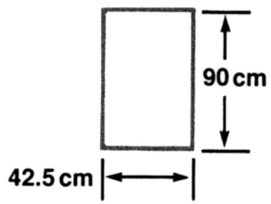
$$I_x = \frac{\pi(a^4 - b^4)}{64} = I_y$$

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

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:

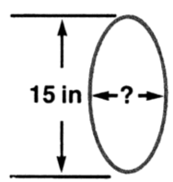
For the rectangular section below, what is the moment of inertia about the x axis? What is the moment of inertia about the y axis?



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:

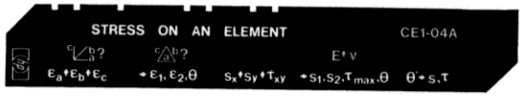
For the elliptical section below, what is the required value of b to make $I_x = 1000$? What is the area of the section?



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

Notes

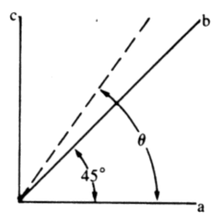
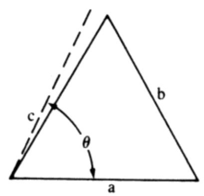
STRESS ON AN ELEMENT



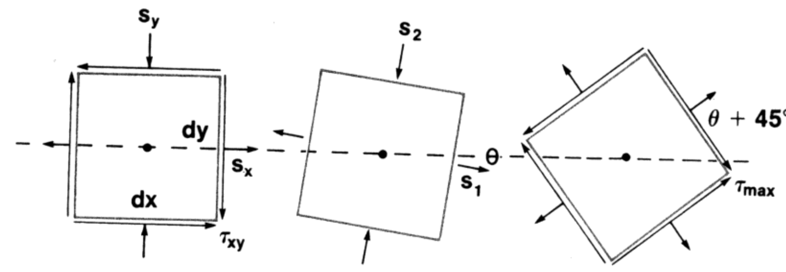
This program reduces data from rosette strain gage measurements and/or performs Mohr circle stress analysis calculations.

Correlations for rectangular and equiangular rosette configurations are included.

Strain Gage Equations:

CONFIGURATION CODE	1	2
TYPE OF ROSETTE	RECTANGULAR	DELTA (EQUIANGULAR)
		
PRINCIPAL STRAINS: ϵ_1, ϵ_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'.



Stress State　　Principal Stresses　　Maximum Shear Stress

Mohr Circle Equations:

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

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

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

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

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

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

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:

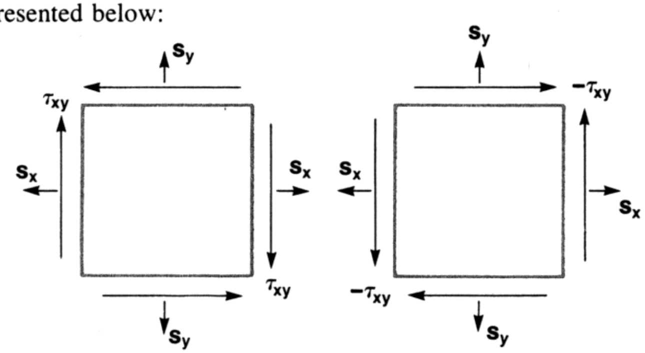
Spotts, M.F., *Design of Machine Elements,* Prentice-Hall, 1971.

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:

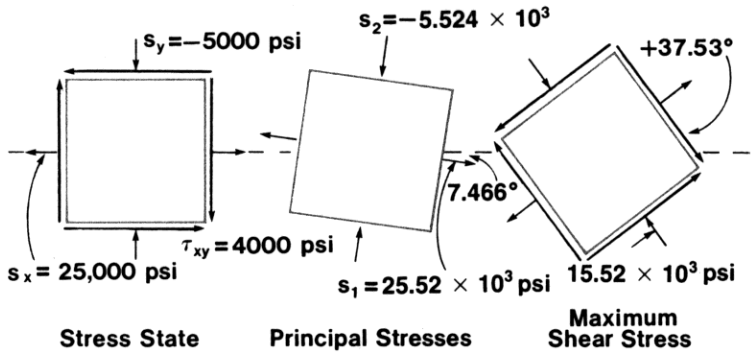


STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	If a stress configuration is			
	known, go to step 8 for Mohr			
	circle evaluation. Continue			
	with step 3 for strain gage			
	data reduction.			
3	Select strain gage			
	configuration:			
	Rectangular		f A	1.000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

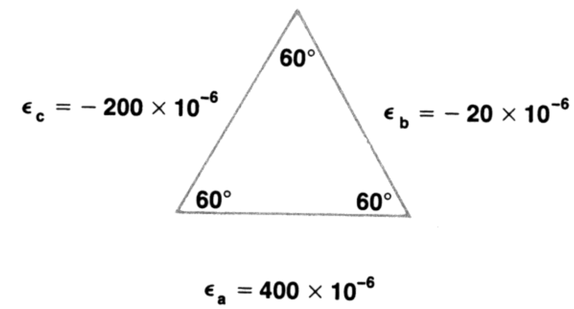
Keystrokes:	Outputs:
f A ⟶	1.000 00
30 EEX 6 ENTER↑ .3 f D ⟶	30.00 06
90 EEX CHS 6 ENTER↑ 137	
EEX CHS 6 ENTER↑ 305 EEX CHS	
6 A ⟶	90.00–06
B ⟶	320.9–06 *** (ϵ_1)
	74.14–06 *** (ϵ_2)
	14.69 00 *** (θ)
D ⟶	11.31 03 *** (s_1)
	5.618 03 *** (s_2)
	2.847 03 *** (τ_{max})
	14.69 00 *** (θ)

Example 3:

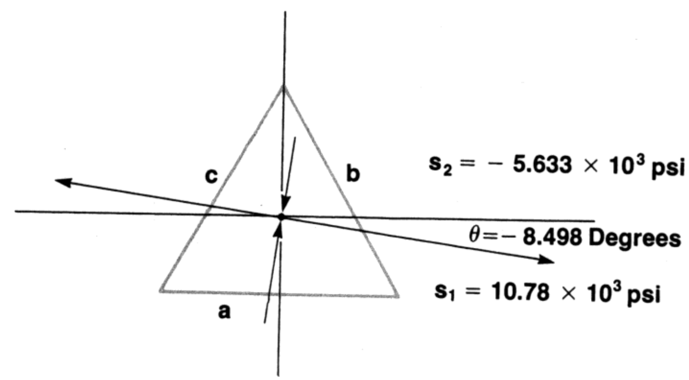
An equiangular rosette measures the strains below. What are the principal strains and stresses?

$E = 30 \times 10^6$ 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)

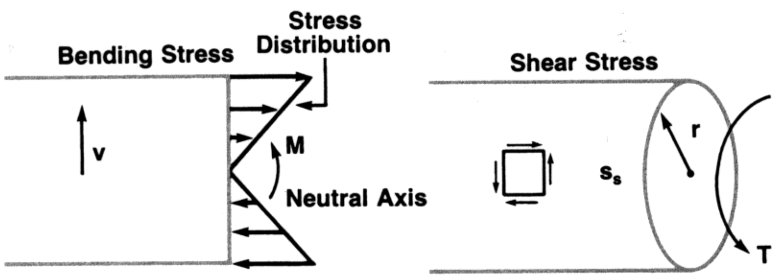


BENDING OR TORSIONAL STRESS

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 [x²] [x²] [π] [×] 32 [÷] →	1.571 00	in⁴ (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)

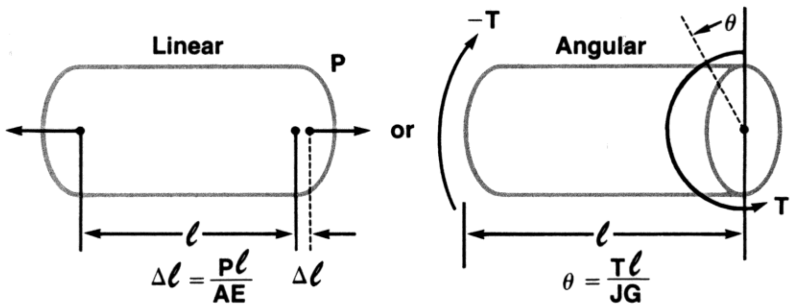
Notes

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:



$$\Delta\ell = \frac{P\ell}{AE} \qquad \theta = \frac{T\ell}{JG}$$

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/m²

Keystrokes:	Outputs:	
50000 [D] .001 [B] 10 [C]		
2.068 [EEX] 11 [E] [A] ⟶	2.418 −03	m²

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

.05 [x²] [A] [B] ⟶	967.1 −06	m

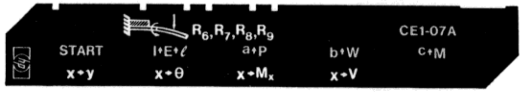
Example 2:

