Part 8

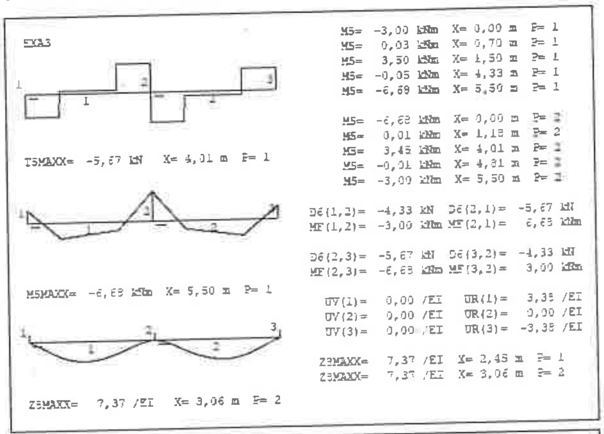
BEAMPROGRAM111 page 1 to 31

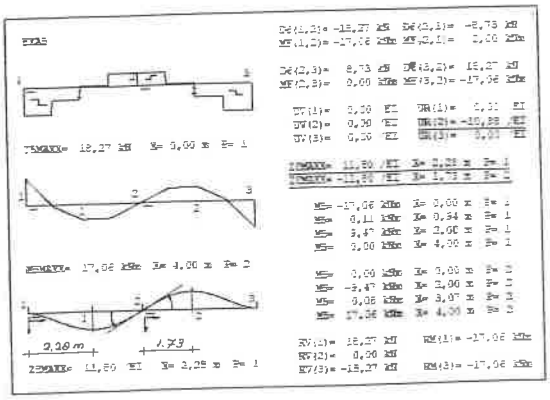
EXA1 to EXA8 to click on, neceassary data or given.

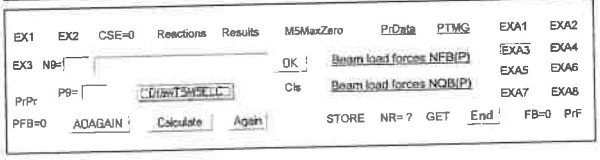
And labels to click on, try the order of clicking,
Reactions for support reactions,
Results for member end forces and moments,
M5MAXZERO for maximum bending moments
and bending moment zero points,
PrData to see the given data,

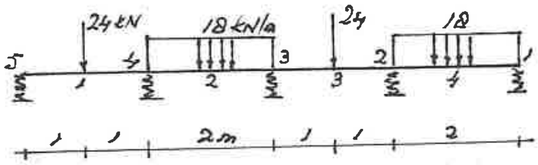
After a click on Calculate to click DrawT5M5ELC
for the diagrams to appear.

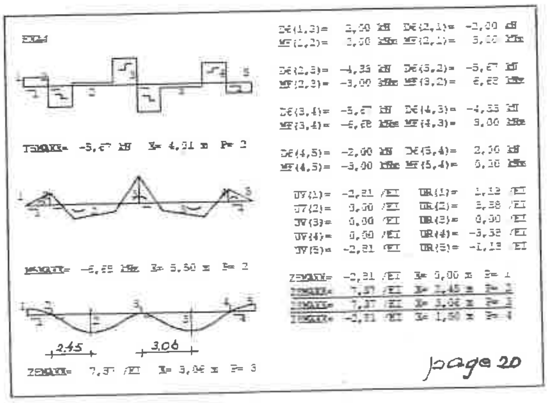
Much more to discover with the examples, how to
put in data, etc. And how to store data with
STORE NR=? GET. Etc. Etc.

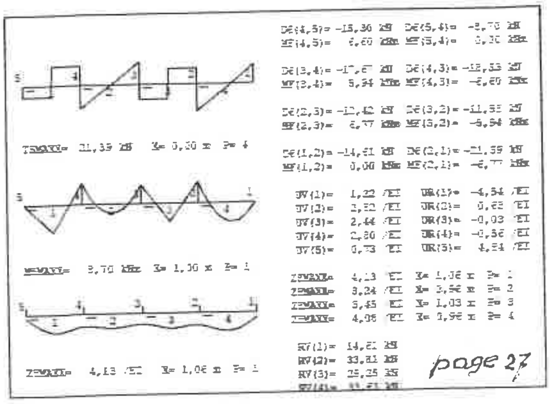












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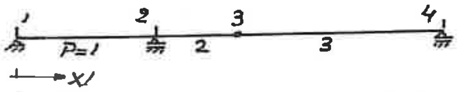


Fig.1.

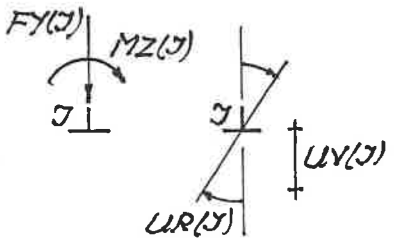


Fig.2.

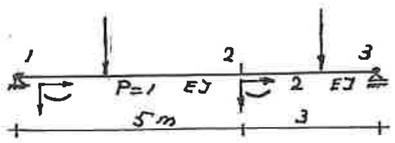


Fig.3.

N9= 3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	0	0	0	5	0	0	0	0
3	0	1	0	0	8	0	0	0	0

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	1	0	1	1
2	2	3	0	1	2	1

Calculation of UR(2) and UV(2),

and HE(1,2) and HE(3,2).

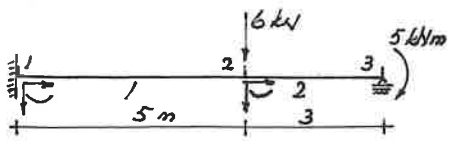


Fig.4.

N9= 3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	0	0	0	5	0	0	0	0
3	0	1	0	0	8	0	0	0	0

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

Calculation of UR(2), UV(2) and UR(3).

Assumptions for BEAMPROGRAM111.

Fig.1

A continuous beam with
N9=4 joints and P9=3 beams/members.

Fig.2, 3 and 4.

Joint variable assumptions.

I FY PV UV SV X1 MZ PR UR SR

I joint number
FY(I) vertical joint load force, downward

PV(I)=0
joint displacement UV(I) not prescribed
PV(I)=1
vertical joint displacement prescribed
UV(I)=0 or <>0

UV(I) in /EI
vertical displacement assumed downward
SV(I) vertical spring constant in EI

X1(I) joint distance from left end in m

MZ(I)
joint load moment assumed to the right in kNm

PR(I)=0
joint rotation UR(I) not prescribed, a clamp
PR(I)=1
joint rotation, the clamp rotation prescribed,
UR(I)=0 or <>0

UR(I) joint rotation assumed to the right /EI

SR(I) joint rotation spring constant

Beam/member variables assumptions

P LL HH NL NH BA EI

P beam/member number
LL(P) lowest beam end number L
HH(P) highest beam end number H

NL(P)=0
Beam end with lowest beam end number is seen as a 'real' joint, of which joint rotation UR(I) will be calculated.
NL(P)=1
Beam end with lowest beam end number, joint, is seen as a hinge, of which beam end rotation HE(L,H) will be calculated.

NH(P)=0 with highest beam end number is seen as a 'real' joint, of which joint rotation UR(I) will be calculated.
NH(P)=1 with highest beam end number, joint, is seen as a hinge, of which beam end rotation UR(I) will be calculated.

BA(P)=L or BA(P)=H, beam end where the beam axis system is placed.

Bending stiffness EI, for input EII(P).

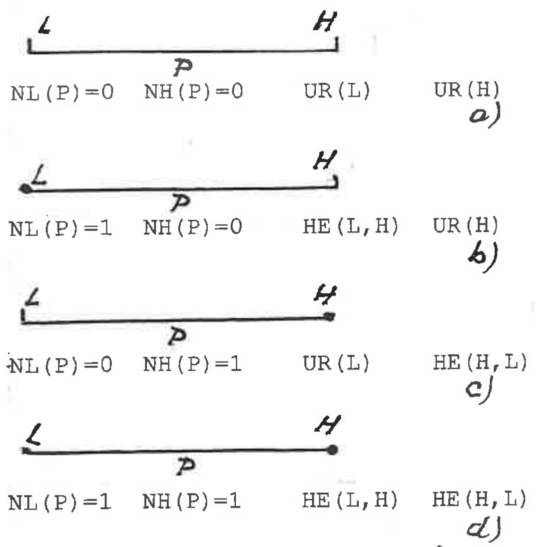


Fig. 5.

Figures 5.

a) Both ends a 'real' joint, joint rotations UR(L) and UR(H) to be calculated.

b) A hinge at beam end L, end H a 'real' joint, beam end rotation, slope deflection, HE(L,H) and joint rotation UR(H) to be calculated.

c) A hinge at beam end H, end L a 'real' joint, beam end rotation, slope deflection, HE(H,L) and joint rotation UR(L) to be calculated.

d) Both beam end a hinge, beam end rotations, slope deflections HE(L,H) and HE(H,L) to be calculated.

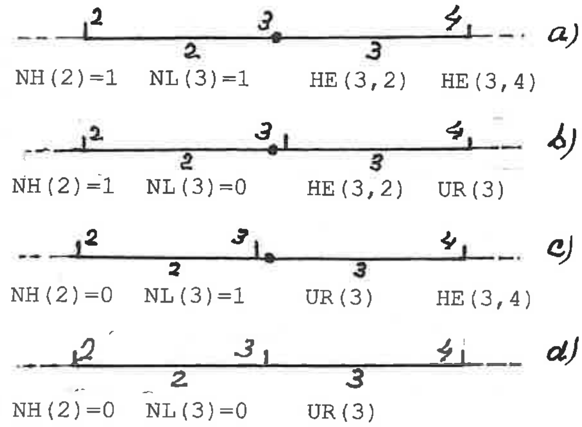


Fig. 6.

Figures 6.

About joint I=3.

<u>A joint, hinge and 'real' joint at same place.</u>

A hinge is indicated with a bold dot, a 'real' joint with a short stripe. A joint can be a hinge and 'real' joint at same time.

a) Beam P=2, beam end with highest beam end number is a hinge, NH(2)=**1**,
beam P=3, beam end with lowest beam end number is a hinge, NL(3)=**1**.
Calculation of HE(3,2) and HE(3,4).

b) Beam P=2, NH(2)=1,
Beam P=3, beam end with lowest beam end number is a 'real' joint, NL(3)=**0**.
Calculation of HE(3,2) and UR(3).

c) and d) with similar approach.

Note. The way of indication with works correctly if members/beams and joints are regularly numbered from left to right.

The calculation is correctly carried out as well when both joints and beams are irregularly numbered, but hinge/joint, bold dot/little stripe does not work correctly... alas.

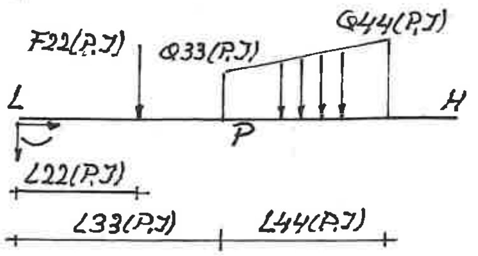


Fig. 7a.

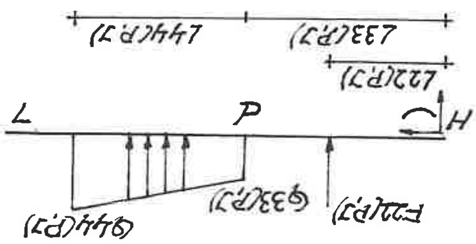


Fig. 7b.

Fig.7a. Beam end numbers L-H or H-L.
The beam axis system is placed at beam end number L, <u>BA(P)=L</u>.

Beam lood forces F22(P,I), distance F22(P,I).
Distributed beam load forces indicated with Q33(P,I) with distance L33(P,I) and Q44(P,I) with length of loads L44(P,I).

Fig.7b. Beam end numbers L-H or H-L.

The beam axis sytem is placed at the other beam end, number H, <u>BA(P)=H</u>.

Beam load forces and distances like fig. 7a.

L and H can be exchanged, the place of determines how load data are put in.

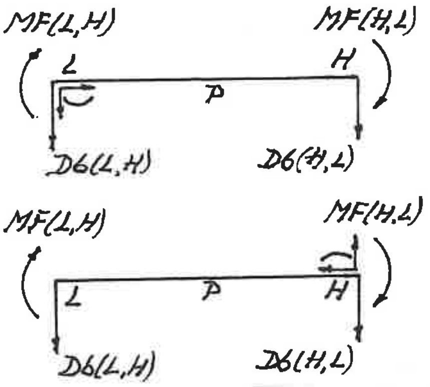


Fig.8.

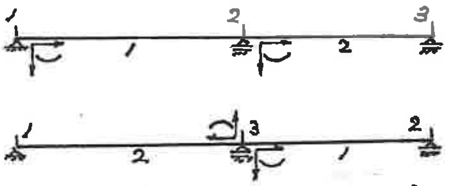


Fig.9.

1	2
2	1

1	3	3	2	2	1
2	1	2	3	1	3
3	2	1	1	3	2

P9=2
1*2= 2

N9=3
1*2*3= 6

2*2= 4 places

<u>2*6*4= 48 possible calculations</u>

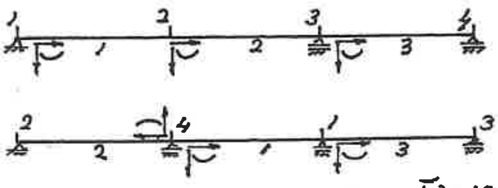


Fig.10.

1	3	3	2	2	1
2	1	2	3	1	3
3	2	1	1	3	2

P9=3
1*2*3= 6

2	2	3	1	4	4	4	1	1	1	3	1
1	3	4	3	3	1	2	2	3	2	4	4
3	1	1	4	2	3	1	3	2	4	2	2
4	4	2	2	1	2	3	4	4	3	1	3

3	4	1	3	2	3	2	3	2	2	4	4
1	1	4	2	4	1	4	2	1	3	3	2
2	2	3	1	3	4	1	4	4	4	1	3
4	3	2	4	1	2	3	1	3	1	2	1

N9=4
1*2*3*4= 24

2*2*2= 8

<u>6*24*8= 1152 possible calculations</u>

<u>Assumptions for beam end forces and beam end moments.</u>

Fig. 8.
There are four possible situations depending on lowest and highest beam end number L resp H, and the place of the 'beam end system' .

The direction of the beam end forces D6(L,H) and D6(H,L) are assumed downward and the direction of the beam end moments MF(L,H) and MF(H,L) are assumed to the right.

A negative value of the variables after the calculations means,
'as large as but opposite directed'.
Two more cases, L and H exchanged.

<u>Possible ways of numbering joints and beams.</u>

Fig.9.

<u>**N9=3** joints and **P9=2** beams/members.</u>

<u>Joint numbereing</u>. There are 1*2*<u>3</u>= 6 ways of numbering the three joints.

<u>Beam numbering</u>. There are 1*<u>2</u>= 2 ways of numbering the two beams.

Each way of numbering the joints can be combined with each way of numbering the beams. That makes together 6*2=<u>12</u> different ways of numbering, <u>12</u> ways of input data, 12 possible calculations with same final results.

But, the beam axis sytem can be at two beam ends of each beam, with 2 beams 2*2= 4 possibilities. Each possibility can be combined with 12 possible numberings, so

<u>4*12= 48! possible calculations</u>. And ofcourse with same final results.

Fig.10.

<u>**N9=4** joints and **P9=3** beams/members.</u>

<u>Joint numbering</u>, 1*2*3*<u>4</u>= 24 ways of numbering the four joints.

<u>Beam numbering</u>, 1*2*<u>3</u>= 6 ways of numbering the three beams.

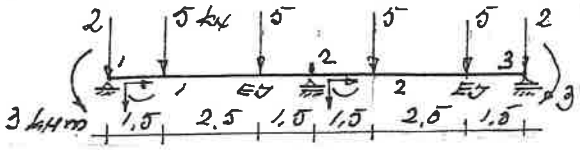
Makes 24*6= <u>144</u> differnt ways of numbering.

But the place of the beam axis system gives with 3 beams 2*2*2= 8 more possibilties and when combines with 144 makes

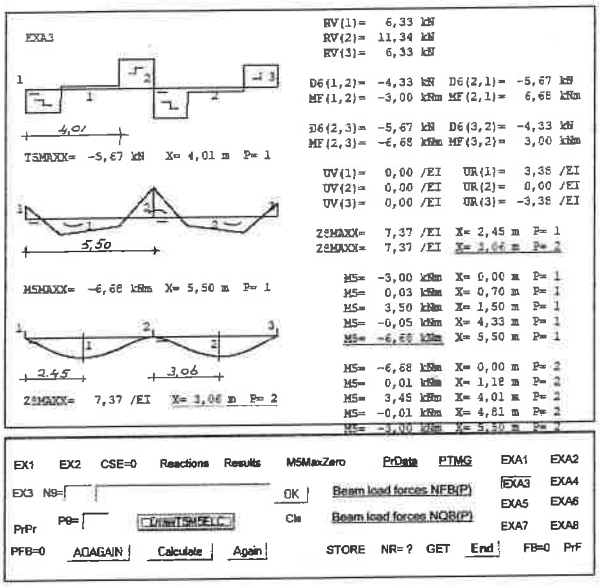
<u>8*144= 1152! possible calculations.</u>

Fig.11.

<u>**N9=5** joints and **P9=4** beams/members.</u>
1*2*3*4*<u>5</u>= 120 ways of numbering joints,
1*2*3*<u>4</u>= 24 ways of numbering beams,
2*2*2*<u>2</u>= 16 possible plces of .
120*24*16= 46080 possible calculations!

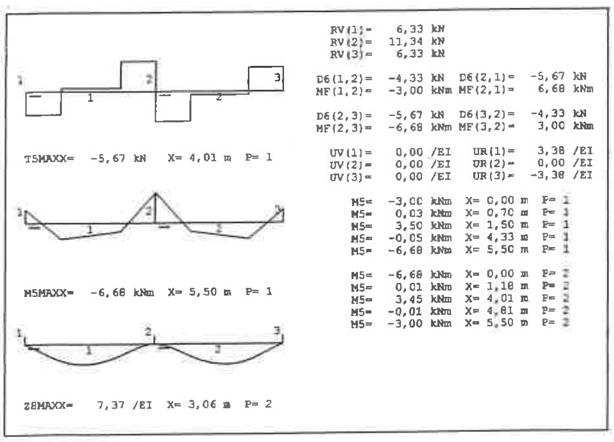



```
N9= 3
I    FY   FV   UV  SV   X1    MZ   PR   UR   SR
1    2    1    0,0 0    0     -3   0    0,0  0
2    0    1    0,0 0    5,5   0    0    0,0  0
3    2    1    0,0 0    11    3    0    0,0  0
P9= 2
P    LL HH   NL NH   BA   EI       L1
1    1  2    0  0    1    1        5,5
NFB(1)=2     I   F2      L2
             1   5       1,5
             2   5       4
P    LL HH   NL NH   BA   EI       L1
2    2  3    0  0    2    1        5,5
NFB(2)=2     I   F2      L2
             1   5       1,5
             2   5       4
```



PTMG
As example, P=1,G=.7 Enter in TSTRING and next a click on TPMG calculates shear force and bending moment for each step G=.7 m. See page

Click on the right, FB=0 to PB=1 then Form text bold.
Click on the left PFB=0 to PFB=1 then printer text bold.



BEAMPROGRAM111 and screen form controls.

Number of joints N9=, text box TN9.
Number of beams/members, text box TP9.

TSTRING is the large text box for input of joint and member data, followed by Enter.
Click PrData (is Show) to see the data put in.

Controls EXA1 to EXA8 (page 17) to click on with given data for direct use.

As example click EXA3 and PrData, data appear on the right half of the form. A click on Cls clears the right half of the form.

Click Calculate to carry out the calculations, next DrswT5M5ELC to get the three diagrams on the left of the form.

Shear force diagram with largest shear force below it, here of member P=1,
T5MAXX= -5,67 kN at 4,01 m from the left, where the beam axis system is placed, that is just left of load force of 5 kN.

Bending moment diagram with largest bending moment, here of member P=1,
M5MAXX= -6,88 kNm at 5,50 m from the left, a member end moment, or, support moment.

Elasti curve diagram with the largest displacement, here of member 2,
Z8MAXX= 7,37 /EI at 3,06 m from the left.
Because of symmetry Z8MAXX= 7,37 /EI for P=1 as well, now at 2,45 m from the left.

Reactions, support reactions RV(I) and RM(I).

Results, member end forces D6(L,H) and D6(H,L) and member end moments MF(L,H) and MF(H,L), assumptions on page 3.

Vertical joint displacements UV(I) and joint rotations UR(I).
If a member end is a hinge then the slope deflection ('member end rotation') is separately calculated, HE(L,H) or HE(H,L).

Z8MAXX the largest vertical displacement of a member, mostly between the member ends.

M5MaxZero, the largest bending moments and zero point of each member.

Reactions, Results and M5MaxZero can be clicked in arbitrary order, to be tried out. Not always space enough for all results...
With a click shown data disappear.

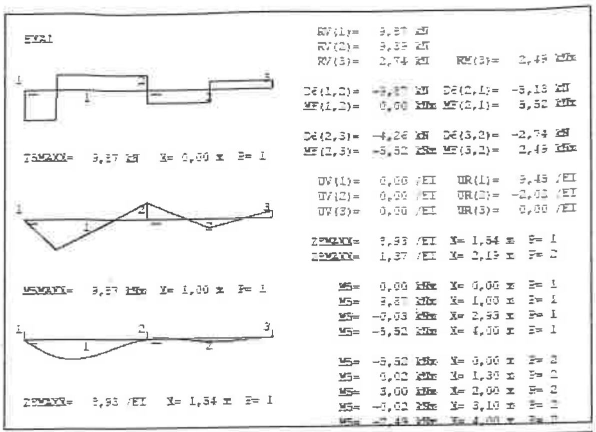
PrPr for a printer print, shown on the left, always printed with the same results and same order of results.

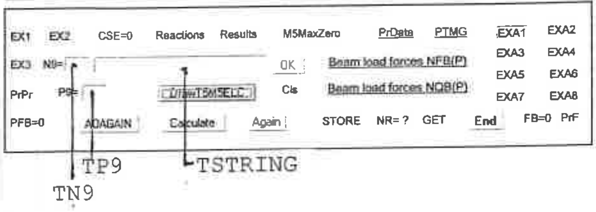
EX1, EX2 and EX3 examples page 23 to 30.

Again, UV(I) and UR(I) are set zero.
AOAGAIN back to start position.

Click EXA1 and PrData, next Again, Calculate, DrawT5M5ELC to get the diagrams. Next Reactions, Results and M5MaxZero.

```
N9= 3
I  PY  PV  UV SV  XI   MZ  PR  UR  SR
1  0   1   0,0 0  0    0   0   0,0 0
2  0   1   0,0 0  4    0   0   0,0 0
3  0   1   0,0 0  8    0   1   0,0 0
P9= 2
P  LL BB  NL NB  BA  EI    LI
1  1  2   0  0   1   1     4
NFB(1)=1  I   F2    L2
          1   15    1
P  LL BB  NL NB  BA  EI    LI
2  2  3   0  0   2   1     4
NFB(2)=1  I   F2    L2
          1   7     2
```

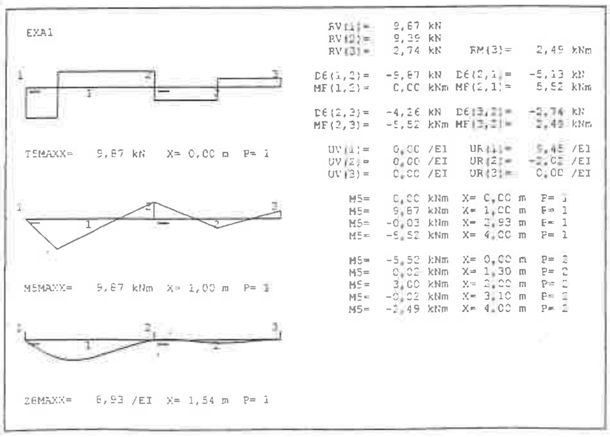




PTMG Click first CSE=0 to red CSE=1!
To type in TSTRING P=3,G=.65 Enter.
P is beam number, G is step value in m measured from beam end with beam axis system. Shear forces and bending moments at G meter appear after clicking PTMG, moment zero points and moment maximum as well, ex. page 15 .

A click on AOAGAIN, all over again, resets to start position.

With a click on PrF the screen results will be printed, a copy, with FB=1 text will be bold printed.
With a click on PrPr a 'printer print' is printed like shown here below, with fixed order of results. With PFB=1 then bold text.



BEAMPROGRAM111

Short introduction, examples on the following pages will explain all in detail.

Text box TN9 for input of number of joints N9, text box TP9 for input of number of beams P9, double click to empty them.
Text box TSTRING for input of rows of joint data, beam data and beam load data. Double click to empty TSTRING.

Concentrated beam load forces see page

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	2	1	12	3.2
1	2	2	7	1.5

Click Beam load forces NFB(P) getting bold and type in TSTRING a row with data, Enter, bold disappears, and for the second row of data, click Beam load forces NFB(P) etc.

Distributed beam load forces

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
3	1	1	6	12	2.4	3.1

Click Beam load forces NQB(P) getting bold etc. like done for concentrated loads.
With right mouse button bold of Beam load... disappears.

A click on PrData shows the data put in, to check them, eventually to change them.

After data input click Again to make all UV(I) and UR(I) zero.
If wanting to put in prescribed variables UV(I)<>0 or UR(I)<>0 then they have to be put in after clicking Again.
With Calculate the calculations are carried out and with DrawT5M5ELC the diagrams are drawn.

Reactions, Results and M5MaxZero to be clicked in wished arbitrary order to get the results printed on the screen like shown on the left.

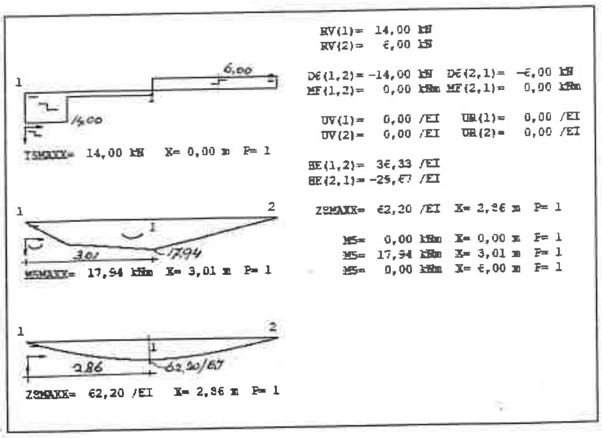
To save data with STORE NR=? GET
Click NR with left mouse button number up, with right button number down.
Store NR=5 GET
Click STORE, gets underlined, NR=5 as well,
STORE NR=5 GET
Number up or down, underlining disappears.
Going back to underlined number 5, click GET,
STORE NR=5 GET gets underlined,
next Again etc. to get diagrams and results printed.
With right mouse button on GET removes data, underlining of GET and NR=5 disappears.

A click on **CSE=0** makes it **CSE=1**, becoming red.
With CSE=1 variables can be changed, e.g.
NL(3)=1 Enter, etc.

NH(P) BA(P) EII(P) NFB(P) NQB(P) PY(I)

PV(I) UV(I) SV(I) MZ(I) PR(I) UR(I) SR(I)

Cls to click to clear the right half of the screen print. To click Reactions, Results, M5MaxZero in arbitrarily chosen order.



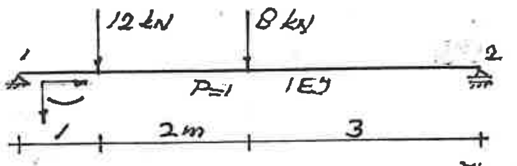


Fig.1.

Fig.2 like fig.1
but with the beam axis system at beam end number 2. To start with the data of fig.1 click Again and then PrData.

Type 1 in TP9, Tab, cursor in TSTRING, click CSE=0 To CSE=1 getting red and type BA(1)=2 Enter. Click PrData to see the change.

Next the two beam load forces.

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	2	1	-12	5
1	2	2	-8	3

Click Beam load forces NFB(P), getting bold and type in TSTRING
1,2,1,-12,5 Enter, 1,2,2,-8,3 Enter.
Click PrData to check the input. ok
Clic Again, Calculate, etc. See the results here below.

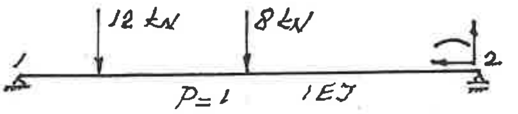
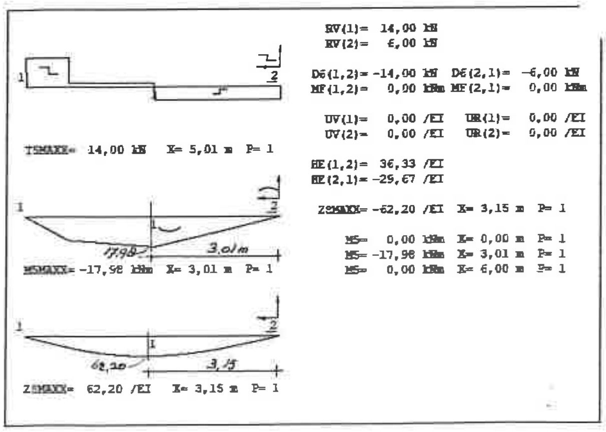


Fig.2.



Example.

Fig.1.
A simple beam on two supports with two beam load forces.

N9=2 joints, the beam ends, number 1 and 2.
PV(1)=1, vertical displacement prescribed and zero, UV(1)=0 and PV(2)=1 and UV(2)=0.
No springs precribed/assumed, SV(I)=0, SR(I)=0.

N9=2 joints, type 2 in text box TN9 on the right of N9=, next Tab to get the cursor in the large text box TSTRING, or, click in TSTRING to get the cursor there.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	1	0	0	6	0	0	0	0

Type the two rows of data in TSTRING,
1,0,1,0,0,0,0,0,0,0 Enter and
2,0,1,0,0,6,0,0,0,0 Enter.

The beam data for beam P9=1.

P	LL	HH	NL	NH	BA	EI
1	1	2	1	1	1	1

Lowest beam end number LL(1)=1, highest beam end number HH(1)=2, both beam ends are seen as hinges NL(1)=1 and NH(1)=1, the beam axis system is placed at beam end 1 BA(1)=1 and the bending stiffness is EII(1)=1.

P9=1 beam/member, type 1 in text box TP9 on the right of P9=, next Tab, or click in TSTRING, to get the cursor in TSTRING, and type
1,1,2,1,1,1,1 Enter.

Two beam load forces

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	2	1	12	1
1	2	2	8	3

Click Beam load forces NFB(P), getting bold, and to type in TSTRING, CSE=0,
1,2,**1**,12,1 Enter and 1,2,**2**,8,3 Enter.

Store the data, click NR= to a number not underlined, e.g. NR=4, click STORE, STORE and NR=4 get underlined.

Next click Again, Calculate and DrawT5M5ELC to get the diagrams shown on the left, click PrData to check them again.
Click Reactions (the data disappear), Results and M5MaxZero to print all results.

The beam ends, joints, are hinges, NL(1)=1 and NH(1)=1, the beam end rotations are separately calculated,
HE(1,2)= 36,33/EI and HE(2,1)= -29,67/EI.

Fig.1.	Fig.2.
ZMAXX= 62,20/EI	ZMAXX= -62,20/EI
M5= 17,94 kNm	M5= -17,98 kNm

Positive and negative values, but the shear force and bending moment signs are the same, in other words, the final results are the same.

Example.

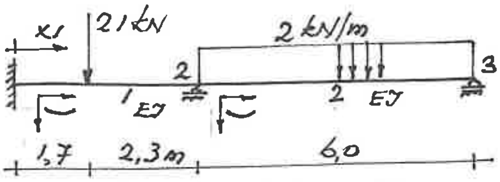


Fig. 1.

```
N9= 3
I  FY  PV UV SV  X1  MZ  PR  UR   SR
1  0   1  0  0   0   0   1   0,0  0,0
2  0   1  0  0   4   0   0   0,0  0,0
3  0   1  0  0   10  0   0   0,0  0,0
P9= 2
P  LL HH  NL NH  BA  EI   L1
1  1  2   0  0   1   1    4
NFB(1)=1  I  F2   L2
          1  21   1,7
P  LL HH  NL NH  BA  EI   L1
2  2  3   0  0   2   1    6
NQB(2)=1  I  Q3   Q4   L3   L4
          1  2    2    0    6
```

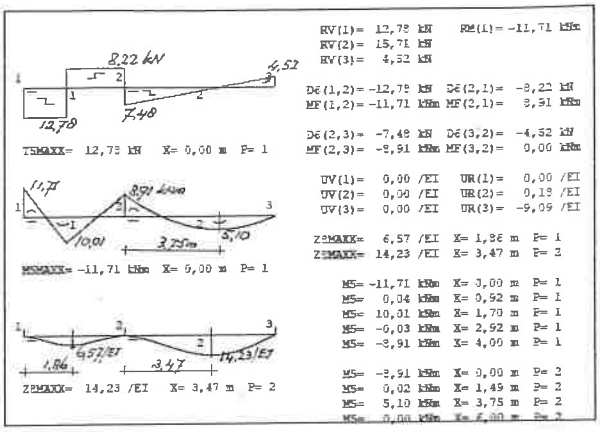


Fig.1.
N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	0	1	0	0	4	0	0	0	0
3	0	1	0	0	10	0	0	0	0

Type 3 in TN9, Tab, cursor in TSTRING and type the three rows of joint data in TSTRING.
P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	1	2	1

Type 2 in TP9, Tab, cursor in TSTRING and type the two rows of member data in TSTRING.

Beam loads. Type 2 in TP9, Tab.

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	1	1	21	1.7

Click Beam load forces NFB(P), getting bold, and type in TSTRING, CSE=0,
1,1,1,21,1.7 Enter.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
2	1	1	2	2	0	6

Click Beam load forces NQB(P), getting bold, and type in TSTRING, CSE=0,
2,1,1,2,2,0,6 Enter.

Beam end 3 of beam 2 seen as a 'real' joint, with CSE=1 to type in TSTRING NH(2)=0 Enter.

Click PrData and see on the left how the data print looks like.

Click Again, Calculate and DrawT5M5ELC, next Reactions, Results and M5MaxZero.

UR(3)= -9,09/EI and UR(2)= 0,18/EI.

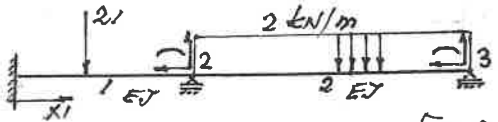


Fig.2.

```
N9= 3
I  FY  PV UV SV  X1  MZ  PR  UR   SR
1  0   1  0  0   0   0   1   0,0  0,0
2  0   1  0  0   4   0   0   0,0  0,0
3  0   1  0  0   10  0   0   0,0  0,0
P9= 2
P  LL HH  NL NH  BA  EI   L1
1  1  2   0  0   2   1    4
NFB(1)=1  I  F2   L2
          1  -21  2,3
P  LL HH  NL NH  BA  EI   L1
2  2  3   0  1   3   1    6
NQB(2)=1  I  Q3   Q4   L3   L4
          1  -2   -2   0    6
```

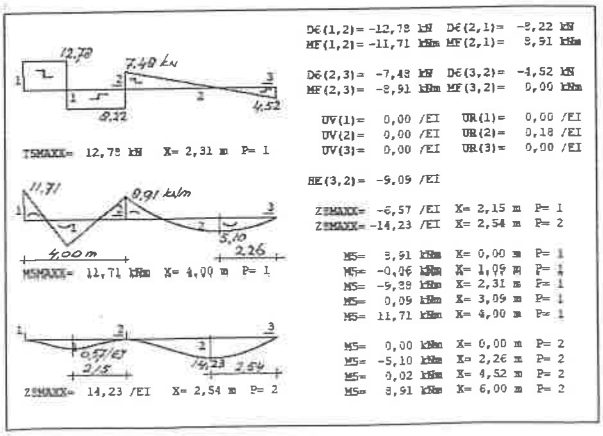


Fig.2.
The beam axis systems at the other beam ends, with CSE=1 to type in TSTRING
BA(1)=2 Enter and BA(2)=3 Enter.

Beam loads. Type 2 in TP9, Tab.

P	NFB(P)	I	F22(P<I)	L22(P,I)
1	1	1	-21	2.3

Click Beam load forces NFB(P), getting bold, and type in TSTRING, CSE=0,
1,1,1,-21,2.3 Enter.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
2	1	1	-2	-2	0	6

Click Beam load forces NQB(P), getting bold, and type in TSTRING, CSE=0,
2,1,1,-2,-2,0,6 Enter.

Now beam end 3 of beam 2 seen as a hinge, then with CSE=1 to type in TSTRING NH(2)=1 Enter.

Click PrData and see on the left how the data print looks like. Further Again etc.

Now the angle at beam end 3 is separately calculated because of the hinge, no little stripe at end 3, see the third diagram.
HE(3,2)= -9,09/EI and again UR(2)= 0,18/EI.