A 6 inch outside/5.5 inch inside diameter steel pipe (G = 11.5×10^6 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	in^4 (J)
[A] 15 [ENTER↑] 12 [×] [C] 11.5 [EEX]		
6 [E] 1 [D→R] [B] [D] ⟶	41.70 03	in-lb (T)

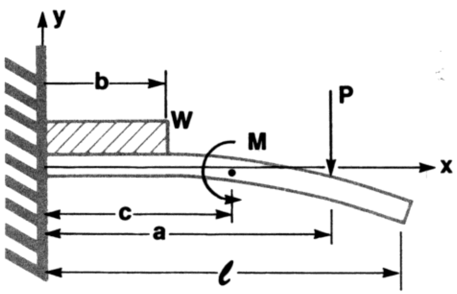
Notes

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:



$y = y_1 + y_2 + y_3$ (total deflection)

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

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

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

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

$\theta = \theta_1 + \theta_2 + \theta_3$ (total slope)

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

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

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

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

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

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

$M_{x3} = M\,(x \leq c)$ (applied moment)

$V = V_1 + V_2 + V_3$ (total shear)

$V_1 = P\,(x \leq a)$ (shear due to point load)

$V_2 = W\,(b - X_2)$ (distributed load)

$V_3 = 0$ (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 $x \leq a$ or a if $x > a$;
- $X_2 = x$ if $x \leq b$ or b if $x > b$
- $X_3 = x$ if $x \leq c$ 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	↻	+

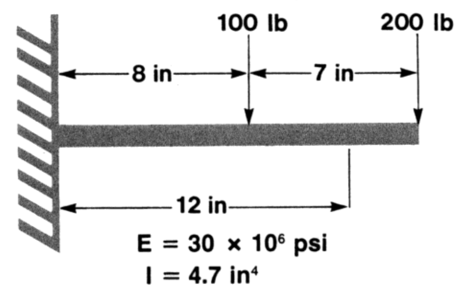
Sums of y, θ, M_x and V may be stored in R_6, R_7, R_8, and R_9, respectively. Note that these registers are indicated on the magnetic card.

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.



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:

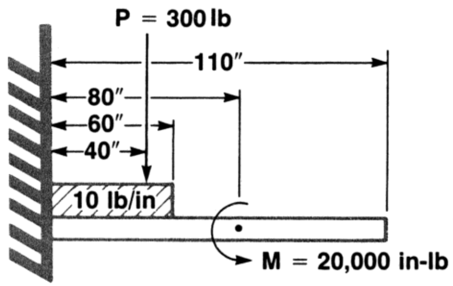
15 [ENTER↑] 200 [f] [C] 12 [A] ⟶ –1.123–03

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.

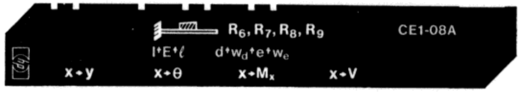


$I = 23 \text{ in}^4$
$E = 30 \times 10^6$ psi

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

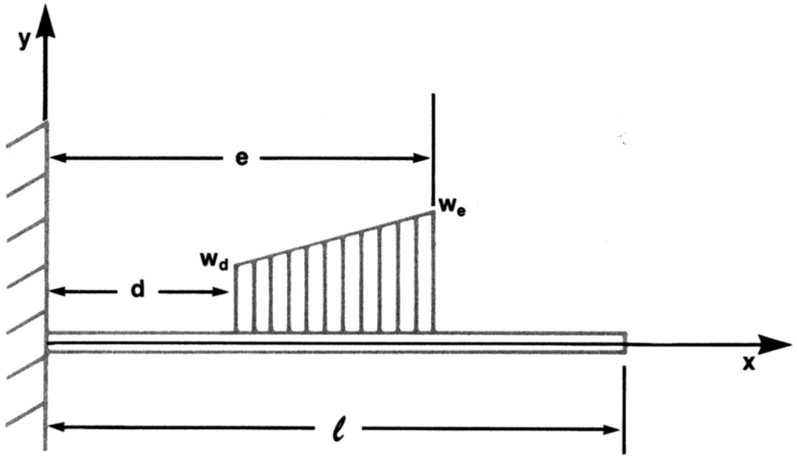
Notes

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 distrib-ted 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 $E = 30 \times 10^6$ psi $\ell = 75$ in $x = 40$ in

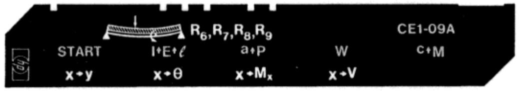
What is the deflection at $x = 55$?

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

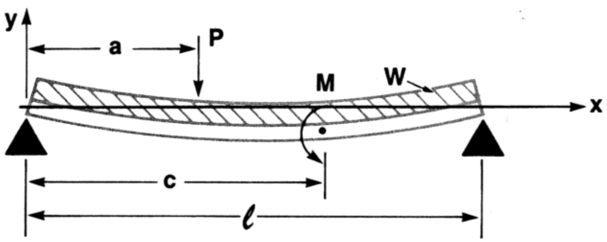
Notes

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:



$y = y_1 + y_2 + y_3$ (total deflection)

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

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

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

$\theta = \theta_1 + \theta_2 + \theta_3$ (total moment)

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

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

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

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

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

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

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

$V = V_1 + V_2 + V_3$ (total shear)

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

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

$V_3 = \frac{M}{\ell}$ (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.

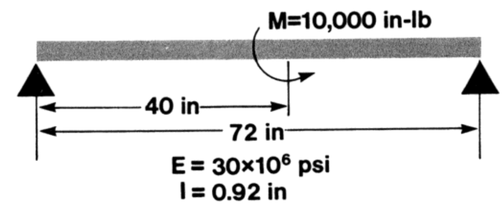
Registers R_{S0}–R_{S9} are available for user storage.

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:

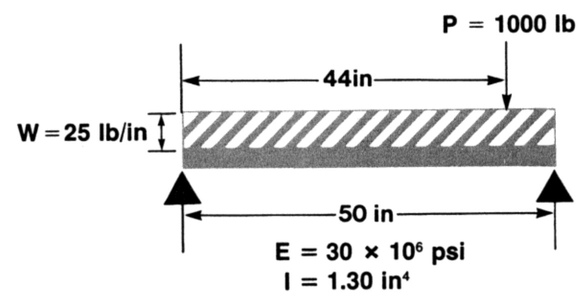
Find the deflection, slope, internal moment and shear at distances of 0, 24 and 60 inches for the beam below. Neglect the weight of the beam.



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:

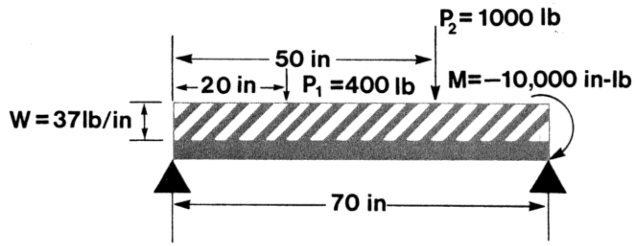
What is the slope of the beam below at x = 38 inches?



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.

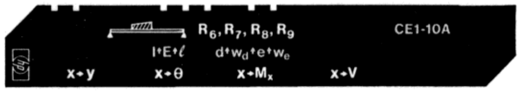
STO 6 →	21.66 03	(in-lb)

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.

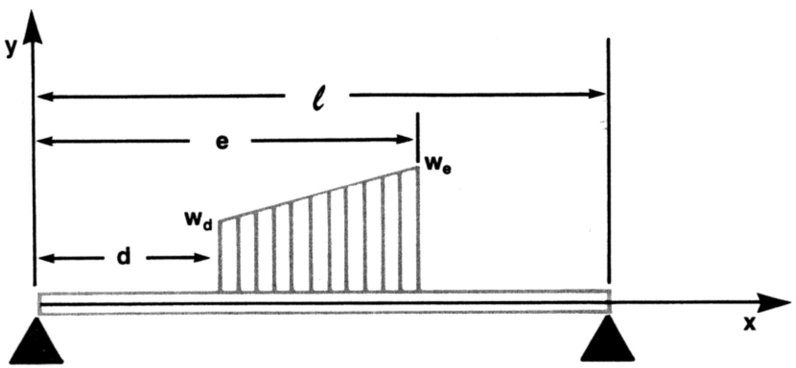
f A 50 ENTER↑ 1000 f C →	50.00 00	
35 C →	10.00 03	(in-lb)
RCL 6 + →	31.66 03	(in-lb)