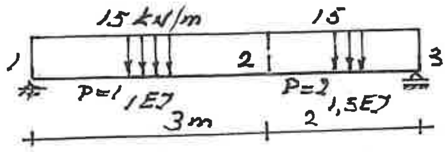
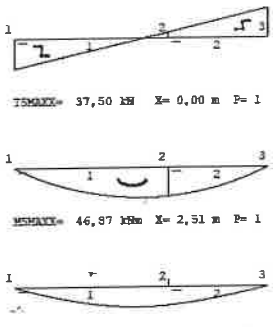


Fig.1.

```
NS= 3
I   FY    PV UV SV  X1    MZ  PR  UR  SR
1   0     1  0  0   0     0   0   0,0 0,0
2   0     0  0  0   3     0   0   0,0 0,0
3   0     1  0  0   5     0   0   0,0 0,0
PS= 2
P   LL HH  NL NH  BA  EI     L1
1   1  2   1  0   1   1      3
NQB(1)=1   I   Q3    Q4     L3     L4
           1   15    15     0      3
P   LL HH  NL NH  BA  EI     L1
2   2  3   0  1   2   1,5    2
NQB(2)=1   I   Q3    Q4     L3     L4
           1   15    15     0      2
```




```
RV(1)=  37,50 kN
RV(2)=   0,00 kN
RV(3)=  37,50 kN

D6(1,2)= -37,50 kN  D6(2,1)=  -7,50 kN
MF(1,2)=   0,00 kNm MF(2,1)= -45,00 kNm

D6(2,3)=   7,50 kN  D6(3,2)= -37,50 kN
MF(2,3)=  45,00 kNm MF(3,2)=   0,00 kNm

UV(1)=   0,00 /EI   UR(1)=   0,00 /EI
UV(2)= 102,25 /EI   UR(2)= -27,79 /EI
UV(3)=   0,00 /EI   UR(3)=   0,00 /EI

HE(1,2)=  73,46 /EI
HE(3,2)= -64,46 /EI

ZSMAXX= 110,63 /EI   X= 2,41 m  P= 1
ZSMAXX= 102,25 /EI   X= 0,00 m  P= 2

MS=   0,00 kNm  X= 0,00 m  P= 1
MS=  46,87 kNm  X= 2,51 m  P= 1
MS=  45,00 kNm  X= 3,00 m  P= 1

MS=  45,00 kNm  X= 0,00 m  P= 2
MS=   0,00 kNm  X= 2,00 m  P= 2

TSMAXX=  37,50 kN   X= 0,00 m  P= 1
MSMAXX=  46,87 kNm  X= 2,51 m  P= 1
ZSMAXX= 110,63 /EI  X= 2,41 m  P= 1
```

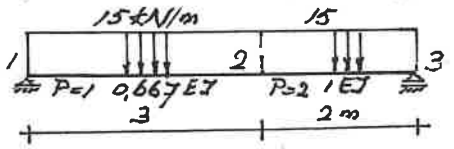
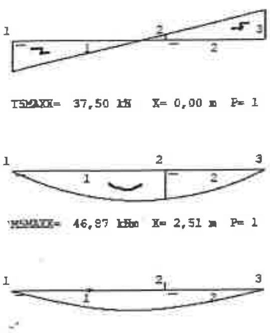


Fig.2.

```
NS= 3
I   FY    PV UV SV  X1    MZ  PR  UR  SR
1   0     1  0  0   0     0   0   0,0 0,0
2   0     0  0  0   3     0   0   0,0 0,0
3   0     1  0  0   5     0   0   0,0 0,0
PS= 2
P   LL HH  NL NH  BA  EI     L1
1   1  2   1  0   1   0,667  3
NQB(1)=1   I   Q3    Q4     L3     L4
           1   15    15     0      3
P   LL HH  NL NH  BA  EI     L1
2   2  3   0  1   2   1      2
NQB(2)=1   I   Q3    Q4     L3     L4
           1   15    15     0      2
```




```
RV(1)=  37,50 kN
RV(2)=   0,00 kN
RV(3)=  37,50 kN

D6(1,2)= -37,50 kN  D6(2,1)=  -7,50 kN
MF(1,2)=   0,00 kNm MF(2,1)= -45,00 kNm

D6(2,3)=   7,50 kN  D6(3,2)= -37,50 kN
MF(2,3)=  45,00 kNm MF(3,2)=   0,00 kNm

UV(1)=   0,00 /EI   UR(1)=   0,00 /EI
UV(2)= 153,32 /EI   UR(2)= -41,66 /EI
UV(3)=   0,00 /EI   UR(3)=   0,00 /EI

HE(1,2)= 110,14 /EI
HE(3,2)= -96,66 /EI

ZSMAXX= 165,88 /EI   X= 2,41 m  P= 1
ZSMAXX= 153,32 /EI   X= 0,00 m  P= 2

MS=   0,00 kNm  X= 0,00 m  P= 1
MS=  46,87 kNm  X= 2,51 m  P= 1
MS=  45,00 kNm  X= 3,00 m  P= 1

MS=  45,00 kNm  X= 0,00 m  P= 2
MS=   0,00 kNm  X= 2,00 m  P= 2

TSMAXX=  37,50 kN   X= 0,00 m  P= 1
MSMAXX=  46,87 kNm  X= 2,51 m  P= 1
ZSMAXX= 165,88 /EI  X= 2,41 m  P= 1
```

Example.

Fig.1.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	0	0	0	3	0	0	0	0
3	0	1	0	0	5	0	0	0	0

Type 3 in TN9, Tab, cursor in TSTRING and type the three rows of joint data in TSTRING.

P9=3 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	1	0	1	1
2	2	3	0	1	2	1.5

Type 2 in TP9, Tab, cursor in TSTRING and type the two rows of member data in TSTRING.

Beam loads. Type 2 in TP9, Tab.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	15	15	0	3

Click Beam load forces NQB(P), getting bold, and type in TSTRING, CSE=0, 1,1,1,15,15,0,3 Enter.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
2	1	1	15	15	0	2

Click Beam load forces NQB(P), getting bold, and type in TSTRING, CSE=0, 2,1,1,15,15,0,2 Enter.

Click PrData to check the data put in, and store the data, click NR=, not underlined etc.

Next Again, Calculate, DrawT5M5ELC, Reactions,
Results, M5MaxZero.

Fig.2
Like fig.1 with different bending stiffnesses.
Beam 1 with 1/1.5= 0,667EI and
beam 2 with 1.5/1.5= 1EI.
With CSE=1 to type in TSTRING
EII(1)=.667 Enter and EII(2)=1 Enter.

With PrData to see the changed stiffnesses.

Next Again etc.

De values of the displacements of case 1 and case 2 are different, shear forces and bending moments the same.

1st case UV(2)= 102,25/EI UR(2)= -27,79/EI
HE(1,2)= 73,46/EI HE(3,2)= -64,46/EI

2nd case UV(2)= 153,32/EI UR(2)= -41,66/EI
HE(1,2)= 110,14/EI HE(3,2)= -96,66/EI

(1,5)*102,25/EI= 153,38/EI 'is' 153,32/EI etc.

Suppose beam end 1 and 3 of the second case are real joints, with CSE=1 to type in TSTRING NL(1)=0 Enter, lowest beam end number, and NH(2)=0 Enter, highest beam end number.

Again etc.
Results UR(1)= 110,14/EI and UR(3)= -96,66/EI.

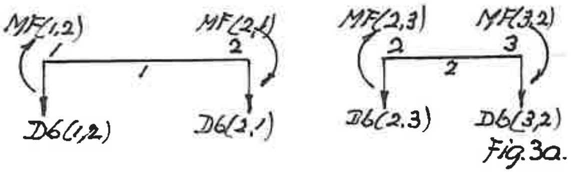


Fig.3a.

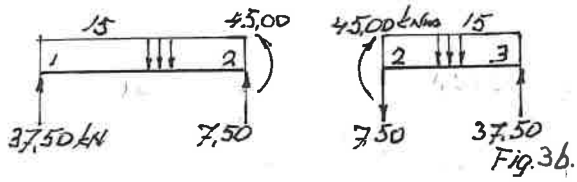


Fig.3b.

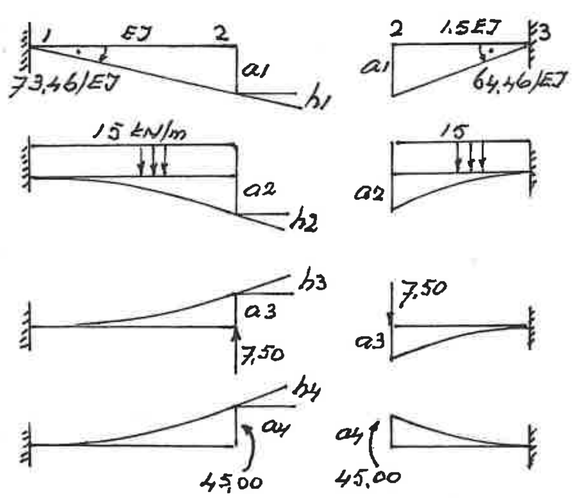


Fig.4.

Fig.3a.
The two beams with beam end forces and beam end moments with the assumed directions.

Fig. 3b.
The beam end forces and beam end moments drawn with their real directions.

Figures 4.
Beam 1 with 1EI, figures on the left.
Four separated cases to find the vertical displacement of beam end 2. See formulas page .

a1 ↓ = (73,46/EI)*3= 220,38/EI

a2 ↓ = (15*3^4)/8EI= 151,88/EI

a3 ↑ = (7,5*3^3)/3EI= 67,50/EI

a4 ↑ = (45,00*3^2)/2EI= 202,50/EI

a ↓ =(220,38+151,88 -67,50-202,50)/EI= 102,26/EI

The joint rotation UR(2)= -27,79/EI. Check.

h1 ⋜ = 73,46/EI

h2 ⋜ = (15*3^3)/6EI= 67,50/EI

h3 ⋝ = (7,5*3^2)/2EI= 33,75/EI

h4 ⋝ = (45,00*3)/EI= 135,00/EI

h ⋜ = (73,46+67,50-33,75-135,00)/EI= -27,79/EI

not ⋜ as assumed but ⋝.   Or assumption

h ⋝ = (33,75+135,00-73,46-67,50)/EI= 27,79/EI

as assumed so ⋝.

Beam 2 with 1,5EI, figures on the right.
Second calculation check of the displacement of beam end 2.

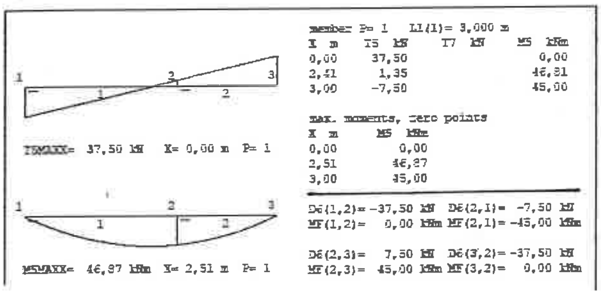
a1 ↓ = (64,46/EI)*2= 128,92/EI

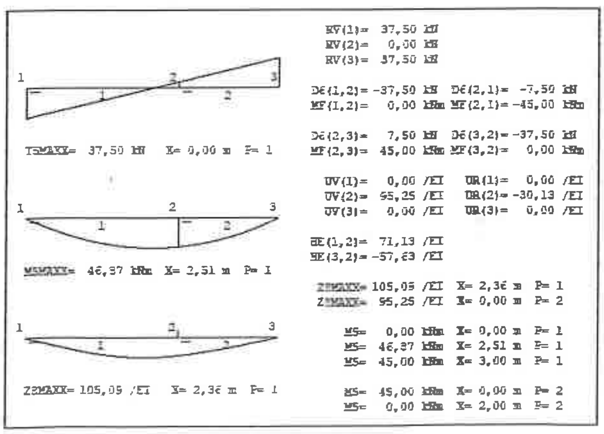
a2 ↓ = (15*2^4)/8*1,5EI= 20,00/EI

a3 ↑ =(7,5*2^3)/3*1,5EI= 13,33/EI

a4 ↑ = (45*2^2)/2*1,5EI= 60,00/EI

a ↓ =(128,92+20,00+13,33 -60,00)/EI= 102,25/EI





Case of fig.1.
Z8MAXX= 110,63/EI at 2,41 m from beam end 1 of beam 1. This value follows also with PTMG as follows. With CSE=1 to type in TSTRING P=1,G=2.41 Enter. Next click PTMG and see the results on the right of the diagrams.

Case of fig.1.
Suppose beam 2 with bending stiffness 2EI instead of 1,5EI. With CSE=1 to type in TSTRING EII(2)=2 Enter. Next Again etc. See the print on the left. Deformation is different, shear forces and bending moments the same, beacause, statically determinated construction.

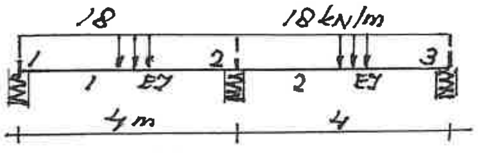
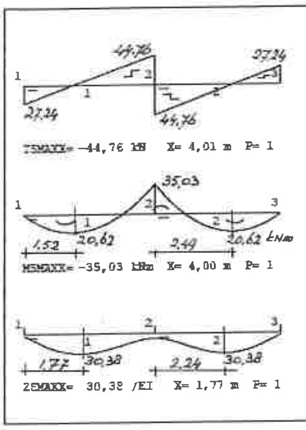
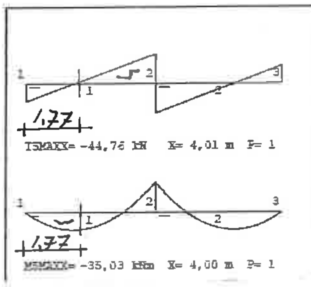


Fig.1.

```
N9= 3
I   FY    PV UV SV  X1    MZ  PR  UR   SR
1   0     0  0  12  0     0   0   0,0  0,0
2   0     0  0  12  4     0   0   0,0  0,0
3   0     0  0  12  8     0   0   0,0  0,0
P9= 2
P   LL HH  NL NH  BA  EI    L1
1   1  2   0  0   1   1     4
NQB(1)=1   I   Q3    Q4    L3    L4
           1   18    18    0     4
P   LL HH  NL NH  BA  EI    L1
2   2  3   0  0   2   1     4
NQB(2)=1   I   Q3    Q4    L3    L4
           1   18    18    0     4
```




```
RV(1)=  27,24 kN
RV(2)=  89,51 kN
RV(3)=  27,24 kN

D6(1,2)= -27,24 kN  D6(2,1)= -44,76 kN
MF(1,2)=   0,00 kNm MF(2,1)=  35,03 kNm

D6(2,3)= -44,76 kN  D6(3,2)= -27,24 kN
MF(2,3)= -35,03 kNm MF(3,2)=   0,00 kNm

UV(1)=   2,27 /EI   UR(1)=  25,95 /EI
UV(2)=   7,46 /EI   UR(2)=   0,00 /EI
UV(3)=   2,27 /EI   UR(3)= -25,95 /EI

Z8MAXX=  30,38 /EI  X= 1,77 m  P= 1
Z8MAXX=  30,38 /EI  X= 2,24 m  P= 2

   M5=   0,00 kNm  X= 0,00 m  P= 1
   M5=   0,27 kNm  X= 0,01 m  P= 1
   M5=  20,62 kNm  X= 1,52 m  P= 1
   M5=  -0,08 kNm  X= 3,03 m  P= 1
   M5= -35,03 kNm  X= 4,00 m  P= 1

   M5= -35,03 kNm  X= 0,00 m  P= 2
   M5=   0,19 kNm  X= 0,98 m  P= 2
   M5=  20,62 kNm  X= 2,49 m  P= 2
   M5=   0,00 kNm  X= 4,00 m  P= 2
```




```
member P= 1   L1(1)= 4,000 m
X  m    T5  kN      T7  kN     M5  kNm
0,00     27,24                   0,00
1,77     -4,62                  20,02
3,54    -36,48                 -18,34
4,00    -44,76                 -35,03

max. moments, zero points
X  m      M5  kNm
0,00        0,00
0,01        0,27
1,52       20,62
3,03        0,00
4,00      -35,03
```

PTMG

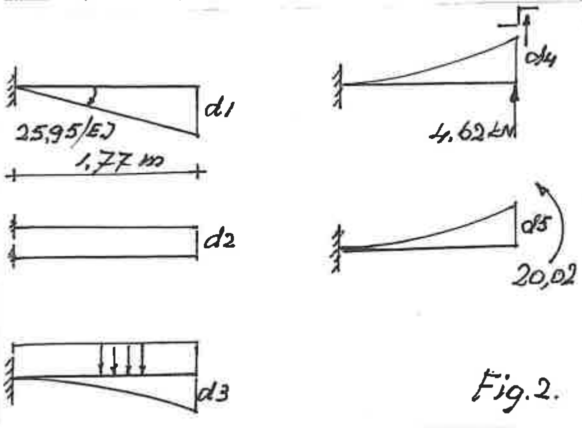


Fig.2.

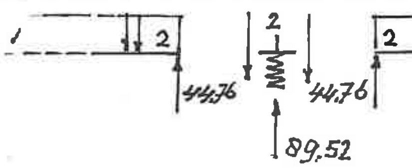


Fig.3.

Example.

Fig.1.
N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	0	0	12	0	0	0	0	0
2	0	0	0	12	4	0	0	0	0
3	0	0	0	12	8	0	0	0	0

The joints 1, 2 and 3 are supported by springs with spring constant SV(I)= 12EI. The vertical displacements of these three joints is not prescribed, so *PV(I)=0* instead of *PV(I)=1*.

P9=3 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

Beam loads.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	18	18	0	4
2	1	1	18	18	0	4

Click Beam load forces NQB(P), getting bold, and type in TSTRING, CSE=0,
1,1,1,18,18,0,4 Enter.

Click *Beam load forces NQB(P), getting bold,* and type in TSTRING, CSE=0,
2,1,1,15,15,0,2 Enter.

Click PrData to check the data put in, and store the data, click NR=, not underlined etc.

Next Again, Calculate, DrawT5M5ELC, etc.

Figures 2.
See the deformation line, third diagram, left part with at 1,77 m Z8MAXX= 30,38/EI. Check.

Applying PTMG to find shear force and bending moment at 1,77 m from beam end 1 of beam P=1. With CSE=1 to type in TSTRING
P=1,G=1.77 Enter, click PTMG to see some results appear,

shear force -4,62 kNm, minus sign means, the shear force sign indicates that the force is directed upward, see d4.
The bending moment 20,02 kNm, positive answer, so , so acting to the left, see d5.