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:

$$y = y_d - y_e$$

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

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

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

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

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

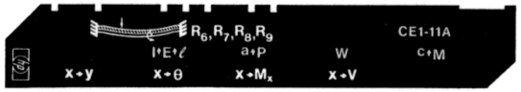
$I = 5$ in^4 $E = 30 \times 10^6$ psi $\ell = 75$ in $x = 55$ in

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

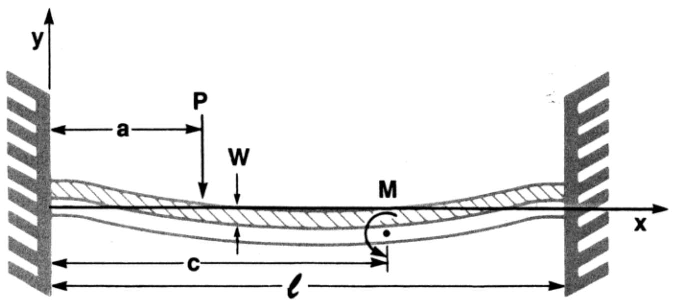
Notes

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:



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

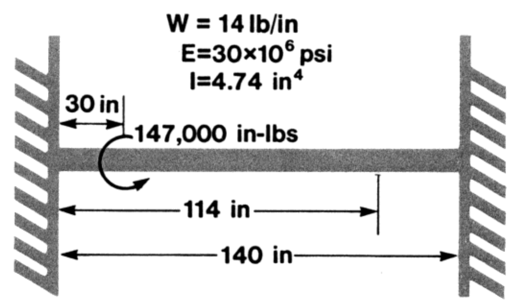
Sums of y, θ, M_x and V may be stored in R_6, R_7, R_8, R_9, respectively. Note that these registers are indicated on the magnetic card.

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:

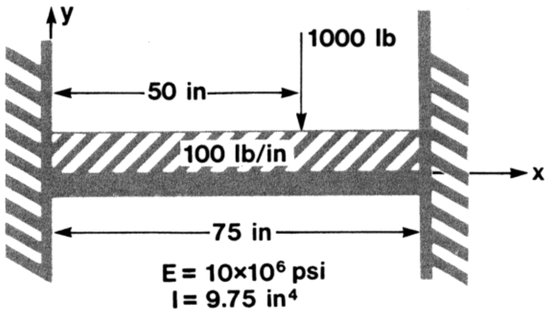
For the beam below, what are the values of deflection, slope, moment, and shear at an x of 114 inches?



Keystrokes:	**Outputs:**	
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.



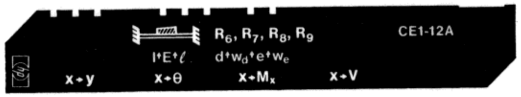
Keystrokes:	**Outputs:**
9.75 ENTER↑ 10 EEX 6 ENTER↑	
75 f B ⟶	97.50 06
0 f E 100 f D 50 ENTER↑	
1000 f C ⟶	50.00 00
0 C ⟶	–52.43 03 (M_0)

Also, find the deflection at x = 40.

40 A ⟶	–101.0 –03 (Y_{40})

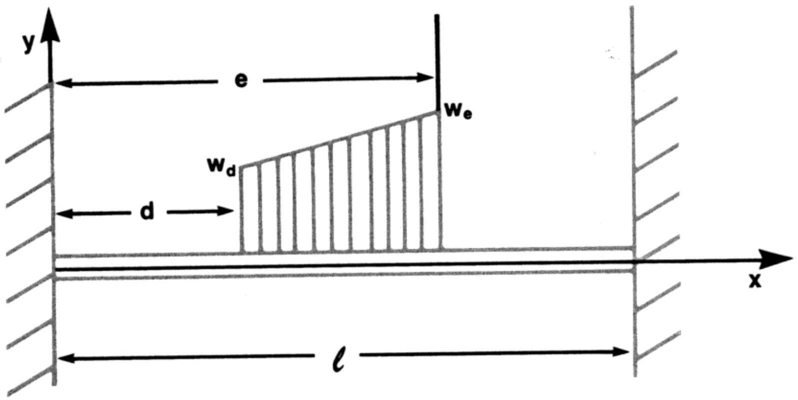
Notes

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:

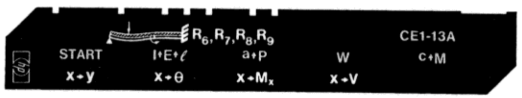
d = 23 inches	w_d = 35 lb/in	e = 47 inches	w_e = 27 lb/in
I = 5 in^4	E = 30 × 10^6 psi	ℓ = 75 in	x = 55 in

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

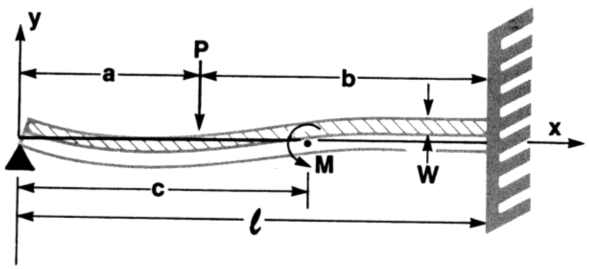
Notes

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:



$y = y_1 + y_2 + y_3$ (total deflection)

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

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

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

$y_3 = \frac{M}{EI} G(x^3 - 3\ell^2 x) + \ell x - ½\,(x^2 + c^2);\ x > c$

$\theta = \theta_1 + \theta_2 + \theta_3$ (total slope)

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

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

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

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

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

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

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

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

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

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

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

$V = V_1 + V_2 + V_3$ (total shear)

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

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

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

$V_3 = 6MG$ (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.

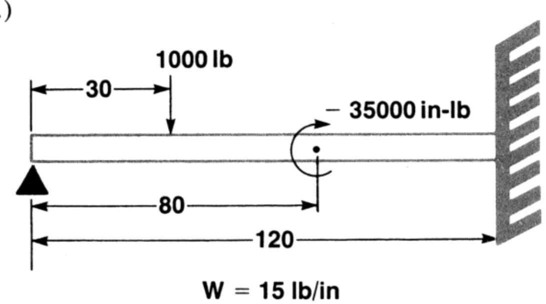
Sums of y, θ, M_X and V may be stored in R_6, R_7, R_8 and R_9, respectively. Note that those registers are indicated on the magnetic card.

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:

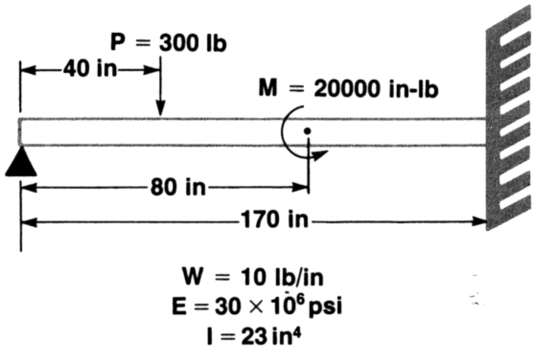
What are the values of moment and shear at both ends of the beam below? (It is not necessary to know the values of E or I since deflection and slope are not required.)



Keystrokes:	Outputs:	
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:

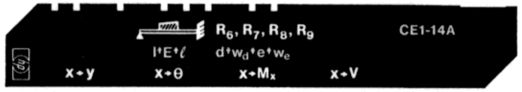
Calculate the deflection, slope, moment and shear at x = 90 for the beam below.



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)

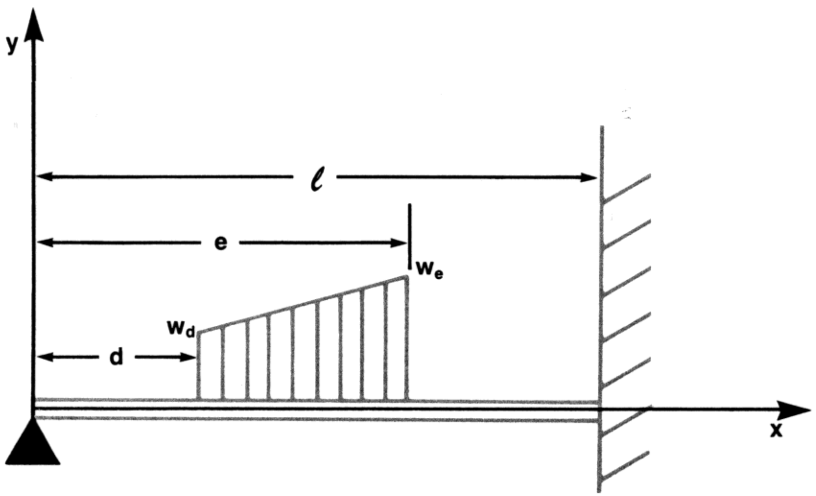
Notes

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:

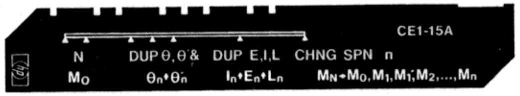
d = 23 inches	w_d = 35 lb/in	e = 47 inches	w_e = 27 lb/in
I = 5 in^4	E = 30 × 10^6 psi	ℓ = 75 in	x = 55 in

What is the deflection at x = 40?