With the formulas the displacements d1 to d5 can be calculated, page .
UV(1)= 2,27/EI   UR(1)=25,95/EI

d1 ↓ =(25,95)*1,77/EI= 45,93/EI

d2 ↓ =(18*1,77^4)/8EI= 22,08/EI   d3 ↓ = 2,27/EI

d4 ↑ =(4,62*1,77^3)/3EI= 8,54/EI

d5 ↑ = (20,02*1,77^2)/2EI= 31,36/EI

d ↓ =(45,93+22,08+2,27 -8,54-31,36)/EI= 30,38/EI

Fig.3. Support 2. Spring constant 12EI.

F= UV(2)*SV(2)= (7,46/EI)*12EI= 89,52 kN   ok

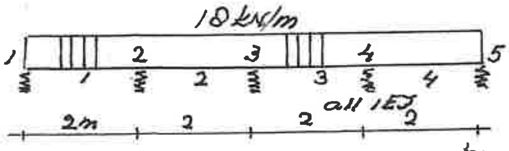
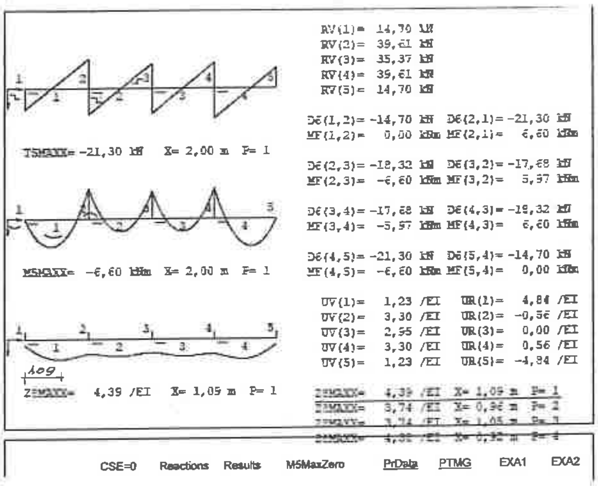
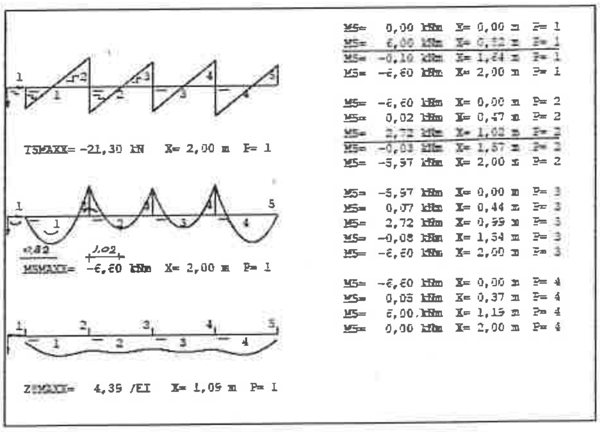
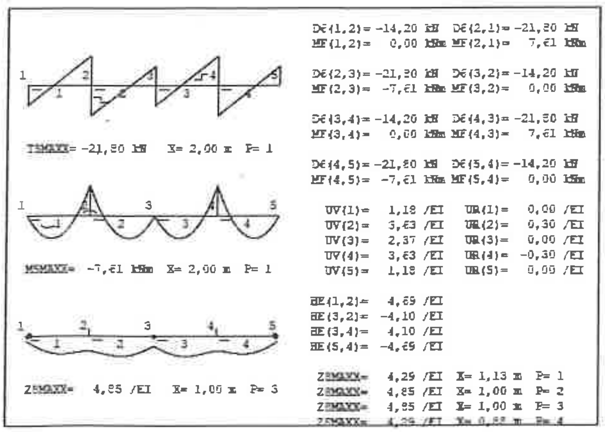


fig. 1







Example.

Fig.1.
N9=5 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	0	0	12	0	0	0	0	0
2	0	0	0	12	2	0	0	0	0
3	0	0	0	12	4	0	0	0	0
4	0	0	0	12	6	0	0	0	0
5	0	0	0	12	8	0	0	0	0

Type 5 in TN9, Tab and type 5 rows in TSPRING.

P9=4 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1
3	3	4	0	0	3	1
4	4	5	0	0	4	1

Type 4 in TP9, Tab and type 4 rows in TSTRING.

Beam loads.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	18	18	0	2
2	1	1	18	18	0	2
3	1	1	18	18	0	2
4	1	1	18	18	0	2

Beam P=1.
Double click in TP9 and type **1**, Tab and click Beam load forces NQB(P), and type in TSTRING
1,1,1,18,18,0,2 Enter.

Beam P=2.
Double click in TP9 and type **2**, Tab and click Beam load forces NQB(P), and type in TSTRING
2,1,1,18,18,0,2 Enter.

Similar way for beam P=3 and P=4.
Click PrData to see the data put in.

Next Again, Calculate and DrawT5M5E1C.
Click Reactions, Results and M5MaxZero in arbitrary order and clicking Cls.

Beam end 1 and beam end 5 are seen as 'real' joints, NL(1)=0 and NH(4)=0.
Make them hinges with CSE=1 to type in TSTRING
NL(1)=1 Enter and NH(4)=1 Enter.

Click Again, Calculate, DrawT5M5ELC, Results to

HE(1,2)= 4,84/EI was UR(1)= 4,84/EI and
HE(5,4)= -4,84/EI was UR(5)= -4,84/EI.

Suppose joint 3 is a hinge, then with CSE=1 to type in TSTRING
NH(2)=1 Enter and NL(3)=1 Enter.

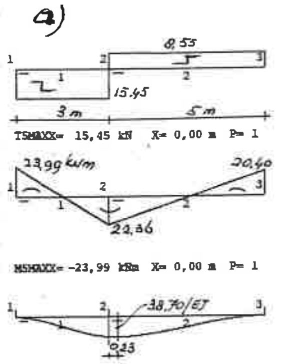
Again, Calculate etc.
With Results, see print on the left,

HE(3,2)= -4,10/EI, and UR(3)= 4,10/EI because for beam end 3 is NL(3)=0, a 'real' joint.

With joint displacement UV(3)= 2,37/EI follows
F= UV(3)*SV(3)= (2,37/EI)*12EI= 28,44 kN

Support reaction RV(3)= 28,39 kN, ok.

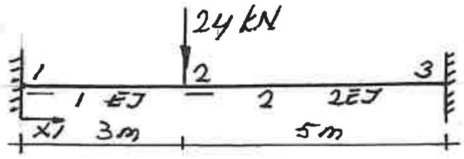
a)




```
TSMAXX= 15,45 kN   X= 0,00 m   P= 1
MSMAXX= -23,99 kNm  X= 0,00 m   P= 1
Z8MAXX= 38,70 /EI   X= 0,23 m   P= 2

RV(1)=  15,45 kN      RM(1)= -23,99 kNm
RV(2)=   0,00 kN
RV(3)=   8,55 kN      RM(3)=  20,40 kNm

D6(1,2)= -15,45 kN  D6(2,1)=  15,45 kN
MF(1,2)= -23,99 kNm MF(2,1)= -22,36 kNm

D6(2,3)=   8,55 kN  D6(3,2)=  -8,55 kN
MF(2,3)=  22,36 kNm MF(3,2)=  20,40 kNm

UV(1)=   0,00 /EI    UR(1)=   0,00 /EI
UV(2)=  38,43 /EI    UR(2)=   2,45 /EI
UV(3)=   0,00 /EI    UR(3)=   0,00 /EI

Z8MAXX=  38,43 /EI   X= 3,00 m   P= 1
Z8MAXX=  38,70 /EI   X= 0,23 m   P= 2

MS= -23,99 kNm   X= 0,00 m   P= 1
MS=   0,11 kNm   X= 1,56 m   P= 1
MS=  22,36 kNm   X= 3,00 m   P= 1

MS=  22,36 kNm   X= 0,00 m   P= 2
MS=  -0,05 kNm   X= 2,62 m   P= 2
MS= -20,40 kNm   X= 5,00 m   P= 2
```

Exercises with BEAMPROGRAM111.

Joint data for all cases the same.



N9=3 joints.

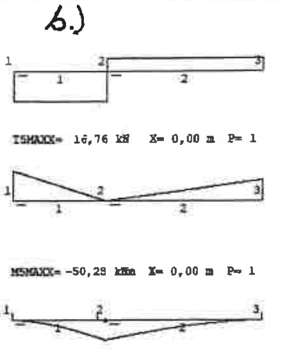
I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	-0	0	0	0	1	0	0
2	24	0	0	0	3	0	0	0	0
3	0	1	0	0	8	0	1	0	0

P9=2 beams.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	2

UV(2)= 38,43/EI   and   UR(2)= 2,45/EI

b.)



```
TSMAXX= 16,76 kN   X= 0,00 m   P= 1
MSMAXX= -50,28 kNm  X= 0,00 m   P= 1
Z8MAXX= 150,84 /EI  X= 0,00 m   P= 2

RV(1)=  16,76 kN      RM(1)= -50,28 kNm
RV(2)=   0,00 kN
RV(3)=   7,24 kN      RM(3)=  36,20 kNm

D6(1,2)= -16,76 kN  D6(2,1)=  16,76 kN
MF(1,2)= -50,28 kNm MF(2,1)=   0,00 kNm

D6(2,3)=   7,24 kN  D6(3,2)=  -7,24 kN
MF(2,3)=   0,00 kNm MF(3,2)=  36,20 kNm

UV(1)=   0,00 /EI    UR(1)=   0,00 /EI
UV(2)= 150,84 /EI    UR(2)=  75,42 /EI
UV(3)=   0,00 /EI    UR(3)=   0,00 /EI

HE(2,3)= -45,25 /EI

Z8MAXX= 150,84 /EI   X= 3,00 m   P= 1
Z8MAXX= 150,84 /EI   X= 0,00 m   P= 2

MS= -50,28 kNm   X= 0,00 m   P= 1
MS=   0,00 kNm   X= 3,00 m   P= 1

MS=   0,00 kNm   X= 0,00 m   P= 2
MS= -36,20 kNm   X= 5,00 m   P= 2
```

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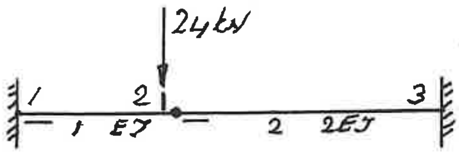

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N9=3 joints.

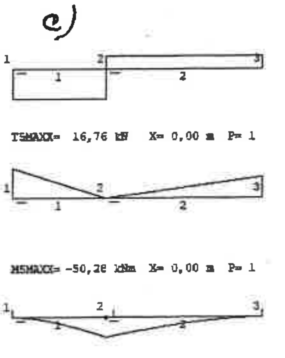
I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	24	0	0	0	3	0	0	0	0
3	0	1	0	0	8	0	1	0	0

P9=2 beams.

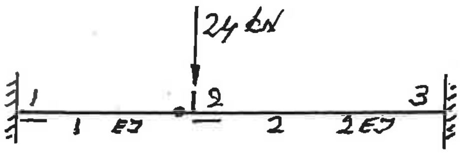
P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	1	0	2	2

HE(2,3)= -45,25/EI   and   UV(2)= 150,84/EI

c)



```
TSMAXX= 16,76 kN   X= 0,00 m   P= 1
MSMAXX= -50,28 kNm  X= 0,00 m   P= 1
Z8MAXX= 150,84 /EI  X= 0,00 m   P= 2

RV(1)=  16,76 kN      RM(1)= -50,28 kNm
RV(2)=   0,00 kN
RV(3)=   7,24 kN      RM(3)=  36,20 kNm

D6(1,2)= -16,76 kN  D6(2,1)=  16,76 kN
MF(1,2)= -50,28 kNm MF(2,1)=   0,00 kNm

D6(2,3)=   7,24 kN  D6(3,2)=  -7,24 kN
MF(2,3)=   0,00 kNm MF(3,2)=  36,20 kNm

UV(1)=   0,00 /EI    UR(1)=   0,00 /EI
UV(2)= 150,84 /EI    UR(2)= -45,25 /EI
UV(3)=   0,00 /EI    UR(3)=   0,00 /EI

HE(2,1)=  75,42 /EI

Z8MAXX= 150,84 /EI   X= 3,00 m   P= 1
Z8MAXX= 150,84 /EI   X= 0,00 m   P= 2

MS= -50,28 kNm   X= 0,00 m   P= 1
MS=   0,00 kNm   X= 3,00 m   P= 1

MS=   0,00 kNm   X= 0,00 m   P= 2
MS=  -0,07 kNm   X= 0,01 m   P= 2
MS= -36,20 kNm   X= 5,00 m   P= 2
```



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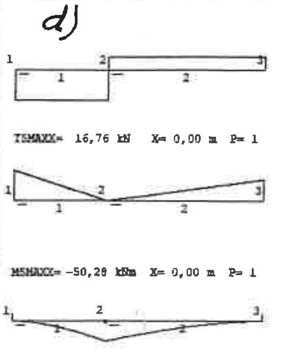
P9=2 beams.

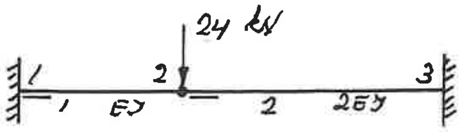
P	LL	HH	NL	NH	BA	EI
1	1	2	0	1	1	1
2	2	3	0	0	2	2

HE(2,1)= 75,42/EI   and   UV(2)= 150,84/EI

d)



```
TSMAXX= 16,76 kN   X= 0,00 m   P= 1
MSMAXX= -50,28 kNm  X= 0,00 m   P= 1
Z8MAXX= 150,84 /EI  X= 0,00 m   P= 2

RV(1)=  16,76 kN      RM(1)= -50,28 kNm
RV(2)=   0,00 kN
RV(3)=   7,24 kN      RM(3)=  36,20 kNm

D6(1,2)= -16,76 kN  D6(2,1)=  16,76 kN
MF(1,2)= -50,28 kNm MF(2,1)=   0,00 kNm

D6(2,3)=   7,24 kN  D6(3,2)=  -7,24 kN
MF(2,3)=   0,00 kNm MF(3,2)=  36,20 kNm

UV(1)=   0,00 /EI    UR(1)=   0,00 /EI
UV(2)= 150,84 /EI    UR(2)=   0,00 /EI
UV(3)=   0,00 /EI    UR(3)=   0,00 /EI

HE(2,1)=  75,42 /EI
HE(2,3)= -45,25 /EI

Z8MAXX= 150,84 /EI   X= 3,00 m   P= 1
Z8MAXX= 150,84 /EI   X= 0,00 m   P= 2

MS= -50,28 kNm   X= 0,00 m   P= 1
MS=   0,00 kNm   X= 3,00 m   P= 1

MS=   0,00 kNm   X= 0,00 m   P= 2
MS= -36,20 kNm   X= 5,00 m   P= 2
```



page 6-18

P9=2 beams.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	1	1	1
2	2	3	1	0	2	2

HE(2,1)= 75,42/EI
HE(2,3)= -45,25/EI   and   UV(2)= 150,84/EI

Example.

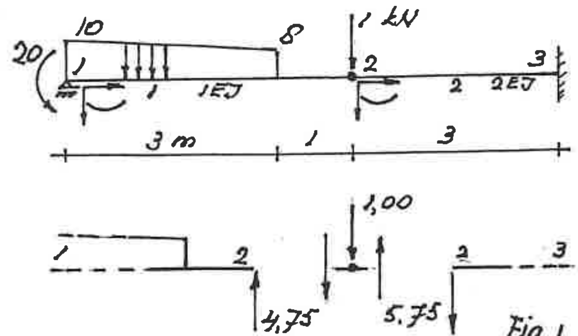
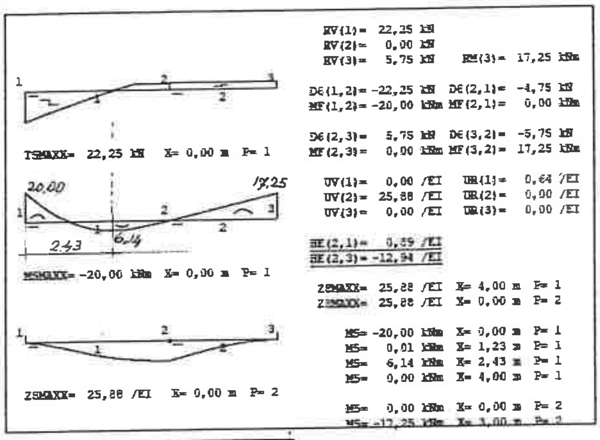
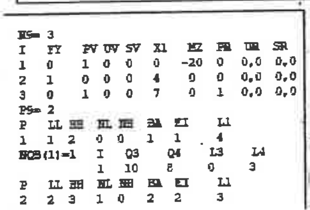
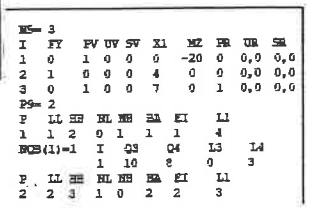


Fig. 1.







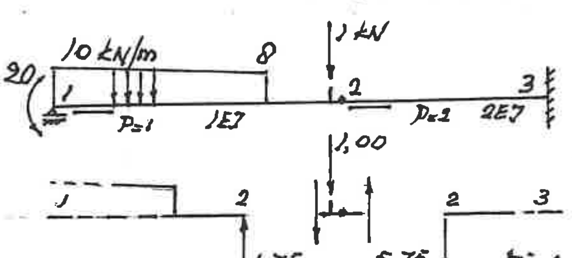


Fig.2.

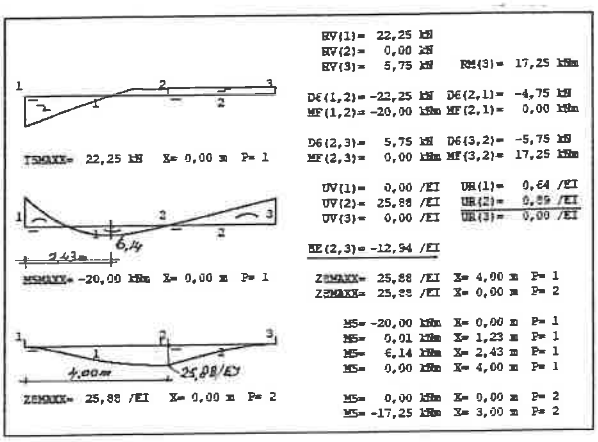


Fig.1.
A beam consisting of two parts connected with a hinge. Beam P=1 loaded with a distributed load, the hinge loaded with a vertical load force of 12 kN and at left end 1 of beam 1 acts a couple of forces with moment 20 kNm to the left.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	-20	0	0	0
2	1	0	0	0	4	0	0	0	0
3	0	1	0	0	7	0	1	0	0

Type 3 in text box TN9, next Tab, and type in TSTRING the 3 rows of joint data.
1,0,1,0,0,0,-20,0,0,0 Enter,
2,1,0,0,0,4,0,0,0,0 Enter and
3,0,1,0,0,7,0,1,0,0 Enter.

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	**0**	**1**	1	1

Type 1 in TNP, Tab, and type in TSTRING
1,1,2,0,1,1,1 Enter.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	Q44
1	1	1	10	8	0	3

Click Beam load forces NQB(P), and type
1,1,1,10,8,0,3 Enter.

P	LL	HH	NL	NH	BA	EI
2	2	3	**1**	0	2	2

Double click in TP9, type 2, Tab, in TSTRING
2,2,3,1,0,1,1 Enter.

Click Again, Calculate and DrawT5M5ELC to get the diagrams.
Next Reactions, Results and M5MaxZero.

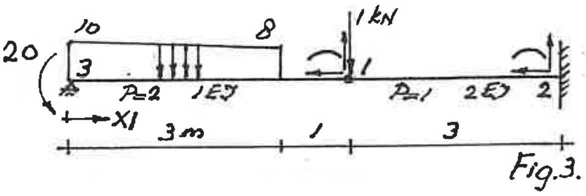
Since NH(1)=1 and NL(2)=1 two slopes/angles are separately calculated, see results on the left.
HE(2,1)= 0,98/EI and HE(2,3)= -12,94/EI,
no joint rotation UR(2).

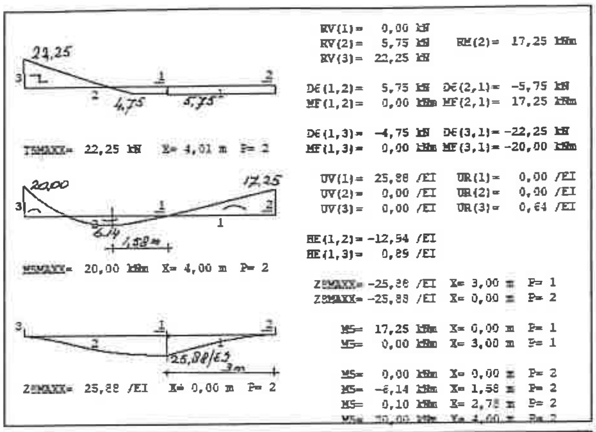
Store the results, click NR= to say 4, then click STORE, underlining STORE and NR=4.
Next day? Click GET, gets underlined, to get the stored data back.

Fig.2 like fig.1 with a little difference.
See the short stripe, beam end 2 of beam 1 is seen as a 'real' joint, therefore NH(1)=0!
When going on with the results just found, click CSE=0 to CSE=1, getting red, and type in TSTRING NH(1)=0 Enter. The results show
UR(2)= 0,98/EI and HE(2,3)= -12,94/EI.

This way one can see beam end 2 of beam 2 as a 'real' joint, then the little stripe is drawn on the right of the hinge. When going on then with CSE=1 to type in TSTRING
NH(1)=1 Enter and NL(2)=0 Enter.

Click Again etc. to find following results
HE(2,1)= 0,98/EI and UR(2)= -12,94/EI.
Three cases with same diagrams... ofcourse.





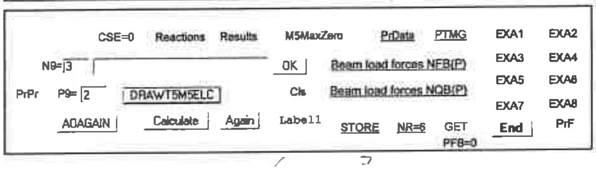


Fig.3.
Like on the preceding page but with different joint and beam/member numbering and with the beam axis systems at the other beam ends.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	1	0	0	0	4	0	0	0	0
2	0	1	0	0	7	0	1	0	0
3	0	1	0	0	0	-20	0	0	0

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	**1**	**0**	2	2
2	1	3	1	0	1	1

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	Q44
2	1	1	-8	-10	1	3

Again, Calculate and DrawT5M5ELC, Reactions, Results and M5MaxZero.

HE(1,2)= -12,94/EI to the left

HE(1,3)= 0,98/EI to the right

Fig.4.
Mirrored fig.3. but not the beam axis systems because that's not possible, axis system must be placed at the 'left end' of the beam.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	1	0	0	0	3	0	0	0	0
2	0	1	0	0	0	0	1	0	0
3	0	1	0	0	7	20	0	0	0

P9=2 beams/members.

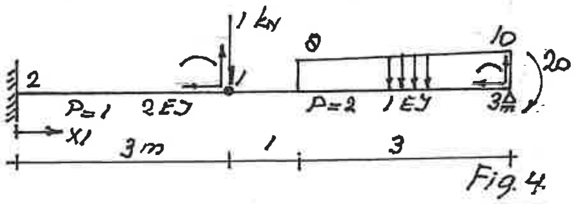
P	LL	HH	NL	NH	BA	EI
1	1	2	**1**	**0**	1	2
2	1	3	1	0	3	1

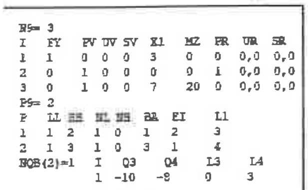
P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	Q44
2	1	1	-10	-8	0	3

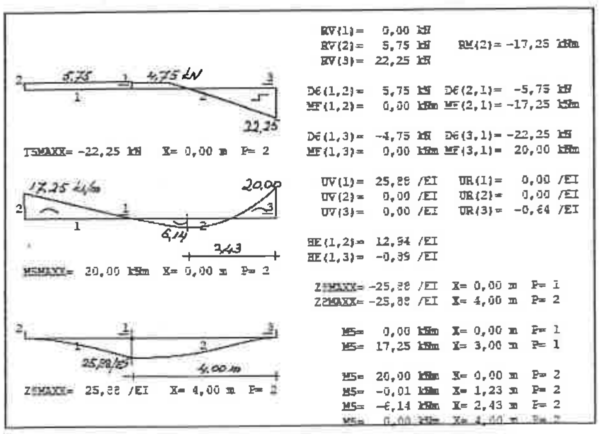
Again, etc.

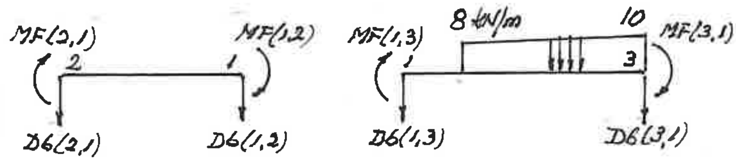
HE(1,2)= 12,94/EI to the right

HE(1,3)= -0,98/EI to the left

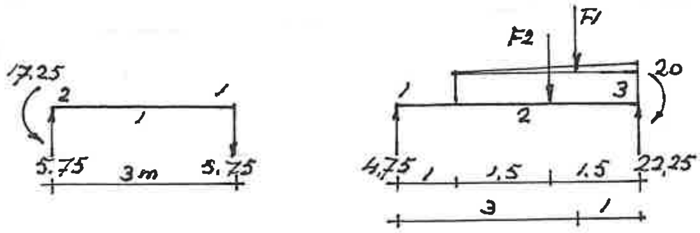








Forces and moments with assumed directions.

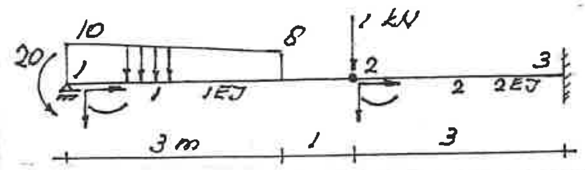


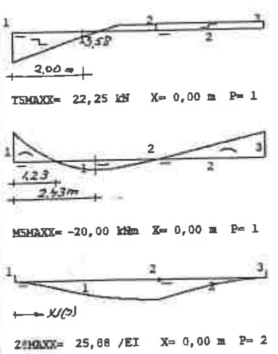
Forces and moments with real directions.

Beam 2 F1=(2*3)/2= 3 kN F2=8*3= 24 kN

∑ vert.=0 4,75-3,00-24,00+22,25=0 ok

∑ mom. joint 1=0
3*3 +24*2,5 +20 -22,25*4= 9+60+20-89=0 ok





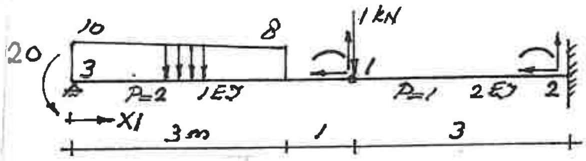
member P= 1 L1(1)= 4,000 m

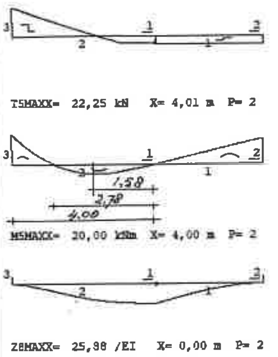
X m	T5 kN	T7 kN	M5 kNm
0,00	22,25		-20,00
0,50	17,33		-10,11
1,00	12,58		-2,64
1,50	8,00		2,50
2,00	3,58		5,39
2,50	-0,67		6,11
3,00	-4,75		4,75
3,50	-4,75		2,38
4,00	-4,75		0,00

max. moments, zero points

X m	M5 kNm
0,00	-20,00
1,23	0,00
2,43	6,14
4,00	0,00

page 12





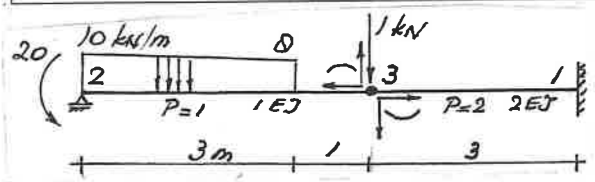
member P= 2 L1(2)= 4,000 m

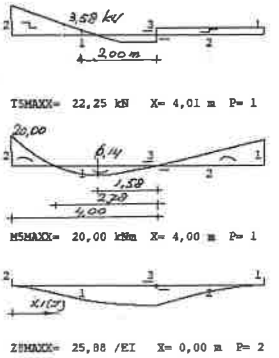
X m	T5 kN	T7 kN	M5 kNm
0,00	-4,75		0,00
0,50	-4,75		-2,38
1,00	-4,75		-4,75
1,50	-0,67		-6,11
2,00	3,58		-5,39
2,50	8,00		-2,50
3,00	12,58		2,64
3,50	17,33		10,11
4,00	22,25		20,00

max. moments, zero points

X m	M5 kNm
0,00	0,00
1,58	-6,14
2,78	0,00
4,00	20,00

page 13





member P= 1 L1(1)= 4,000 m

X m	T5 kN	T7 kN	M5 kNm
0,00	-4,75		0,00
0,50	-4,75		-2,38
1,00	-4,75		-4,75
1,50	-0,67		-6,11
2,00	3,58		-5,39
2,50	8,00		-2,50
3,00	12,58		2,64
3,50	17,33		10,11
4,00	22,25		20,00

max. moments, zero points

X m	M5 kNm
0,00	0,00
1,58	-6,14
2,78	0,00
4,00	20,00

Examples with PTMG.

Calculating shear force and bending moment for beam P at each step G measured from the beam end with the beam axis system.

Example of page 12.

After input of data click CSE=0 to red CSE=1, type in TSTRING for beam P=1 and step G=.5 P=1,G=.5 Enter.

Click PTMG for the results shown on the screen, from support 1 to the right.
x= 0,00 m   T5= 22,25 kN   M5= -20,00 kNm
T5 a positive value and M5 a negative value according to the assumptions made with the beam axis system.

With and at support 1,
a positive value means and ,
a negative value means and .

A 'maximum' moment of 5,14 kNm at 2.43 m from suppurt 1. A zero point M5=0 at 1,23 m.

Example of page 13.

The beam axis sytems are placed at the other beam ends. See page for input of data. Now the first beam is P=2, support are numbered 3-1-2 instead of 1-2-3!

Next like done above.
CSE=1 and in TSTRING P=2,G=.5 Enter.
Now distances measured from beam end 1.
Because of the place of the beam axis system the order of the printed results is different.

With and at support 1,
a positive value means and ,
a negative value means and .

Values of the shear forces are the same, values of the bending moments have an opposite sign.

Above X= 2,50 m T5= -0,67 kN M5= 6,11 kNm,
now X= 1,50 m T5= -0,67 kN M5= -6,11 kNm.

Third example.

Changed numbering of supports and beams.
N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	7	0	1	0	0
2	0	1	0	0	0	-20	0	0	0
3	1	0	0	0	4	0	1	0	0

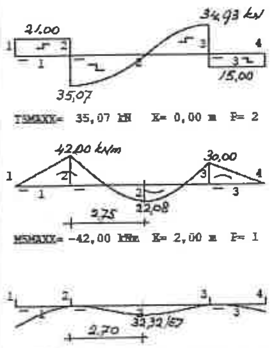
P9=2 beams

P	LL	HH	NL	NH	BA	EI
1	2	3	0	1	3	1
2	1	3	0	1	3	2

When choosing a special step, e.g. 2,75 m then CSE=1 and P=1,G=2.75 Enter, click PTMG,

X= 2,75 m   T5= -5,75 kN   M5= 1,44 kNm.

```
N9= 4
I   FY    PV UV SV  X1    MZ  PR  UR   SR
1   21    0  0  0   0     0   0   0,0  0,0
2   0     1  0  0   2     0   0   0,0  0,0
3   0     1  0  0   7     0   0   0,0  0,0
4   15    0  0  0   9     0   0   0,0  0,0
P9= 3
P   LL HH  NL NH  BA  EI    L1
1   1  2   0  0   1   1     2
2   2  3   0  0   2   1     5
NQB(2)=2   I   Q3    Q4    L3    L4
           1   0     28    0     3
           2   28    0     3     2
P   LL HH  NL NH  BA  EI    L1
3   3  4   0  0   3   1     2
```




```
TSMAXX=  35,07 kN    X= 0,00 m   P= 2
M5MAXX= -42,00 kNm   X= 2,00 m   P= 1
Z8MAXX=  68,51 /EI   X= 0,00 m   P= 1

RV(1)=   0,00 kN
RV(2)=  56,07 kN
RV(3)=  49,93 kN
RV(4)=   0,00 kN

DE(1,2)=  21,00 kN  DE(2,1)= -21,00 kN
MF(1,2)=   0,00 kNm MF(2,1)=  42,00 kNm

DE(2,3)= -35,07 kN  DE(3,2)= -34,93 kN
MF(2,3)= -42,00 kNm MF(3,2)=  30,00 kNm

DE(3,4)= -15,00 kN  DE(4,3)=  15,00 kN
MF(3,4)= -30,00 kNm MF(4,3)=   0,00 kNm

UV(1)=  68,51 /EI   UR(1)= -48,26 /EI
UV(2)=   0,00 /EI   UR(2)=  -6,26 /EI
UV(3)=   0,00 /EI   UR(3)=  -7,09 /EI
UV(4)=  25,82 /EI   UR(4)=  22,91 /EI

Z8MAXX=  68,51 /EI   X= 0,00 m   P= 1
Z8MAXX=  32,32 /EI   X= 2,70 m   P= 2
Z8MAXX=  25,82 /EI   X= 2,00 m   P= 3
```

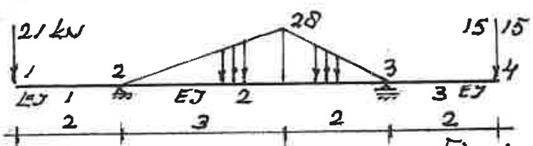


Fig. 1.

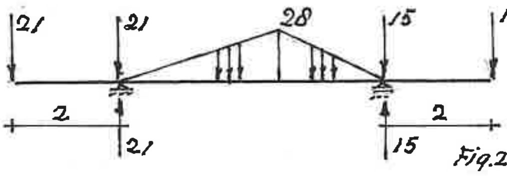


Fig.2a

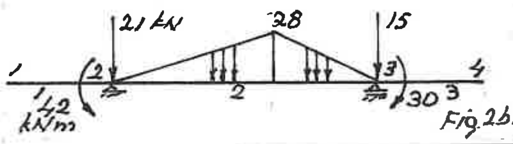
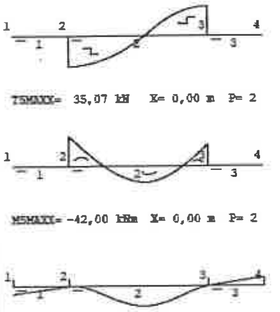


Fig.2b.

```
N9= 4
I   FY    PV UV SV  X1    MZ  PR  UR   SR
1   0     0  0  0   0     0   0   0,0  0,0
2   21    1  0  0   2   -42   0   0,0  0,0
3   15    1  0  0   7    30   0   0,0  0,0
4   0     0  0  0   9     0   0   0,0  0,0
P9= 3
P   LL HH  NL NH  BA  EI    L1
1   1  2   0  0   1   1     2
2   2  3   0  0   2   1     5
NQB(2)=2   I   Q3    Q4    L3    L4
           1   0     28    0     3
           2   28    0     3     2
P   LL HH  NL NH  BA  EI    L1
3   3  4   0  0   3   1     2
```



```
TSMAXX=  35,07 kN    X= 0,00 m   P= 2
M5MAXX= -42,00 kNm   X= 0,00 m   P= 2
Z8MAXX=  32,32 /EI   X= 2,70 m   P= 2

RV(1)=   0,00 kN
RV(2)=  56,07 kN
RV(3)=  49,93 kN
RV(4)=   0,00 kN

DE(1,2)=   0,00 kN  DE(2,1)=   0,00 kN
MF(1,2)=   0,00 kNm MF(2,1)=   0,00 kNm

DE(2,3)= -35,07 kN  DE(3,2)= -34,93 kN
MF(2,3)= -42,00 kNm MF(3,2)=  30,00 kNm

DE(3,4)=   0,00 kN  DE(4,3)=   0,00 kN
MF(3,4)=   0,00 kNm MF(4,3)=   0,00 kNm

UV(1)=  12,51 /EI   UR(1)=  -6,26 /EI
UV(2)=   0,00 /EI   UR(2)=  -6,26 /EI
UV(3)=   0,00 /EI   UR(3)=  -7,09 /EI
UV(4)= -14,18 /EI   UR(4)=  -7,09 /EI

Z8MAXX=  12,51 /EI   X= 0,00 m   P= 1
Z8MAXX=  32,32 /EI   X= 2,70 m   P= 2
Z8MAXX= -14,18 /EI   X= 2,00 m   P= 3
```

Example.

Fig.1.
N9=4 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	21	0	0	0	0	0	0	0	0
2	0	1	0	0	2	0	0	0	0
3	0	1	0	0	7	0	0	0	0
4	15	0	0	0	9	0	0	0	0

P9=3 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1
3	3	4	0	0	3	1

Beam 2 with distributed beam loads.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	Q44
2	2	1	0	28	0	3
2	2	2	28	0	3	2

Type 4 in TN9, Tab, cursor in TSTRING and type the four rows of data in TSTRING,
1,21,0,0,0,0,0,0,0,0 Enter etc. Cursor in TP9.