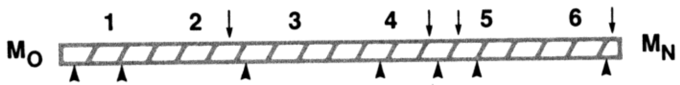
Keystrokes:	**Outputs:**
23 ENTER↑ 35 ENTER↑ 47 ENTER↑	
27 f C 5 ENTER↑ 30 EEX	
6 ENTER↑ 75 f B ⟶	150.0 06
55 A ⟶	–8.849–03
55 B ⟶	674.9–06
55 C ⟶	–336.0 00
55 D ⟶	–472.6 00
40 A ⟶	–17.47–03

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:

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

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:

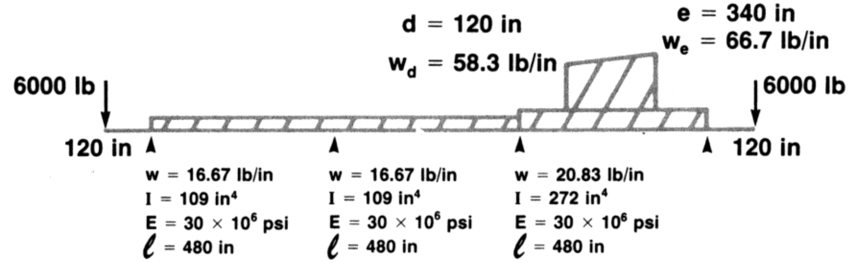
This program uses a trial and error procedure. It is possible that no answer would ever be found for some loadings.

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 ≤ n ≤ 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,...,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.			

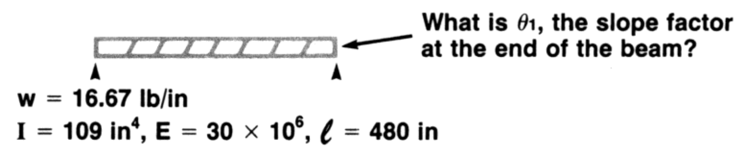
Example:



For the three span beam above, calculate th› 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

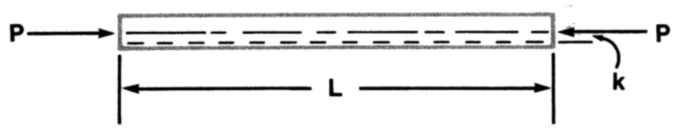
Span 3		
272 ENTER↑ 30 EEX 6 ENTER↑		
480 C ⟶	3.000 00	
720 CHS EEX 3 D ⟶	720.0 03	M_0
	-125.5 03	M_1
	125.5 03	M_1'
	-698.3 03	M_2
	698.3 03	M_2'
	-720.0 03	M_3

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.

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:



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

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

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

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

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

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.

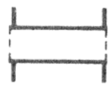
Remarks:

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/m^2)	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)

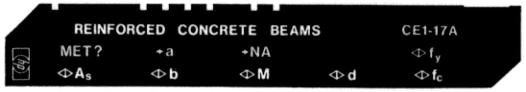
Example 2:

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)

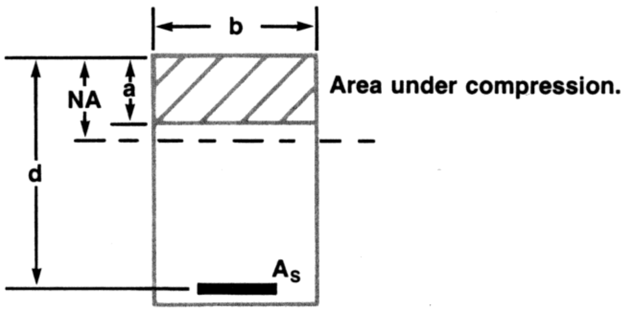
Notes

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

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

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.

$M = 1.2 \times 10^6$ 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 $M = 1.6 \times 10^6$ kg-cm $f_c = 281$ kg/cm²

$f_y = 4219$ kg/cm²

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?

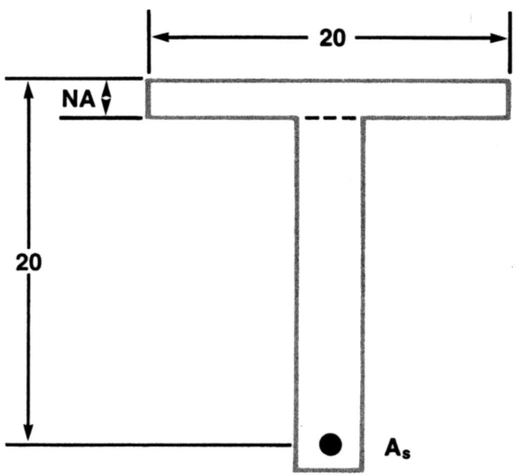
16 A D ⟶	32.01 00	cm

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

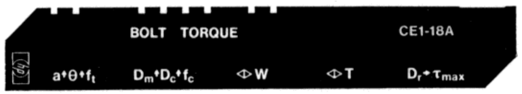
$f_y = 60{,}000$ psi



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 $\qquad f_c = 0.30$

$\alpha = 3.40°$ $\qquad D_c = 0.8750$

$f_t = 0.15$ $\qquad D_r = 0.2983$

$\theta = 30°$

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**

VECTOR STATICS

Convert from polar to rectangular.

```
001  *LBLA
002   X⇄Y
003    →R
004   X⇄Y
```

Store x, y components of $\vec{V}_1$.

```
005  *LBLa
006   STOB
007   X⇄Y
008   STOA
009   X⇄Y
010   RTN
```

Convert from polar to rectangular.

```
011  *LBLB
012   X⇄Y
013    →R
014   X⇄Y
```

Store x, y components of $\vec{V}_2$.

```
015  *LBLb
016   STOD
017   X⇄Y
018   STOC
019   X⇄Y
020   RTN
```

Store F cos ϕ and F sin ϕ.

```
021  *LBLd
022   X⇄Y
023    →R
024   STO8
025   X⇄Y
026   STO9
027   RTN
```

$\vec{V}_1 + \vec{V}_2$

```
028  *LBLC
029   SPC
030   RCLD
031   RCLB
032    +
033   RCLA
034   RCLC
035    +
036    →P
037   PRTX
038   X⇄Y
039   PRTX
040   RTN
```

$\vec{V}_1 \times \vec{V}_2$

```
041  *LBLD
042   SPC
043   RCLA
044   RCLD
045    x
046   RCLC
047   RCLB
048    x
049    -
050   PRTX
051   RTN
```

$\vec{V}_1 \cdot \vec{V}_2$

```
052  *LBLE
053   SPC
054   RCLA
055   RCLC
056    x
057   RCLB
058   RCLD
059    x
060    +
061   STOE
062   PRTX
063   RTN
```

Calculate angle between vectors.

```
064   RCLE
065   RCLA
066   RCLB
067    →P
068   X⇄Y
069   CLX
070   RCLC
071   RCLD
072    →P
073   X⇄Y
074    R↓
075    x
076    ÷
077   COS⁻¹
078   RCLE
079   X⇄Y
080   PRTX
081   RTN
```

Calculate R_1.

```
082  *LBLe
083   SPC
084   RCLB
085   RCLA
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    x
104    R↓
105    x
106    R↑
107    -
108   STOE
109   RCL8
110   RCL7
111    x
112   RCL9
113   RCL6
114    x
115    -
116   RCLE
117    ÷
118   PRTX
```

Calculate R_2.

```
119   RCL9
120   RCL4
121    x
122   RCL8
123   RCL5
124    x
125    -
126   RCLE
127    ÷
128   PRTX
129   RTN
```

REGISTERS

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

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	

LABELS

A	B	C	D	E
$r_1 \uparrow \theta_1$	$r_2 \uparrow \theta_2$	$\rightarrow \vec{V}_1 + \vec{V}_2$	$\rightarrow \vec{V}_1 \times \vec{V}_2$	$\rightarrow V_1 \cdot V_2 ; \gamma$
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

Clear registers.

```
001 *LBLa
002  CLRG
003   RTN
```

Store coordinates.

```
004 *LBLA
005  STOD
006    R↑
007  STOA
008    R↑
009  STOB
010    R↑
```

Sum ΔA.

```
011  STOC
012  RCLA
013     +
014  STO8
015  RCLD
016  RCLB
017     -
018  STO7
019     x
020     2
021     ÷
```