Type 3 in TP9, Tab, cursor in TSTRING and type the three rows of data,
1,1,2,0,0,1,1 Enter, etc.

Click Beam load forces NQB(P), getting bold, and type in TSTRING, with CSE=0,
2,2,1,0,28,0,3 Enter and
2,2,2,28,0,3,2 Enter.

Click PrData, the data appear on the screen in correct order.

Click Again, Calculate and DrawT5M5ELC to get the diagrams.
Click Reactions, Results and M5MaxZero.

Fig.1, 2a and 2b.
The force of 21 kN at joint 1 is resolved into a force of 21 kN at joint 2 plus a couple of forces with a moment of 21*2= 42 kNm acting at joint 2.
In similar way the force of 15 kN at beam end 4 is resolved into 15 kN at joint 3 plus a couple of forces with moment of 15*2= 30 kNm acting at joint 3.
Beam 1 and 3 are not loaded any more but they are still there, so still 4 joints and 3 beams.

N9=4 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	0	0	0	0	0	0	0	0
2	0	1	0	0	2	-42	0	0	0
3	0	1	0	0	7	30	0	0	0
4	0	0	0	0	9	0	0	0	0

Going on with the example here above. Joint data with som changes.
Click CSE=0 To CSE=1 and type successively in TSTRING the changed joint data as follows,
FY(1)=0 Enter, FY(4)=0 Enter,
MZ(2)=-42 Enter and MZ(3)=30 Enter.
The data of all beams are like given before.
Click PrData to see the changes.
Again, Calculate and M5MaxZero to get the same results for beam 2 as above.

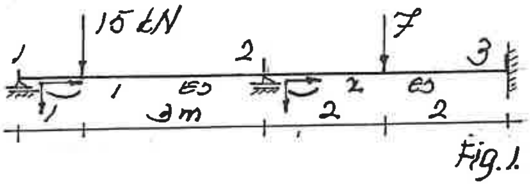
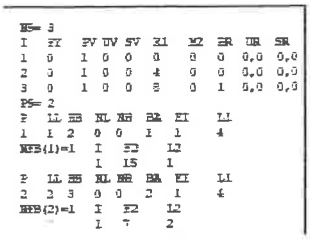
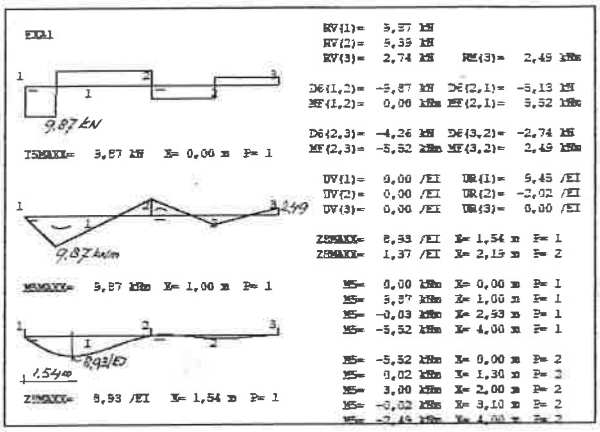
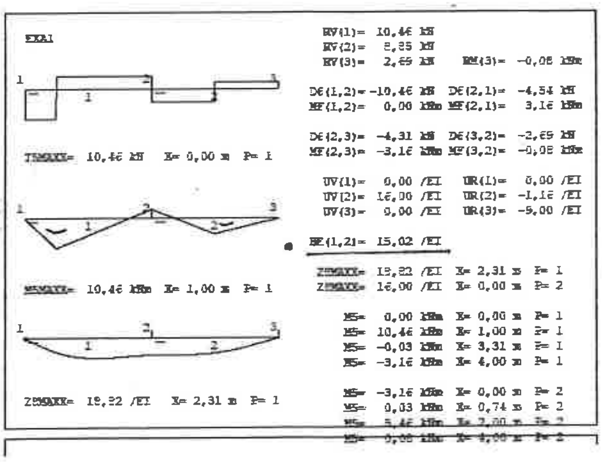
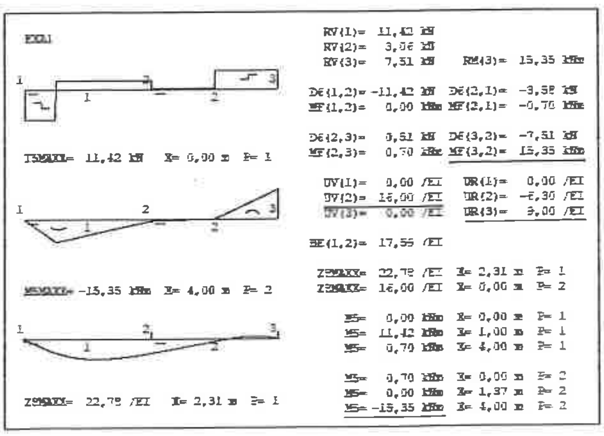


Fig.1









Examples EXA1 to EXA8 to click on, with given data to check by clicking PrData.

Fig.1 is EXA1.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	1	0	0	4	0	0	0	0
3	0	1	0	0	8	0	1	0	0

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	1	1	15	1
2	1	1	7	2

Click on EXA1, next on Again, Calculate and DrawT5M5ELC to get the diagrams printed, next Reactions, Results, M5MaxZero. See the print.

The joints have the short stripes indicating the joints are seen as 'real joints' of which the rotations are calculated, UR(1)= 9,45   UR(2)= -2,02   UR(3)= 0,00   /EI.

T5MAXX= 9,87 kN is the largest shear force, a positive value, so as assumed according ,

M5MAXX= 9,87 kNm, the largest bending moment, a positive value, so as assumed according .

ZMAX= 8,93/EI the largest vertical displacement by bending, a positive value, so as assumed downward.

Assume a vertical translation UV(2)= 16/EI of joint 2 and a joint rotation to the left UR(3)= -9/EI of joint/clamp 3.

Beam end 1, joint 1, will be seen as a hinge NL(1)=1 instead of a 'real joint' NL(1)=0.

Before input of these data click Again to make all UV(I) and UR(I) zero. Next click CSE=0 to CSE=1 and type in TSTRING UV(2)=16 Enter and UR(3)=-9 Enter and NL(1)=1 Enter.

To carry out the calculation do not click Again because it deletes UV(2) and UR(3)! So click Calculate, DrawT5M5ELC etc. to get the second print.

See the bold dot at joint 1 to indicate it is seen as a hinge. UR(1)= 0,00/EI to be ignored (not programmed) HE(1,2)= 15,02/EI separately calculated.

The clamp moment is MF(3,2)= -0,08 kNm, assumption to the right, because of the negative value not as assumed, so to the left, according to .

With UR(3)=9, not -9, MF(3,2)= 15,35 kNm. See the tird print, bending moment M5= -15,35 kNm!.

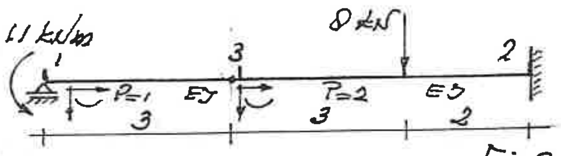
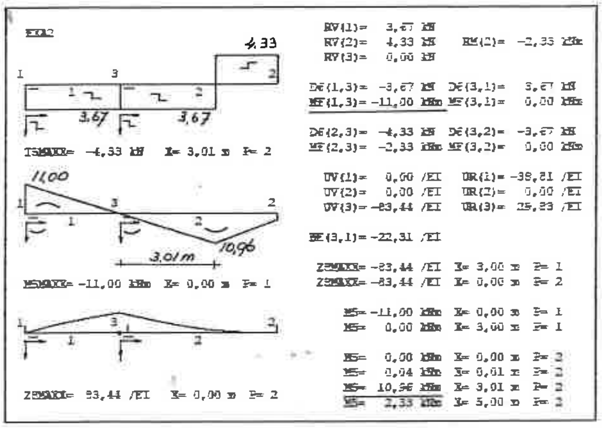


Fig.2.

N9= 3									
I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	-11	0	0,0	0,0
2	0	1	0	0	8	0	1	0,0	0,0
3	0	0	0	0	3	0	0	0,0	0,0

P9= 2							
P	LL	HH	NL	NH	BA	EI	L1
1	1	3	0	1	1	1	3
2	2	3	0	0	3	1	5

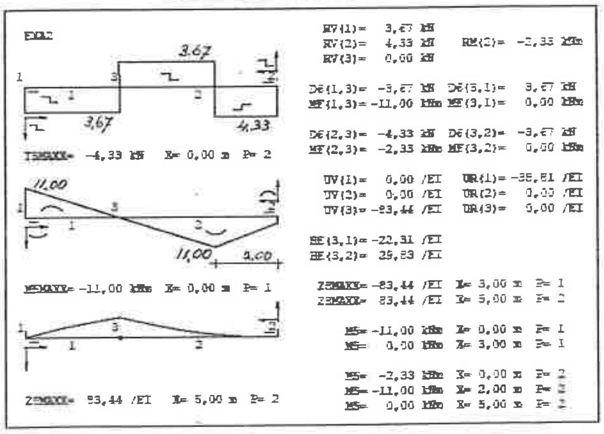
NFB(2)=1	I	F2	L2
	1	8	3



N9= 3									
I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	-11	0	0,0	0,0
2	0	1	0	0	8	0	1	0,0	0,0
3	0	0	0	0	3	0	0	0,0	0,0

P9= 2							
P	LL	HH	NL	NH	BA	EI	L1
1	1	3	0	1	1	1	3
2	2	3	0	1	2	1	5

NFB(2)=1	I	F2	L2
	1	-8	2



Example EXA2

Fig.2.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	-11	0	0	0
2	0	0	0	0	8	0	1	0	0
3	0	1	0	0	3	0	0	0	0

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	3	0	1	1	1
2	2	3	0	0	3	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
2	1	1	8	3

Beam end 1, joint 1, is load with 11 kNm to the left MZ(1)=-11 kNm, therefore NL(1)=0!, it cannot be a hinge with NL(1)=1.

Click EXA2, next Again etc.
UR(1)= -38,81/EI and HE(3,1)= -22,31/EI so beam P=1 is not a straight line, is bent.

Beam end moment MF(2,3)= -2,33 kNm, not as assumed to the right, but to the left.
M5 = 2,33 kNm directed as assumed.

Suppose the beam axis system of beam 2 is placed at beam end 2, BA(2)=2, at the clamp, and beam end 3 of beam 2 is seen as a hinge, so not NH(2)=0 but NH(2)=1.

No values for UV(I) or UR(I) will be put in so it's not necessary to click Again before input like on the preceding page. Do it yet on behalf of PrData before the calculation.

Click Again, CSE=0 to CSE=1 and type in TSTRING BA(2)=2 Enter and NH(2)=1 Enter.

The load data of beam 2 must be changed.

P	NFB(P)	I	F22(P,I)	L22(P,I)
2	1	1	-8	2

Click Beam load forces NFB(P), and with CSE=1

in TSTRING **2,1,1,-8,2** Enter.
Click PrData to see the difference.

First case.		Second case.	
Z8MAXX= -83,44/EI	P=1	Z8MAXX= -83,44/EI	P=1
Z8MAXX= -83,44/EI	P=2	Z8MAXX= 83,44/EI	P=2
MF(1,3)= -11,00	P=1	MF(1,3)= -11,00	p=1
MF(2,3)= -2,33	P=2	MF(2,3)= -2,33	P=2

In every case member end moments MF(L,H) and MF(H,L) assumed direction to the right.

Moments M5 according the places of .

M5= -11,00 kNm	P=1	M5= -11,00 kNm	P=1
M5= 10,96 kNm	P=2	M5= -11,00 kNm	P=2

The deformation of the beams is, ofcourse, the same, the place of does not matter.

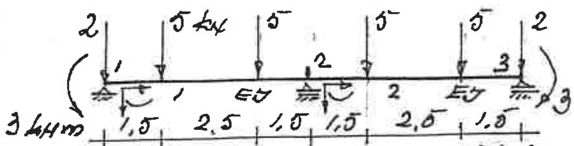


Fig.3.

Example EXA3

Fig.3.

Below the data to start with. The beam ends 1 and 3 are loaded with couples of forces with moments 3 kNm with NL(1)=0 and NH(2)=0!

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	-3	0	0	0
2	0	1	0	0	8	0	0	0	0
3	0	1	0	0	3	3	0	0	0

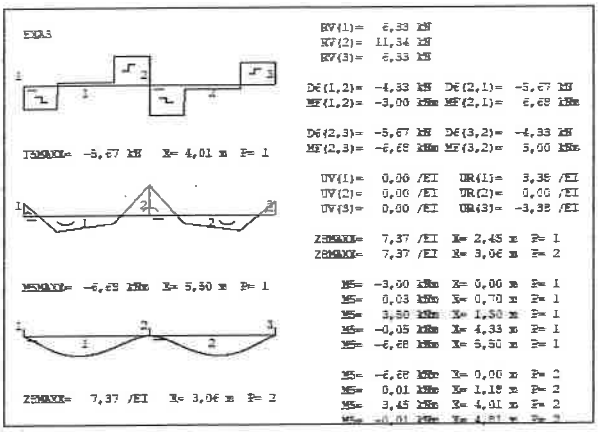
P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

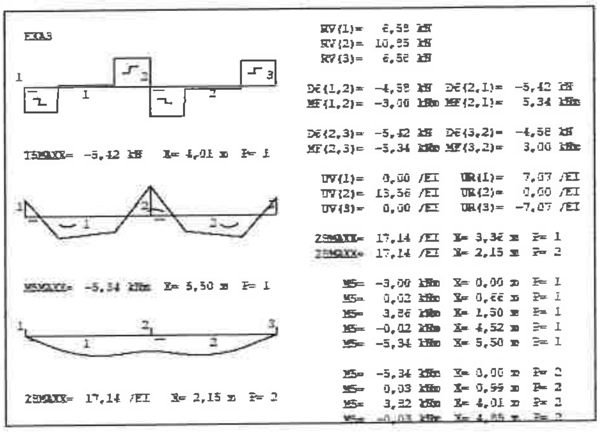
P	NFB(P)	I	F22(P,I)	L22(P,I)
1	2	1	5	1.5
1	2	2	5	4

P	NFB(P)	I	F22(P,I)	L22(P,I)
2	2	1	5	1.5
2	2	2	5	4

Click Again, Calculate, DrawT5M5ELC etc. to get the first print.

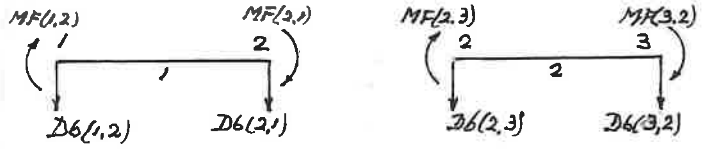


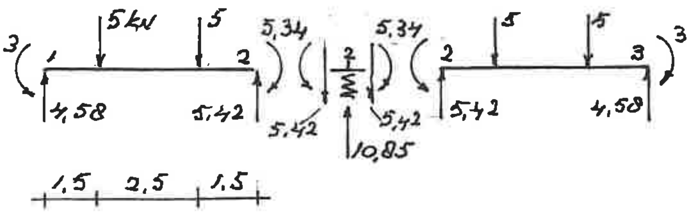
Suppose that support 2 is springy supported, spring constant SV(2)=0.8EI and PV(2)=1 becomes PV(2)=0. With CSE=1 to type in TSTRING SV(2)=0.8 Enter and PV(2)=0 Enter.



Click Again etc.. The second print shows the displacement of support 2, UV(2)= 13,56/EI.

The spring force F is SV(2)*UV(2), F=(0.8EI)*(13,56/EI)= 10,85 kN equals reaction force RV(2)= 13,85 kN.



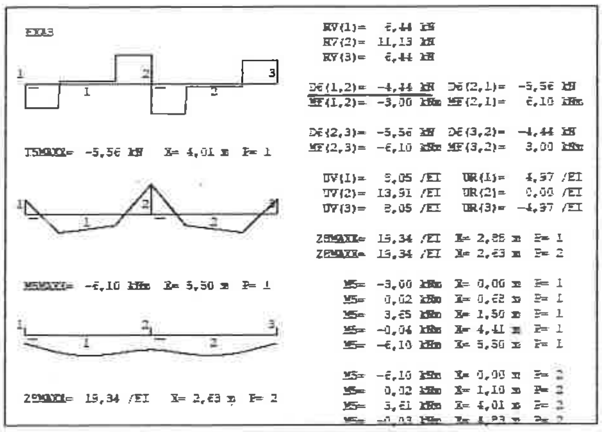


Beam 1 is cut on the right of support 1 and on the left of support 2. Equilibrium?

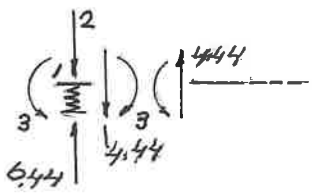
$\sum$ vert.=0 5+5 -4,58-5,42=0 ok

$\sum$ mom. about end 1.

5*1,5+5*4 -5,42*5,5 -3+5,34= 0,03 ok



Now joint 1 and 3 will also being supported by springs with constant 0.8EI. CSE=1, in TSTRING PV(1)=0 Enter and SV(1)=0.8 Enter,



Support 1 displaces UV(1)=8,05/EI

Spring force F=(0,8EI)*(8,05/EI)= 6,44 kN is reaction force RV(1)= 6,44 kN.

D6(1,2)= -4,44 kN 2+4,44= 6,44 eq. support 1.