Sum ΔI_y.

```
022  ST-0
023     1
024     2
025     ÷
026  RCLC
027  RCLA
028     -
029  STO6
030    X²
031  RCL8
032  GSB4
```

Sum ΔI_x.

```
033  ST-4
034  RCL6
035  RCLB
036  RCLD
037     +
038  STO9
039     x
040     2
041     4
042     ÷
043  RCL9
044    X²
045  RCL7
046  GSB4
```

Sum ΔM_x.

```
047  ST+3
048  RCL6
049  RCL9
050  RCL7
051  GSB1
```

Sum ΔM_y.

```
052  ST+2
053  RCL7
054  RCL8
055  RCL6
056  GSB1
```

Sum ΔI_{xy}.

```
057  ST-1
058  RCLC
059  RCLB
060     x
061  RCLA
062  RCLD
063     x
064     -
065  ENT↑
066  ENT↑
067     4
068     ÷
069  RCL8
070     x
071  RCLA
072  RCLC
073     x
074  RCLC
075    X²
076  STO9
077     +
078  RCLA
079    X²
080  ST+9
081     +
082  RCL7
083     x
084     3
085     ÷
086     +
087     x
088  RCL9
089     8
090     ÷
091  RCL8
092     x
093  RCL7
094    X²
095     x
096     +
097  RCL6
098  X≠0?
099     ÷
100  ST+5
```

Recall x_i and y_i for next segment.

```
101  RCLC
102  RCLD
103   RTN
```

Calculate ΔM_x and ΔM_y.

```
104 *LBL1
105    X²
106     3
107     ÷
108   X⇄Y
109  GSB4
110     8
111     ÷
112   RTN
```

REGISTERS									
0 ΣA	1 ΣM_y	2 ΣM_x	3 ΣI_x	4 ΣI_y	5 ΣI_{xy}	6 $(x_{i+1} - x_i)$	7 $(y_{i+1} - y_i)$	8 $(x_{i+1} + x_i)$	9 $(y_{i+1} + y_i)$
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}		

Calculation subroutine.

```
113 *LBL4
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 $x_{i+1} \uparrow y_{i+1}$	B	C $x \uparrow y \uparrow \pm d$	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

(CARD 2)

Step	Key	Comments
001	*LBLA	Output $\bar{x}$, $\bar{y}$ and A.
002	GSB2	
003	PRTX	
004	X⇄Y	
005	PRTX	
006	RCL0	
007	PRTX	
008	RTN	
009	*LBL2	Calculate $\bar{x}$ and $\bar{y}$.
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$\bar{x}$, I$\bar{y}$ and I$\bar{x}\bar{y}$ 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	X^2	
053	RCL0	
054	×	
055	-	
056	STOD	
057	RCLA	
058	X^2	
059	RCL0	
060	×	
061	CHS	
062	RCL3	
063	+	
064	STOC	
065	-	
066	X≠0?	
067	÷	
068	TAN^{-1}	
069	RTN	
070	*LBLD	Calculate I$\bar{x}$, I$\bar{y}$, I$\bar{x}\bar{y}$ and output ϕ.
071	GSB3	
072	STOI	
073	2	
074	÷	
075	PRTX	
076	*LBL6	Rotate to principal axis values.
077	1	
078	→R	
079	X^2	
080	STOA	
081	RCLC	
082	×	
083	X⇄Y	
084	X^2	
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
$x_i, \bar{y}, \cos^2\phi$	$y_i, \bar{x}, \sin^2\phi$	x_{i+1}, I$\bar{y}$	y_{i+1}, I$\bar{y}$	I$\bar{x}\bar{y}$	2ϕ

Step	Key	Comments
113	STOD	
114	GSB2	
115	×	
116	RCL0	
117	×	
118	CHS	
119	RCL5	
120	+	
121	RCLD	
122	RCLB	
123	-	
124	RCLC	
125	RCLA	
126	-	
127	×	
128	RCL0	
129	×	
130	+	
131	STOE	
132	RCLC	
133	X^2	
134	RCLC	
135	RCLA	
136	×	
137	2	
138	×	
139	-	
140	RCL0	
141	×	
142	RCL3	
143	+	
144	STOC	
145	RCLD	
146	X^2	
147	RCLD	
148	RCLB	
149	×	
150	2	
151	×	
152	-	
153	RCL0	
154	×	
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	×	
172	RCLE	
173	RCLI	
174	COS	
175	×	
176	+	
177	PRTX	
178	RTN	

LABELS

A	B	C	D	E
→$\bar{x}$, $\bar{y}$, ϕ	→Ix,Iy,Ixy	→I$\bar{x}$,I$\bar{y}$,I$\bar{x}\bar{y}$	→I$\bar{x}\phi$I$\bar{y}\phi$I$\bar{x}\bar{y}\phi$	
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
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	2

PROPERTIES OF SPECIAL SECTIONS

Step	Key	Comments
001	*LBLa	
002	1	
003	GTO0	Rectangle Code.
004	*LBLb	
005	2	
006	GTO0	Triangle Code.
007	*LBLc	
008	3	
009	GTO0	Ellipse Code.
010	*LBLd	
011	4	
012	GTO0	Circle Code.
013	*LBLe	
014	5	
015	*LBL0	Concentric Circle Code.
016	STOI	Store Code.
017	RTN	
018	*LBLA	
019	STOA	Store a.
020	GTOi	
021	*LBL4	
022	0	
023	STOB	
024	X⇄Y	
025	*LBL1	
026	*LBL2	
027	*LBL3	
028	*LBL5	
029	F3?	
030	RTN	
031	RCLC	
032	RCLB	Calculate a for selected geometry.
033	X≠0?	
034	÷	
035	GTOi	
036	*LBL1	
037	1	
038	2	
039	GTO0	
040	*LBL2	
041	3	
042	6	
043	GTO0	
044	*LBL3	
045	Pi	
046	÷	
047	6	
048	4	
049	*LBL0	
050	x	
051	3	
052	1/X	
053	Y^x	
054	STOA	
055	RTN	
056	*LBL4	
057	*LBL5	
058	RCLC	
059	6	
060	4	
061	x	
062	Pi	
063	÷	
064	RCLB	
065	X²	
066	X²	
067	+	
068	√X	
069	√X	
070	STOA	
071	RTN	
072	*LBLB	Store b and check for circle geometry user error.
073	GTOi	
074	*LBL4	
075	RCLI	
076	SIN⁻¹	
077	*LBL1	
078	*LBL2	
079	*LBL3	
080	*LBL5	
081	STOB	
082	F3?	
083	RTN	
084	GTOi	Calculate for selected geometry.
085	*LBL1	
086	*LBL2	
087	*LBL3	
088	RCLC	
089	1	
090	2	
091	x	
092	RCLA	
093	X²	
094	LSTX	
095	x	
096	÷	
097	GSBi	
098	STOB	
099	RTN	
100	*LBL2	
101	3	
102	x	
103	*LBL1	
104	RTN	
105	*LBL3	
106	3	
107	÷	
108	1	
109	6	
110	x	
111	Pi	
112	÷	
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	
129	*LBLC	Store Ix.
130	STOC	
131	F3?	
132	RTN	
133	RCLB	Calculate Ix.
134	RCLA	
135	GSB9	
136	STOC	
137	RTN	
138	*LBLE	Calculate Ix or Iy.
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	
184	*LBLD	Calculate Area.
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	

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A a	B b	C I_x	D	E	I				

LABELS

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

STRESS ON AN ELEMENT

Step	Key	Comments
001	*LBLa	Store code: 1 = rectangular 2 = equiangular
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	Calculate ϵ_1 and ϵ_2.
020	RTN	
021	*LBLB	
022	RCLA	
023	GTO(i)	
024	*LBL2	
025	RCLB	
026	+	
027	*LBL1	
028	RCLC	
029	+	
030	STO6	
031	0	
032	GTO(i)	
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	GTO(i)	
052	*LBL2	
053	1	
054	+	
055	*LBL1	
056	ST÷5	
057	ST÷6	
058	GSB5	Calculate τ_{max} and $\frac{s_1 + s_2}{2}$ from strains.
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	GTO(i)	
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	
096	*LBL4	Output θ.
097	-	
098	GSB6	
099	R↓	
100	PRTX	
101	RTN	
102	*LBLC	Calculate τ_{max} and $(s_1 + s_2)/2$ from s_x, s_y and τ_{xy}.
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 2θ	3 s_x	4 $s_x - s_y$	5 τ_{max}	6 $(s_1 + s_2)/2$	7	8	9 ν
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A ϵ_a	B ϵ_b	C ϵ_c	D	E E	I 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	0	
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
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
a Rectangular	b Equiangular	c	d $E \uparrow \nu$	e	1
0 Store code	1 Rectangular	2 Equiangular	3	4 Output	2
5 Calc	6 θ	7	8	9	3

SET STATUS				
FLAGS	ON	OFF	TRIG	DISP
0		x	DEG x	FIX
1		x	GRAD	SCI
2		x	RAD	ENG x
3		x		n 3

BENDING OR TORSIONAL STRESS

Keystrokes	Comments
*LBLA 1 GTO0	s code.
*LBLB 2 GTO0	M code.
*LBLC 3 GTO0	v code.
*LBLD 4	I code.
*LBL0 STOI R↓ STOi F3? RTN	Store code and input and stop if input.
1 STOi RCL2 RCL3 x RCL4 ÷ RCL1 ÷ GTOi	Calculate result.
*LBL2 *LBL3 1/X	Reciprocate result to get M or v.
*LBL1 *LBL4 STOi RTN	Store result and stop.

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

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 STO: 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 A (J)	2 Δℓ (θ)	3 ℓ	4 P (T)	5 E (G)	6	7	8	9
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

```
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      Store P and a.
013  *LBLc
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      y1'
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      y2'
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' + y2'
082      -
083   RCLC
084   GSB4
085      6
086      x
087   RCL1
088      3
089      x
090    X⇄Y      y3'
091    F2?
092    CLX
093      +
094   RCL5
095      x
096   RCL1
097      x      y1' + y2' + y2'
098      +
099      6
100      ÷
101   RCLE      y
102      ÷
103    RTN
104  *LBLB
105   STO0
106   RCLA
107   GSB4
108   RCL1      θ1'
109      2
110      ÷
111   RCLA
112      -
```



```
113   RCL3
114      x
115   RCL1
116      x
117   RCLB
118   GSB4
119     R↓
120   RCL1
121      6      θ2'
122      ÷
123   RCLB
124      2
125      ÷
126      -
127   RCL1
128      x
129   RCLB
130     X²
131      2
132      ÷
133      +
134   RCL4
135      x
136   RCL1
137      x
138      -
139   RCLC
140   GSB4
141     R↓      θ3'
142   RCL5
143   RCL1
144      x
145      +
146   RCLE      θ1' + θ2' + θ3'
147      ÷
148    RTN      θ
149  *LBLC
150   STO0
151   RCLA      M1
152   GSB4
153   RCL1
154   RCLA
155      -
156   RCL3
157      x
158   RCLB
159   GSB4
160    CLX
161   RCL1      M2
162      2
163      ÷
164   RCLB
165      -
166   RCL1
167      x
168   RCLB
```

```
169     X²
170      2
171      ÷
172      +
173   RCL4
174      x
175      -      M1 + M2
176   RCLC
177   GSB4
178    CLX      M3
179   RCL5
180    X⇄Y
181    F2?
182      +      M1 + M2 + M3
183    RTN
184  *LBLD
185   STO0
186   RCLA      V1
187   GSB4
188      0
189    F2?
190   RCL3
191   RCLB
192   GSB4
193    CLX
194   RCL1
195   RCLB      V2
196      -
197   RCL4
198      x
199      -
200    RTN      V
201  *LBL4
202    CF2      Select smaller of x and a
203   RCL0      (or b or c) and store as
204   STO1      x'.
205    X⇄Y
206   X≤Y?
207   STO1
208   X>Y?      If x > a set flag.
209    SF2
210      -
211    RTN
```

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	

LABELS

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

FLAGS

Flag	
0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☐
SCI	☐
ENG	☒
n	3

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	1	
026	2	
027	0	
028	÷	
029	RCL4	
030	2	
031	4	
032	÷	
033	+	
034	RCLI	
035	X²	
036	X²	
037	x	
038	-	
039	RCL1	
040	RCL2	
041	RCL0	
042	-	
043	x	
044	+	
045	RCLE	
046	÷	
047	RTN	
048	*LBLB	Calculate slope.
049	GSB9	
050	GSB1	
051	GSB7	
052	GSB1	
053	GTO6	
054	*LBL1	
055	2	
056	4	
057	÷	
058	RCL4	
059	6	
060	÷	
061	+	
062	RCLI	
063	X²	
064	LSTX	
065	x	
066	x	
067	CHS	
068	RCL1	
069	+	
070	RCLE	
071	÷	
072	CHS	
073	RTN	
074	*LBLC	Calculate M_x.
075	GSB9	
076	GSB1	
077	GSB7	
078	GSB1	
079	GTO6	
080	*LBL1	
081	6	
082	÷	
083	RCL4	
084	2	
085	÷	
086	+	
087	RCLI	
088	X²	
089	x	
090	CHS	
091	RTN	
092	*LBLD	Calculate V.
093	GSB9	
094	GSB1	
095	GSB7	
096	GSB1	
097	*LBL6	Sum loading effect and stop for display.
098	CHS	
099	P⇄S	
100	RCL0	
101	P⇄S	
102	+	
103	R/S	
104	*LBL1	
105	2	
106	÷	
107	RCL4	
108	+	
109	RCLI	
110	x	
111	RTN	
112	*LBL9	

REGISTERS

0 x	1 θ_0	2 ℓ	3	4 w_d or w_e	5	6	7	8	9
S0 Sum	S1 w_e	S2 e	S3 w_d	S4 d	S5	S6	S7	S8	S9
A	B w_L	C	D d or e	E EI	I (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	x	
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	x	
161	RCLD	
162	-	
163	x	
164	LSTX	
165	RCL2	
166	-	
167	RCL4	
168	x	
169	2	
170	4	
171	÷	
172	+	
173	RCLD	
174	X²	
175	LSTX	
176	x	
177	ST×1	
178	x	
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	x	
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

```
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      x
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    Compute
033   RCL2
034   ENT↑    y2 (EI) or θ2 (EI).
035      x
036   LSTX
037      x
038   RCL0
039    F0?
040      4
041    F0?
042      x
043   RCL2
044      2
045      x
046    F0?
047      3
048    F0?
049      x
050      -
051   RCL0
052     X²
053      x
054      +
055   RCL4
056      x
057      2
058      4
059      ÷
060   RCL0
061    X⇄Y
062      x
063    F0?
064   LSTX
065    CHS
066   GSB1    ----------------
067   RCL1    Compute
068     X²      y1 (EI)
069    F0?      or
070      3      θ1 (EI).
071    F0?
072      x
073   RCLD
074     X²
075      +
076   RCL2
077     X²
078      -
079      x
080      6
081      ÷    ----------------
082   GSB2    Compute
083   RCL1      y3 (EI)
084     X²      or
085   RCL2      θ3 (EI).
086      ÷
087      6
088      ÷
089    F0?
090      3
091    F0?
092      x
093   RCL2
094      3
095      ÷
096      +
097   RCLD
098     X²
099      2
100      ÷
101   RCL2
102      ÷
103      +
104   RCLD
105      -
106      x
107   RCL2
108      x    ----------------
109   RCLI    y = y1 + y2 + y3
110      +      or
111   RCLE    θ = θ1 + θ2 + θ3
112      ÷
```

REGISTERS									
0 x	1 x,(x − ℓ)	2 ℓ	3 P	4 W	5 M	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A a	B	C c	D (ℓ−a), − a; c, ℓ−c	E EI	I SUM				