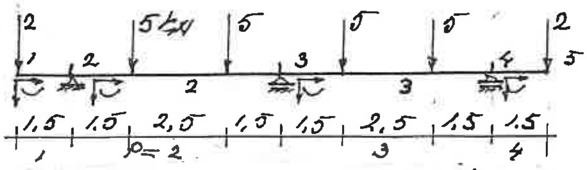
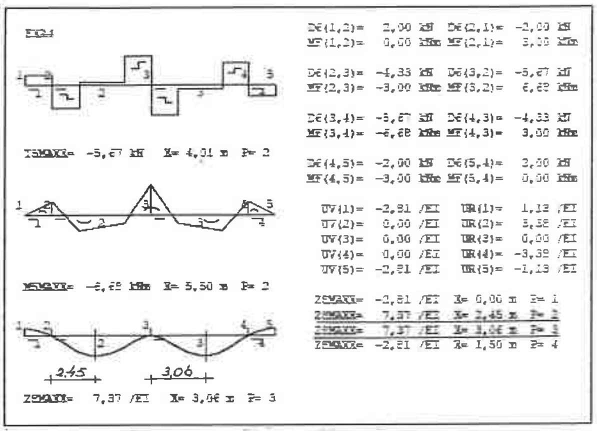
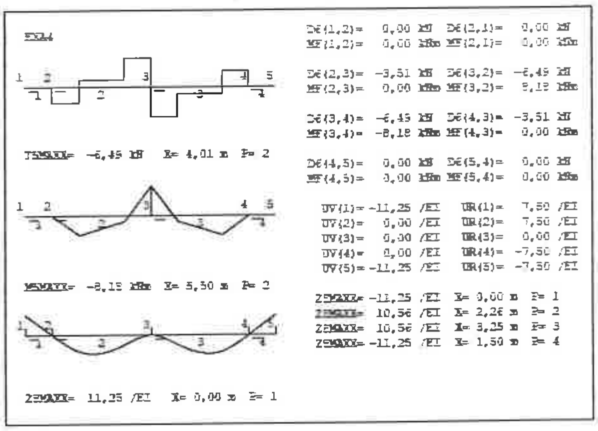


Fig.4.





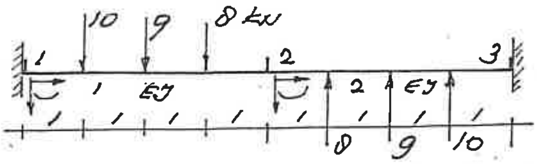
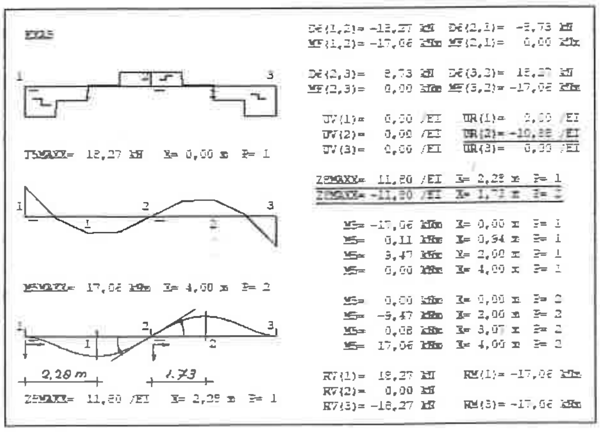


Fig. 5.



Example EXA4

Fig.4.

N9=5 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	2	0	0	0	0	0	0	0	0
2	0	1	0	0	1.5	0	0	0	0
3	0	1	0	0	7	0	0	0	0
4	0	1	0	0	12.5	0	0	0	0
5	2	0	0	0	14	0	0	0	0

P9=4 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1
3	3	4	0	0	3	1
4	4	5	0	0	4	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
2	2	1	5	1.5
2	2	2	5	4

P	NFB(P)	I	F22(P,I)	L22(P,I)
3	2	1	5	1.5
3	2	2	5	4

Click Again, Calculate, DrawT5M5ELC etc. to get the first print.

Suppose Beam load forces FY(1)=2 and FY(5)=2 are removed, then with CSE=1 to type in TSTRing FY(1)=0 Enter and FY(5)=0 Enter.

Click Again, Calculate etc., see second print.

Example EXA5.

Fig.5.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	0	0	0	0	4	0	0	0	0
3	0	1	0	0	8	0	1	0	0

P9=2 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	3	1	10	1
1	3	2	9	2
1	3	3	8	3

P	NFB(P)	I	F22(P,I)	L22(P,I)
2	3	1	-8	1
2	3	2	-9	2
2	3	3	-10	3

Again etc. to get the third print.
Joint 2 is not spported, PV(2)=0. Because of 'symmetrie' joint 2 does not displace, UV(2)=0.

Suppose place at beam end 3 of beam 2.
~~Click~~ Beam load forces NFB(P), and in TSTRING,
2,3,1,-10,1 Enter, Beam load forces NFB(P),
2,3,2,-9,2 Enter, Beam load forces NFB(P),
2,3,3,-8,3 Enter.

After Again etc. a print appears, not shown here, with same elastic curve, deformation line, and same shear force signs and bending moment signs, ofcourse!

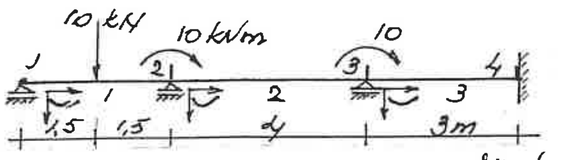
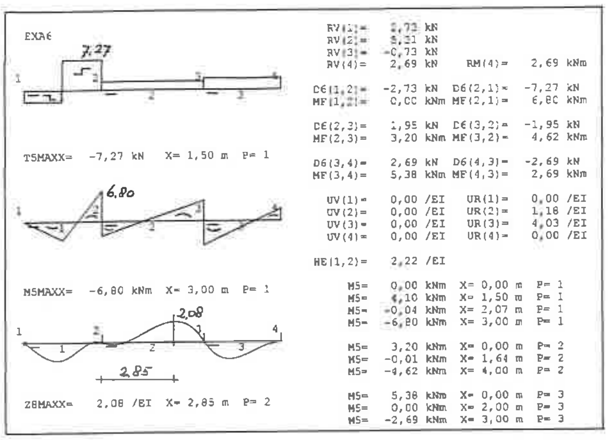
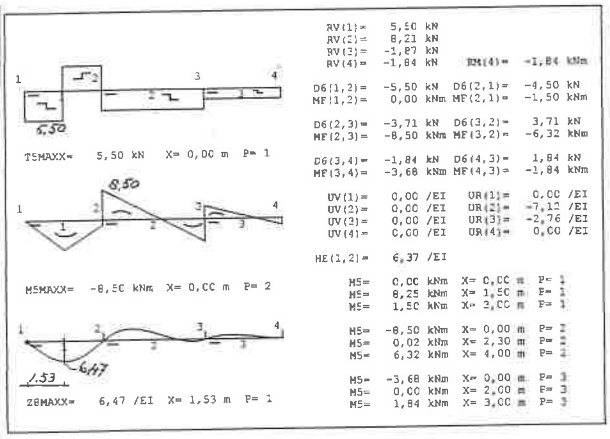
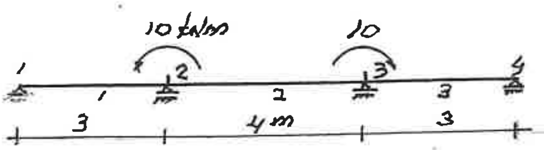
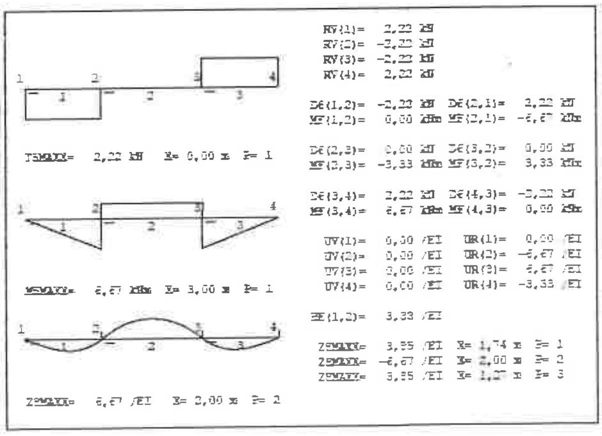


Fig.6.









Example EXA6.

Fig.6.

N9=4 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	1	0	0	3	-10	0	0	0
3	0	1	0	0	7	0	0	0	0
4	0	1	0	0	10	10	1	0	0

P9=3 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	1	0	1	1
2	2	3	0	0	2	1
3	3	4	0	0	3	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	1	1	10	1.5

Joint 2 is loaded with a couple of forces with a moment of 10 kNm to the left, MZ(2)= -10 and joint 3 is loaded with a couple of forces with a moment of 10 kNm to the right, MZ(3)= 10 kNm.

Click Again, Calculate, DrawT5M5ELC etc. to get the first print, by clicking PrPr to get the printer print.
The joints with the little stripes give the calculated joint rotations UR(I) of the joints 2, 3 and 4, joint 1 is not a 'real joint', the member end rotation is separately calculated, HE(1,2)= 2,22/EI, see the bold dot, a hinge.

With no maximum displacements Z8MAXX, they are printed on the screen when double clicking PrF shown here below.

Z8MAXX= 1,59 /EI X= 1,28 m P= 1
Z8MAXX= -2,08 /EI X= 2,85 m P= 2
Z8MAXX= 1,79 /EI X= 1,00 m P= 3

Suppose the joint load moments are given an opposite direction, then with CSE=1 to type in TSTRING MZ(2)=-10 Enter and MZ(3)=-10 Enter.
Click PrPr to get the second print. With HE(1,2)= 6,37/EI to the right.

A third change.
Going on with the second case.
Suppose joint 2 loaded with 10 kNm to the left like the second case, no change, and joint 3 loaded with 10 kNm to the right like the first case. CSE=1 and MZ(3)=10 Enter.

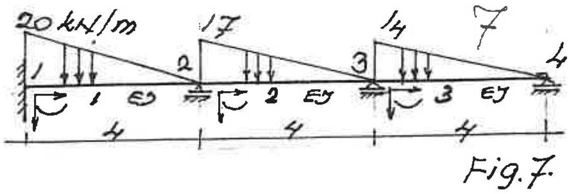
Also beam load force of 10 kN of beam 1 is removed.

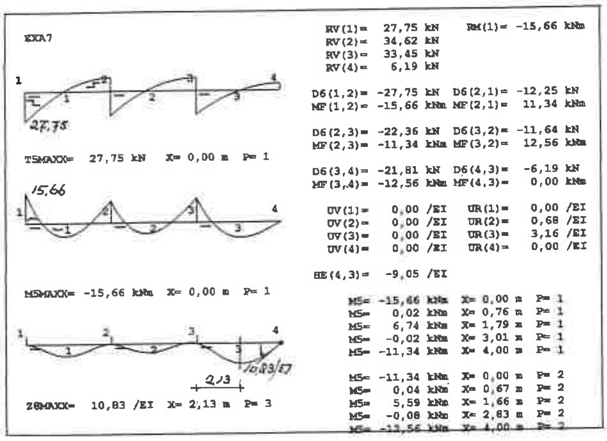
P	NFB(P)	I	F22(P,I)	L22(P,I)
1	1	1	0	1.5

Click Beam load forces NFB(P) and type, with CSE=1 in TSTRING 1,1,1,0,1.5 Enter.

And the clamp at beam end 4 will be removed, CSE=1, in TSTRING PR(4)=0 Enter.

Again, etc. and PrPr to get the third printer print. A print with nice diagrams with HE(1,2)= 3,33/EI, to the right.





Example EXA7.

Fig.7.

N9=4 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	0	1	0	0	4	0	0	0	0
3	0	1	0	0	8	0	0	0	0
4	0	1	0	0	12	0	0	0	0

P9=3 beams/members.

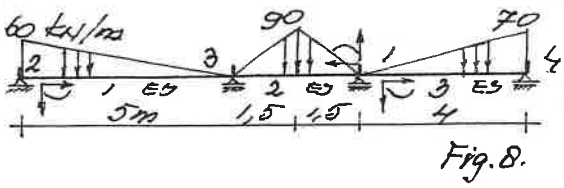
P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1
3	3	4	0	1	3	1

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	20	0	0	4
2	1	1	17	0	0	4
3	1	1	14	0	0	4

Click Again, Calculate, DrawT5M5ELC etc. Then click PFB=0 to PFB=1 to get a 'bold' print by the printer, click PrPr, see the print.
NH(3)=1 therefore HE(4,3)= -9,05/*EI*.

Example EXA8.

Fig.8.



Ah, irregular joint numbering.

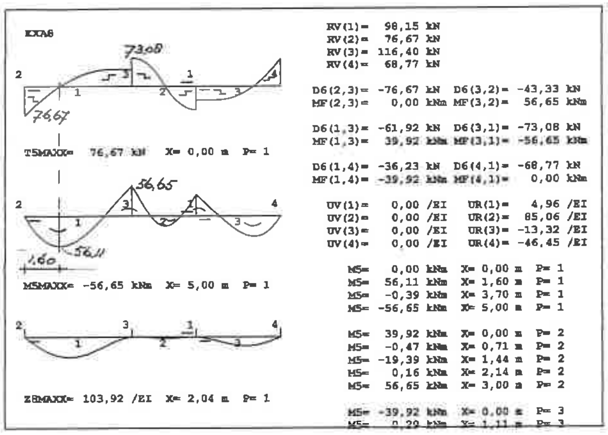
N9=4 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	0	1	0	0	4	0	0	0	0
3	0	1	0	0	8	0	0	0	0
4	0	1	0	0	12	0	0	0	0

P9=3 beams/members.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	3	1
3	3	4	0	0	3	1

Beam axis system of beam 2 to at beam end 3!

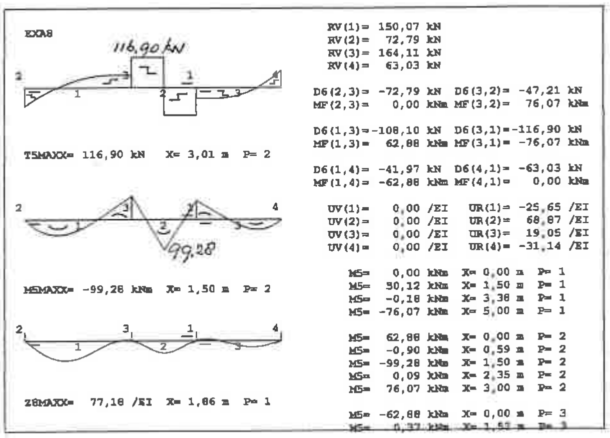


P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	60	0	0	5

The beam axis system of beam 2 is placed at member end 1! So -90 i.s.o. 90.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
2	2	1	0	-90	0	1.5
2	2	2	-90	0	1.5	3
3	1	1	0	70	0	4

Again etc., and PFB=1 for 'bold' printer print, click PrPr.



Second case.
The distributed load of beam 2 will be removed, and replaced by a load force of 225 kN placed in the middle of the beam.

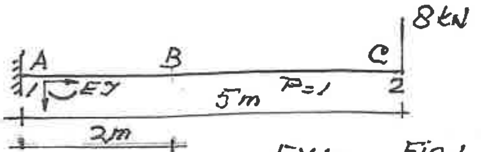
P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
2	2	etc.				

Click Beam load forces NQB(P), in TSTRING 2,0 Enter, only 2,0 that's enough. Number of q-loads was 2, now **0**.

P	NFB(P)	I	F22(P,I)	L22(P,I)
2	1	1	-225	1.5

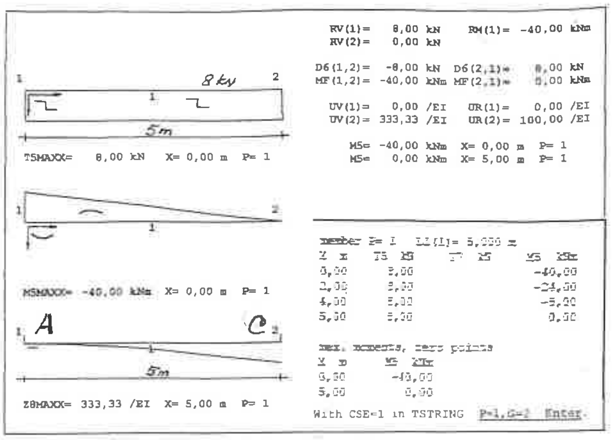
Next click Beam load forces NFB(P), in TSTRING 2,1,1,-225,1.5 Enter, minus 225 because of the place of the beam axis system.
Again, Calculate etc., third printer print.

Examples EX1.
Click them, calculation is carried out, diagrams appear, with clicking Reactions, Results and M5MaxZero results are printed.



EX1a Fig.1.

Fig.1. Length A-C is 5 m.



Example EX1a after clicking EX1.
N9=2 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	8	0	0	0	5	0	0	0	0

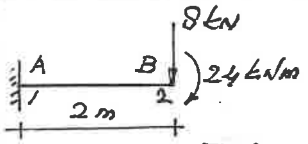
P9=1 beam.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1

Click Calculate, DrawT5M5ELC, Reactions and Results, M5MaxZero.
UV(2)= 333,33/EI and UR(2)= 100,00/EI.

Calculating the displacement at 2 m.
With TPMG it is not programmed to calculate the displacement at each step G (pity). But shear force and bending moment can be calculated first and after that the displacement, the end of a clamped beam of 2 m.

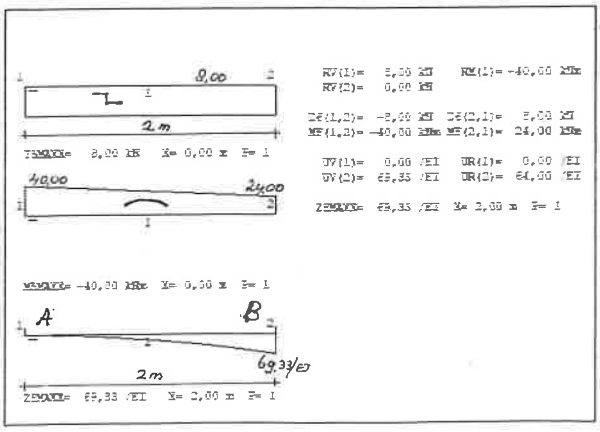
With CSE=1 to type in TSTRING P=1,G=2 Enter.
Next click PTMG, see the results added to the first print.
At 2,00 m T5= 8,00 kN, as assumed so , and M5= -24,00 kNm, not as assumed so



EX1b

Fig 2.

Fig.2. Length A-B is 2m.



Example EX1b after a click on EX1a.
To get the displacement at 2 m the calculation like above can be carried out for a beam with length 2 m with 8 kN and 24 kNm as beam end loads.
N9=2 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	1	0	0
2	8	0	0	0	2	24	0	0	0

P9=1 beam.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1

Click Calculate, DrawT5M5ELC, Reactions and Results, M5MaxZero.
UV(2)= 69,33/EI and UR(2)= 64,00/EI.

EX1c

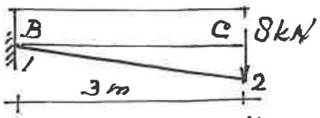
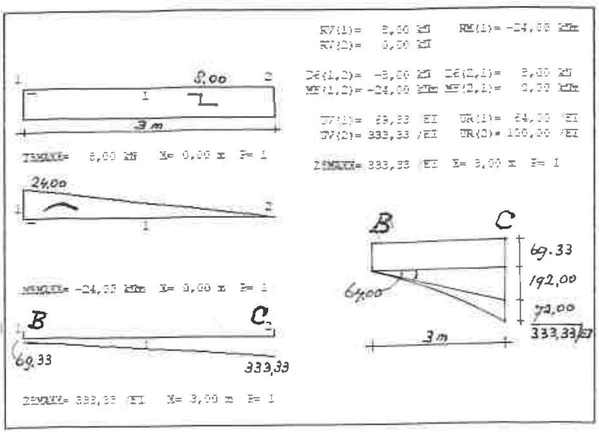


Fig. 3.