```
113    RTN    ----------------
114  *LBLD    Set derivative flag.
115    SF0
116   GTO0    ----------------
117  *LBLC    Clear derivative flag.
118    CF0    ----------------
119  *LBL0
120   STO0    Compute Mx2
121      2      or V2
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    Mx1 or V1
136   GSB2    Mx3 or V3
137   RCLI    M = Mx1 + Mx2 + Mx3
138      +      or
139    RTN    V = V1 + V2 + V3
140  *LBL1    ----------------
141   STOI    Store first results.
142   RCL2    Store ℓ − a
143   RCLA      and
144      -    x
145   STOD
146   RCL0    ----------------
147   STO1    If a > x GTO 0
148   RCLA
149   X>Y?
150   GTO0    ----------------
151   RCLA    Otherwise store −a for ℓ−a
152    CHS    and x−ℓ for x.
153   STOD
154   RCL2
155   ST−1    ----------------
156  *LBL0
157   RCL3    P(ℓ − a)/ℓ
158   RCLD
159      x
160   RCL2
161      ÷
162    F0?    ----------------
163    RTN    P(ℓ − a)x/ℓ
164   RCL1
165      x
166    RTN    ----------------
167  *LBL2    Add first result to second.
168   RCLI
169      +
170   STOI    ----------------
171   RCL0    Store x and c.
172   STO1
173   RCLC
174   STOD    ----------------
175   X>Y?    If c > x GTO 0.
176   GTO0    ----------------
177   RCL0    Otherwise store x − ℓ
178   RCL2    for x and ℓ−c for c.
179      -
180   STO1
181   RCL2
182   RCLC
183      -
184   STOD    ----------------
185  *LBL0
186   RCL5    M/ℓ
187   RCL2
188      ÷
189    F0?    ----------------
190    RTN
191   RCL1    Mx/ℓ
192      x    ----------------
193    RTN    Recall x.
              ----------------
```

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

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

SIMPLY SUPPORTED BEAMS—TRAPEZIODAL LOAD

Step	Key	Comments
001	*LBLa	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	RCL0	
038	X²	
039	RCL1	
040	×	
041	6	
042	÷	
043	+	
044	RCL0	
045	GTO5	
046	*LBLB	
047	GSB9	
048	GSB1	Calculate slope.
049	GSB7	
050	GSB1	
051	GTO6	
052	*LBL1	
053	4	
054	÷	
055	RCL4	
056	-	
057	6	
058	÷	
059	RCLI	
060	X²	
061	×	
062	RCLI	
063	×	
064	+	
065	RCL1	
066	2	
067	÷	
068	RCL0	
069	X²	
070	*LBL5	
071	×	
072	+	
073	RCLE	
074	÷	
075	RTN	
076	*LBLC	
077	GSB9	Calculate M_x.
078	GSB1	
079	GSB7	
080	GSB1	
081	GTO6	
082	*LBL1	
083	6	
084	÷	
085	RCL4	
086	2	
087	÷	
088	-	
089	RCLI	
090	X²	
091	×	
092	RCL1	
093	RCL0	
094	×	
095	+	
096	RTN	
097	*LBLD	
098	GSB9	Calculate V.
099	GSB1	
100	GSB7	
101	GSB1	
102	*LBL6	
103	CHS	Sum loading effect and stop for display.
104	P⇄S	
105	RCL0	
106	P⇄S	
107	+	
108	R/S	
109	*LBL1	
110	2	
111	÷	
112	RCL4	

REGISTERS

0 x	1 R_0	2 ℓ	3	4 w_d or w_e	5	6	7	8	9
S0 Sum	S1 w_e	S2 e	S3 w_d	S4 d	S5	S6	S7	S8	S9
A	B w_ℓ	C	D d or e	E EI	I (x − d) or 0				

Step	Key	Comments
113	-	
114	RCLI	
115	×	
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	×	
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 w_e in stack.
141	STO0	
142	RCL2	
143	RCL1	
144	*LBL8	
145	P⇄S	(x − d) If (x − d) is greater than 0, (x − d) → I, otherwise 0 → I.
146	STO4	
147	R↓	
148	STOD	
149	RCL0	
150	-	
151	CHS	
152	X<0?	
153	CLX	
154	STOI	
155	RCLB	Calculate slope in stack and R_0 in R_1.
156	RCL4	
157	-	
158	STO1	
159	3	
160	0	
161	÷	
162	3	
163	RCLD	
164	×	
165	6	
166	ST÷1	
167	RCL2	
168	×	
169	-	
170	RCLD	
171	×	
172	RCL2	
173	X²	
174	7	
175	×	
176	-	
177	×	
178	RCLD	
179	RCL2	
180	ENT↑	
181	+	
182	-	
183	RCLD	
184	×	
185	RCL2	
186	X²	
187	-	
188	RCL4	
189	2	
190	÷	
191	ST+1	
192	×	
193	+	
194	1	
195	2	
196	÷	
197	RCL2	
198	RCLD	
199	-	
200	X²	
201	RCL2	
202	÷	
203	ST×1	
204	×	
205	RCL4	Calculate $\frac{(w_d \text{ or } w_e - W_\ell)I}{(\ell - d)}$
206	RCLB	
207	-	
208	RCL2	
209	RCLD	
210	-	
211	X≠0?	
212	÷	
213	RCLI	
214	×	
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
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☐
SCI	☐
ENG	☒
n	3

BEAMS FIXED AT BOTH ENDS

001	*LBLd	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	
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	
097	GTO0	
098	*LBLC	Clear derivative flag and start M_2 calculation.
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

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

LABELS

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

FLAGS

0	Derivative
1	P
2	Sign
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

Store EI and ℓ.

```
*LBLb
STO2
R↓
x
STOE
RTN
```

Store w_e, e, w_d, and d.

```
*LBLc
P⇄S
STO1
R↓
STO2
R↓
STO3
R↓
STO4
P⇄S
RTN
```

Calculate y.

```
*LBLA
GSB9
GSB1
GSB7
GSB1
GTO6
*LBL1
5
÷
RCL4
-
2
4
÷
RCLI
X²
X²
x
X⇄Y
6
÷
RCL0
x
RCL1
2
÷
-
RCL0
X²
GTO5
```

Calculate slope.

```
*LBLB
GSB9
GSB1
GSB7
GSB1
GTO6
*LBL1
4
÷
RCL4
-
6
÷
RCLI
X²
LSTX
x
x
X⇄Y
RCL0
x
2
÷
RCL1
-
RCL0
*LBL5
x
+
RCLE
÷
RTN
```

Calculate M_x.

```
*LBLC
GSB9
GSB1
GSB7
GSB1
GTO6
*LBL1
6
÷
RCL4
2
÷
-
RCLI
X²
x
X⇄Y
RCL0
x
+
RCL1
-
RTN
```

Calculate V.

```
*LBLD
GSB9
GSB1
GSB7
GSB1
```

Sum loading effect and stop for display.

```
*LBL6
CHS
P⇄S
RCL0
P⇄S
+
R/S
```

```
*LBL1
2
÷
RCL4
-
RCLI
x
+
RTN
```

Store x and calculate $w_ℓ$.

```
*LBL9
STO0
RCL2
P⇄S
RCL2
-
RCL1
RCL3
-
x
RCL2
RCL4
-
÷
RCL1
+
STOB
RCL4
```

Put d and w_d in stack.

```
RCL3
GTO8
```

Store sum and put e and w_e in stack.

```
*LBL7
P⇄S
STO0
RCL2
RCL1
```

(x − d)
If (x − d) is greater than 0,
(x − d) → I, otherwise 0 → I.

```
*LBL8
P⇄S
STO4
R↓
STOD
RCL0
-
CHS
X<0?
CLX
STOI
```

Calculate R_0 in stack and $-M_0$ in R_1.

```
RCLD
STO1
ENT↑
+
3
ST×1
RCL2
ST+1
ST+1
x
+
RCLB
RCL4
-
ST×1
x
2
0
ST÷1
÷
RCLD
3
ST÷1
x
RCL2
+
RCL4
x
1
2
÷
ST+1
CLX
RCL2
RCLD
+
RCL4
x
2
÷
+
RCL2
RCLD
-
RCL2
ST×1
÷
X²
LSTX
x
ST×1
x
RCL4
RCLB
```

Calculate $\frac{(w_d \text{ or } w_e - w_ℓ)I}{(ℓ - d)}$

```
-
RCL2
RCLD
-
X≠0?
÷
RCLI
x
RTN
```

REGISTERS

0 x	1 $-M_0$	2 ℓ	3	4 w_d or w_e	5	6	7	8	9
S0 Sum	S1 w_e	S2 e	S3 w_d	S4 d	S5	S6	S7	S8	S9
A	B $w_ℓ$	C	D d or e	E EI	I (x − d) or 0				

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	Comments
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	*LBL0	
038	RCL0	Calculate 6 y_2 EI or $6\theta_2$ EI.
039	x	
040	RCL2	
041	÷	
042	-	
043	RCL0	
044	X^2	
045	x	
046	RCL2	
047	X^2	
048	-	
049	RCL2	
050	x	
051	GSB5	Calculate $6y_1$ EI or 6 θ_1 EI.
052	RCL0	
053	X^2	
054	F0?	
055	3	
056	F0?	
057	÷	
058	RCL2	
059	X^2	
060	-	
061	STOD	
062	x	
063	RCLI	
064	X^2	
065	+	
066	GSB4	
067	F2?	
068	GTO0	
069	RCL0	
070	RCLA	
071	-	
072	X^2	
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	X^2	
108	+	
109	F0?	
110	2	
111	F0?	
112	÷	

REGISTERS									
0 x	1 sum	2 ℓ	3 D	4 W	5 M	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A a	B	C c	D $(x^2/3 - \ell^2)$	E EI	I $(\ell - a)$; c				

Step	Key	Comments
113	GTO0	
114	*LBL6	
115	RCLC	
116	GSB4	
117	*LBL0	
118	-	
119	GSB8	
120	RCLE	$y = y_1 + y_2 + y_3$ or $\theta = \theta_1 + \theta_2 + \theta_3$
121	÷	
122	RTN	
123	*LBLD	Store x, clear integral flag, multiply by 2.
124	CF0	
125	STO0	
126	2	
127	x	
128	GTO0	
129	*LBLC	Store x, set integral flag.
130	SF0	
131	STO0	
132	*LBL6	
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	
169	RCL1	or $V = V_1 + V_2 + V_3$
170	RTN	
171	*LBL4	Multiply by x if integral flag is set.
172	F0?	
173	RCL0	
174	F0?	
175	x	
176	RTN	Finish y_2, θ_2, M_2 and V_2 calculations.
177	*LBL5	
178	RCL4	
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	X^2	
208	-	$\frac{\ell^2 - c^2}{4\ell^3}$ on
209	2	
210	F1?	
211	X^2	Second pass.
212	÷	
213	RCL2	
214	3	
215	Y^X	
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 Entry	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	÷	
113	RCL4	
114	-	
115	RCLI	
116	x	
117	+	
118	RTN	
119	*LBL9	Store x and calculate $w_ℓ$.
120	STO0	
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	Store sum and put e and w_e in stack.
140	P⇄S	
141	STO0	
142	RCL2	
143	RCL1	
144	*LBL8	(x − d) If (x − d) is greater than 0, (x − d) → I, otherwise 0 → I.
145	P⇄S	
146	STO4	
147	R↓	
148	STOD	
149	RCL0	
150	-	
151	CHS	
152	X<0?	
153	CLX	
154	STOI	
155	RCLD	Calculate R_0 in stack and −θ in R_1.
156	STO1	
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	8	
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	X²	
197	÷	
198	6	
199	ST÷1	
200	R↓	
201	RCL2	
202	RCLD	
203	-	
204	X²	
205	LSTX	
206	x	
207	ST×1	
208	x	
209	RCL4	Calculate $\frac{(w_d \text{ or } w_e - w_ℓ)\,I}{(ℓ - d)}$
210	RCLB	
211	-	
212	RCL2	
213	RCLD	
214	-	
215	X=0?	
216	GTO6	
217	÷	
218	RCLI	
219	x	
220	RTN	

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

LABELS

A	B	C	D	E
x → y	x → θ	x → M_x	x → V	

a	b	c	d	e
	I↑E↑ℓ	d↑w_d↑e↑w_e		

0	1	2	3	4

5	6	7	8	9
÷ EI	Sum	e, w_e	R_0, θ_0	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

Step	Key	Comment
001	*LBLa	Clear registers.
002	CLRG	
003	P⇄S	
004	CLRG	
005	6	If N is greater than 6, give error.
006	X⇄Y	
007	X>Y?	
008	GTO9	
009	4	Calculate 4N + .04N and store in I.
010	.	
011	0	
012	4	
013	x	
014	STOI	
015	CLX	
016	RTN	
017	*LBLA	Store M_0.
018	STOi	
019	DSZI	
020	RTN	
021	*LBLb	Check for error of slope duplicate on last section.
022	RCLI	
023	INT	
024	3	
025	X=Y?	
026	GTO9	
027	ISZI	Recall last slope factor difference and reset index.
028	ISZI	
029	ISZI	
030	ISZI	
031	RCLi	
032	0	
033	DSZI	
034	DSZI	
035	DSZI	
036	DSZI	Store difference.
037	GSBB	
038	GTOc	Duplicate I, E, ℓ.
039	*LBLB	
040	-	Calculate and store differ- in slope at support.
041	STOi	
042	DSZI	
043	RTN	
044	*LBLc	Recall last IE product and ℓ.
045	ISZI	
046	ISZI	
047	ISZI	
048	1	
049	RCLi	
050	ISZI	
051	RCLi	Reset index.
052	DSZI	
053	DSZI	
054	DSZI	
055	DSZI	
056	*LBLC	
057	STOi	Store ℓ and EI.
058	DSZI	
059	R↓	
060	x	
061	STOi	
062	DSZI	
063	DSZI	
064	*LBL0	Compute span number for display and check to make sure index does not equal 3. If it does, make it 2.
065	RCLI	
066	ENT↑	
067	FRC	
068	EEX	
069	2	
070	x	
071	X⇄Y	
072	INT	
073	3	
074	X=Y?	
075	DSZI	
076	R↓	
077	-	
078	4	
079	÷	
080	INT	
081	RTN	
082	*LBLD	Store M_N and set index to begin span.
083	CF2	
084	CHS	
085	STO6	
086	RCLI	
087	FRC	
088	1	
089	0	
090	1	
091	x	
092	STOI	
093	*LBL8	Evaluate individual intermediate moments.
094	CF1	
095	RCLi	
096	2	
097	÷	
098	DSZI	
099	RCLi	
100	X⇄Y	
101	DSZI	
102	RCLi	
103	DSZI	
104	RCLi	
105	÷	
106	3	
107	÷	
108	STO3	
109	x	
110	-	
111	DSZI	
112	DSZI	

REGISTERS

0 M_N	1 EI_N	2 ℓ_N	3 inter. mom.	4 M_N	5 EI_{N-1}	6 ℓ_{N-1}	7 $(\theta - \theta')$	8 M_{N-1}	9 EI_{N-2}
S0 ℓ_{N-2}	S1 $(\theta - \theta')$	S2 M_{N-2}	S3 EI_{N-3}	S4 ℓ_{N-3}	S5 etc ...	S6 ...	S7 ...	S8 ...	S9 ...

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

Step	Key	Comment
113	DSZI	
114	RCLi	
115	DSZI	
116	RCLi	
117	÷	
118	3	
119	÷	
120	ST+3	
121	DSZI	
122	SF1	
123	RCLi	
124	x	
125	2	
126	÷	
127	-	
128	RCL3	
129	÷	
130	ISZI	Check new moment against old moment to see if change has occurred.
131	ISZI	
132	ISZI	
133	ISZI	
134	RCLi	
135	RND	
136	X⇄Y	
137	STOi	
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	RCLi	Output moments.
153	*LBL4	
154	SPC	
155	PRTX	
156	DSZI	
157	DSZI	
158	DSZI	
159	DSZI	
160	GTO0	
161	RCLi	
162	CHS	
163	PRTX	
164	RTN	
165	*LBL0	
166	RCLi	
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	For span N.
199	RCLI	
200	FRC	
201	2	
202	+	
203	STOI	
204	R↑	
205	RTN	
206	*LBL1	For span 1.
207	RCLI	
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	x	
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	x	
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	x	
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	x	
110	GTO7	
111	*LBL0	
112	RCL7	

REGISTERS									
0	1	2	3	4	5	6 m	7 constant	8 (ℓ/K), "	9 Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A A	B	C C	D I	E k or I	I				

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

LABELS					FLAGS
A A	B ℓ	C k	D →P_{allow}	E →P_{max}	0 I input?
a σ_y (N/m²)	b σ_y (psi)	c	d	e	1 C < ℓ/k
0 C < ℓ/k	1 m	2	3	4	2
5 Error	6	7 A x P/A	8 I → k	9	3

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

REINFORCED CONCRETE BEAMS

Step	Key	Comments
001	*LBLe	
002	6	
003	GTO0	Input values and store control code.
004	*LBLA	
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 interchangeable solutions.
026	.	
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	*LBL0	
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	0	
100	6	
101	F0?	
102	GTO0	Store English constants if flag 0 is not set.
103	4	
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	Comments
113	0	
114	0	
115	*LBL0	
116	RCL6	Check for minimum reinforcing.
117	÷	
118	RCL1	
119	RCL2	
120	RCL4	
121	×	
122	÷	
123	X>Y?	
124	GTO0	
125	R↓	
126	LSTX	Reinforcing below minimum. Display code.
127	×	
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	×	
149	X<0?	
150	CLX	
151	-	
152	STO7	
153	.	
154	6	
155	3	
156	7	
157	5	
158	×	
159	RCL5	
160	×	
161	RCL6	
162	÷	
163	RCL8	
164	RCL6	
165	+	
166	÷	
167	RCL8	
168	×	
169	X>Y?	
170	GTO0	
171	RCL2	Set display for too much steel code and GTO 7.
172	RCL4	
173	×	
174	×	
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	×	
206	RCL2	$a = \beta_1\, NA$
207	÷	
208	RCL6	
209	×	
210	RCL5	
211	÷	
212	F2?	
213	RTN	
214	RCL7	
215	÷	
216	RTN	
217	*LBL8	
218	SF3	Calculate small delta from A_s to correct for any rounding errors.
219	EEX	
220	CHS	
221	4	
222	%	
223	RTN	

LABELS

A	B	C	D	E
A_s	b	M	d	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

Flag	
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 θ, tan α, and intermediate result.

```
*LBLA
STO1
R↓
COS
STO2
R↓
TAN
STO3
RCL1
RCL2
÷
+
1
RCL1
RCL3
×
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
×
RCL4
RCL5
×
+
÷
STO7
RTN
```

Store or calculate torque.

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

Calculate shear stress in bolt.

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	f_t, Used	cos θ	tan α	f_c	$D_c/2$	$D_m/2$	W	T	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.
$\boxed{x}$ 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