Fig.3. Length BC is 3 m.



Example EX1c after a click on EX1b.
Now part C-B with length of 3 m can be treated like above with UV(2) and UR(2) as start values at the clamp. Data to put in here below.
Length C-B is 3 m.

N9=2 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	69.33	0	0	0	1	64	0
2	8	0	0	0	3	0	0	0	0

P9=1 beam.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1

Click Calculate, DrawT5M5ELC, Reactions and Results, M5MaxZero.
Results see the third print, like first print, UV(2)= 333,33/EI and UR(2)= 100,00/EI.

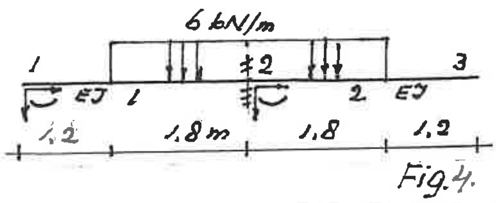
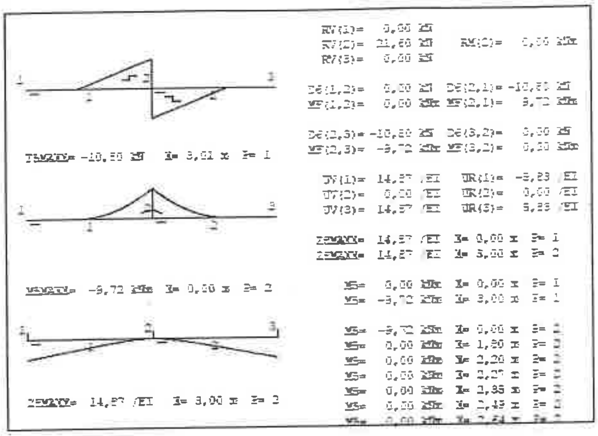
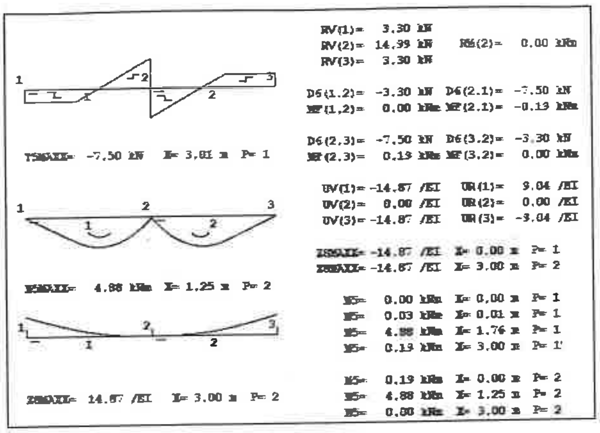


Fig.4.



(surprise... so many zeros...)



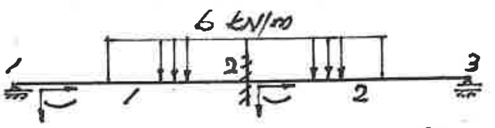
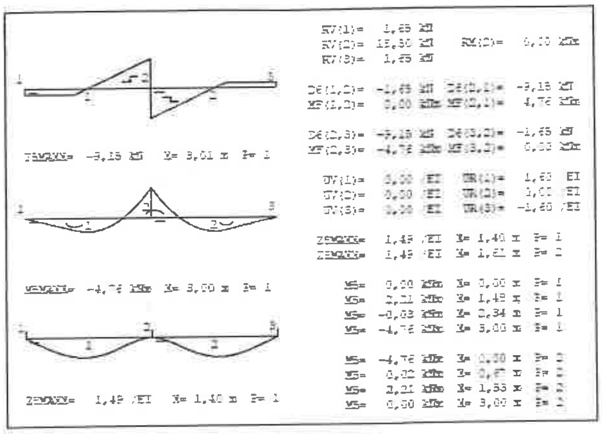


Fig.5.



Example EX1d after a click on EX1c, diagrams appear, calculation results can be added by clicking Reactions, Results and M5MaxZero.

Fig.4.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	0	0	0	0	0	0	0	0
2	0	1	0	0	3	0	1	0	0
3	0	0	0	0	6	0	0	0	0

Type 3 in TN9, Tab, cursor in TSTRING and type there each row of data.
1,0,0,0,0,0,0,0,0,0 Enter,
2,0,1,0,0,3,0,1,0,0 Enter and
3,0,0,0,0,6,0,0,0,0 Enter.

P9=2 beams.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

Cursor appears in TP9. Type there 2, Tab, cursor in TSTRING and type two rows of data,
1,1,2,0,0,1,1 Enter and
2,2,3,0,0,2,1 Enter.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	6	6	1.2	1.8
2	1	1	6	6	0	1.8

Input of distributed beam loads.
Click Beam load forces NQB(P), getting bold, and type in TSTRING
1,1,1,6,6,1.2,1.8 Enter, bold disappears,
click Beam load forces NQB(P), getting bold,
2,1,1,6,6,0,1.8 Enter.

Click Again, Calculate, DrawT5M5ELC, next Reactions, Results and M5MaxZero, first print.

Suppose beam ends 1 and 3 are given a displacement 14,87 upward. When going on with the latest results as follows.
First click Again to make all UV(I) and UR(I) zero, next click CSE=0 to CSE=1, getting red,

and type in TSTRING
UV(1)=-14.87 Enter and PV(1)=1 Enter,
UV(3)=-14.87 Enter and PV(3)=1 Enter. (*)

Click Calculate, DrawT5M5ELC, next Reactions, Results and M5MaxZero, second print.

Bending moment diagram Looks strange...?, but there is a bending moment of 0.19 kNm at support 2, the clamp.
MF(2,1)= -0,19 kNm and MF(2,3)= 0,19 kNm.

Fig.5.

Going on with the example of the second print.
To get this situation with supporta at beam end 1 and 3, click Again to make all UV(I) and UR(I) zero, so UV(1)=0 and UV(3)=0.
Already are PV(1)=1 and PV(3)=1 (*)
(Or PR(2)=0, then same results, symmetrie.)

Click Calculate, DrawT5M5ELC, next Reactions, Results and M5MaxZero, third print.

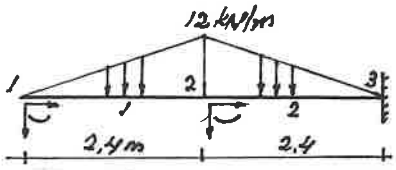
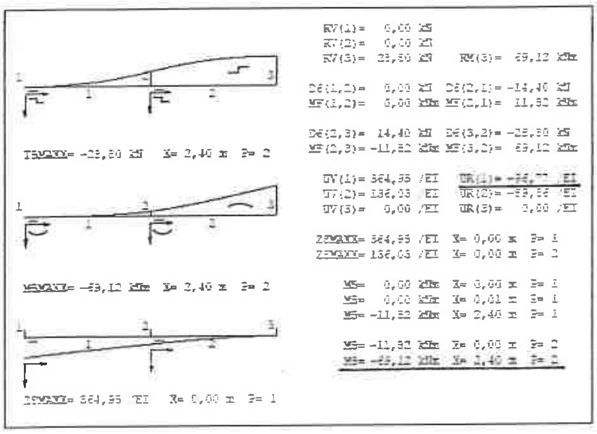


Fig. 6.



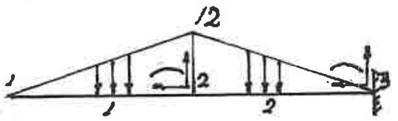
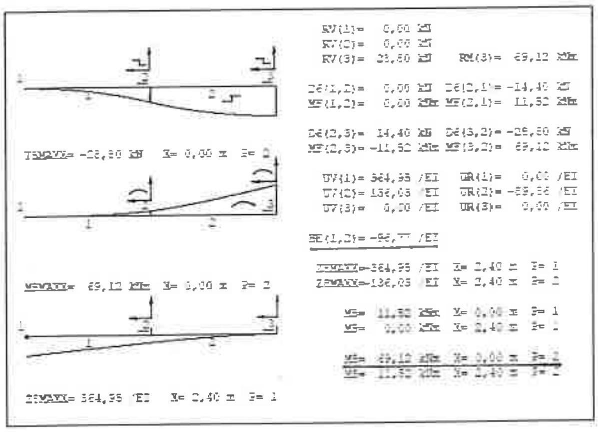


Fig. 7



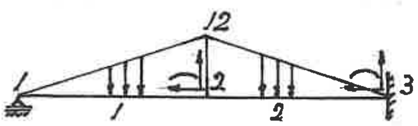
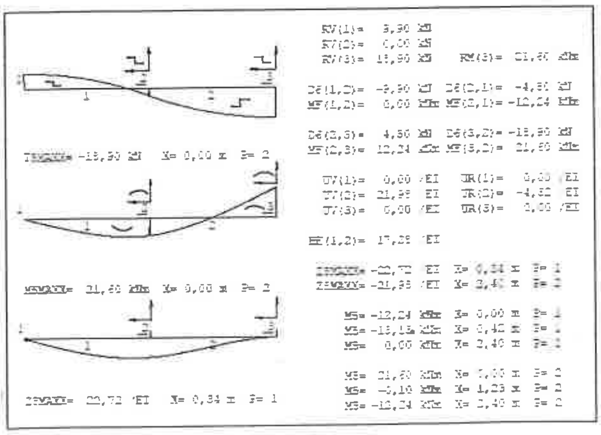


Fig. 8.



Example EX1e after a click on EX1d.

Fig.6.

N9=3 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	2.4	0	0	0	0
3	0	0	0	0	4.8	0	1	0	0

1,0,0,0,0,0,0,0,0,0 Enter,
2,0,0,0,0,2.4,0,0,0,0 Enter and
3,0,0,0,0,4.8,0,1,0,0 Enter.

P9=2 beams.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	0	2	1

1,1,2,0,0,1,1 Enter and
2,2,3,0,0,2,1 Enter.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	0	12	0	2.4
2	1	1	12	0	0	2.4

Click Beam load forces NQB(P), getting bold, and type in TSTRING
1,1,1,0,12,0,2.4 Enter, bold disappears,

click Beam load forces NQB(P), getting bold,
2,1,1,12,0,0,2.4 Enter, bold disappears.

Click Again, Calculate, DrawT5M5ELC, next Reactions, Results and M5MaxZero, first print.

Fig.7.

Beam axis sytems placed at other beam ends. With CSE=1 in TSTRING
BA(1)=2 Enter and BA(2)=3 Enter.

The distributed loads.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	-12	0	0	2.4
2	1	1	0	-12	0	2.4

Click Beam load forces NQB(P), getting bold, and type in TSTRING
1,1,1,-12,0,0,2.4 Enter, bold disappears,

click Beam load forces NQB(P), getting bold,
2,1,1,0,-12,0,2.4 Enter, bold disappears.

And, beam end 1 seen as a hinge, with CSE=1 in TSTRING NL(1)=1 Enter.

Click Again etc. second print.

HE(1,2)= -96,77/EI because beam end 1 seen as a hinge, it is UR(1)= -96,77/EI of fig.6.

Fig.6. M5= -69,12 kNm X= 2,40 m P=2
Fig.7. M5= 69,12 kNm X= 0,00 m P=2
Difference in negativ or positive value because of different place of beam axis system!

Fig.8.

Going on with fig.7, now beam end 1 will be supported, with CSE=1 PV(1)=1 Enter.

Again, Calculate, etc. third print.

Examples EX2a etc.

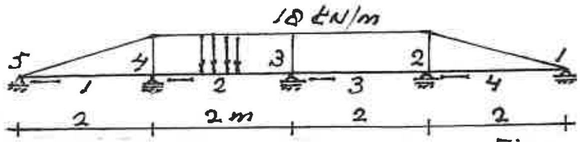


Fig.1.

Fig.1.
Example EX2a after a click on EX2. Diagrams appear, click Results, Reactions first print.

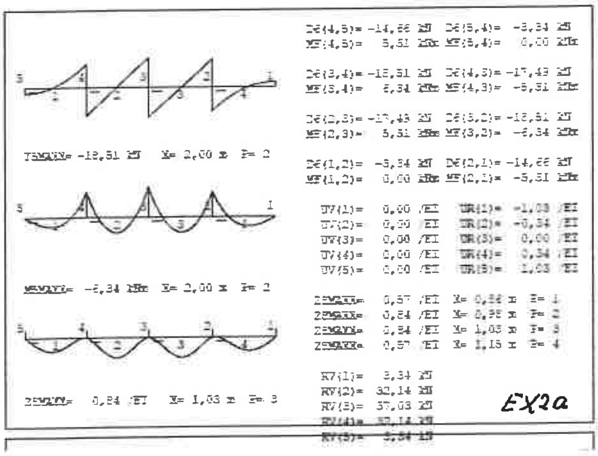
Beam numbering from left to right 1 2 3 4 and joint numbering from left to right 5 4 3 2 1.
N9=5 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	8	0	0	0	0
2	0	1	0	0	6	0	0	0	0
3	0	1	0	0	4	0	0	0	0
4	0	1	0	0	2	0	0	0	0
5	0	1	0	0	0	0	0	0	0

P9=4 beams.

P	LL	HH	NL	NH	BA	EI
1	4	5	0	0	5	1
2	3	4	0	0	4	1
3	2	3	0	0	3	1
4	1	2	0	0	2	1

P	NFB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	1	1	0	18	0	2
2	1	1	18	18	0	2
3	1	1	18	18	0	2
4	1	1	18	0	0	2



Suppose the distributed beam loads of beam 1 and 4 are removed.

P	NQB(P)	I	Q33(P,I)	Q44	L33(P,I)	L44
1	0					

Click Beam load forces NQB, type in TSTRING 1,0 Enter, NQB(1) has become zero, and beam 4, Click Beam load forces NQB, and 4,0 Enter.

Click PrData to see beam 1 and 4 without loads. Click Again, Calculate, DrawT5M5ELC, etc. for the second print.

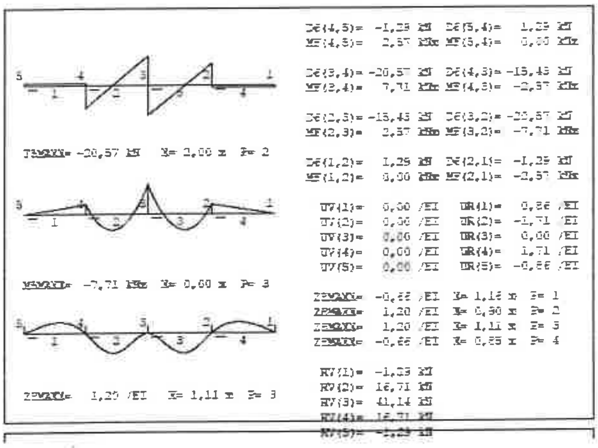


Fig.2.
Example EX2b after a click on EX2a, third print with Results and Reactions.

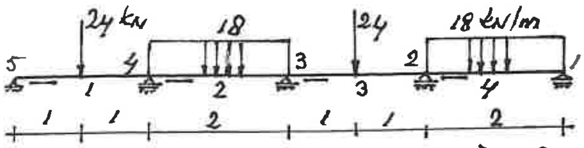
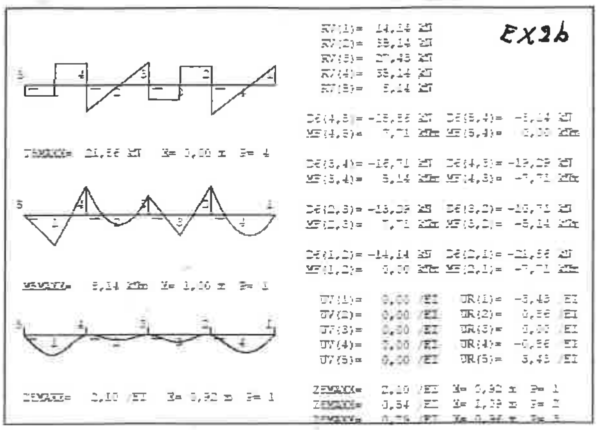
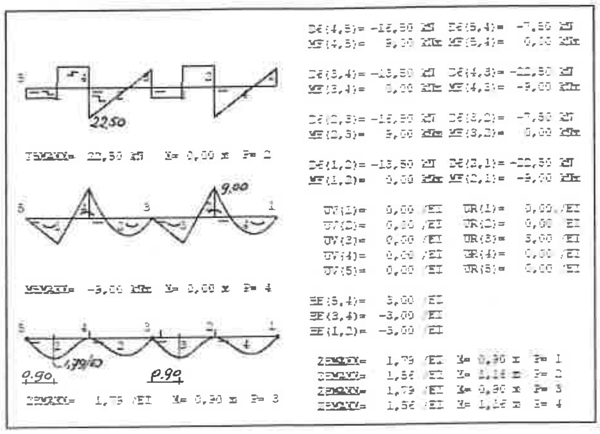


Fig.2.



Suppose beam end 5 and 1 seen as hinges, and at support 3 a hinge, then with CSE=1 in TSTRING NH(1)=1 Enter, NL(4)=1 Enter and NL(2)=1 Enter.
Again, etc., Results, fourth print here below.
With this case just accidental UR(4)=0 and UR(2)=0. With formulas for separated beam 1, (24*2^2)/16EI -(18*2^3)/24EI= (6-6)/EI= 0 /EI.



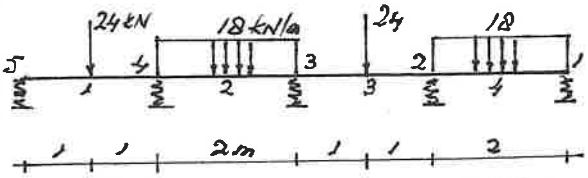


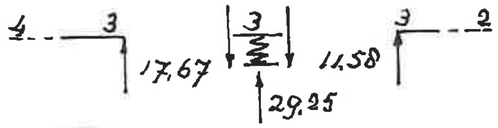
Fig. 3

<u>Example EX2c</u> after a click on EX2b.

Fig.3 like fig.2.
Going on with EX2b.
The supports are springs, spring constant 12EI.
With CSE=1 to type in TSTRING
<u>SV(1)=12 Enter</u>, <u>PV(1)=0 Enter</u>,
<u>SV(2)=12 Enter</u>, <u>PV(2)=0 Enter</u>,
<u>SV(3)=12 Enter</u>, <u>PV(3)=0 Enter</u>,
<u>SV(4)=12 Enter</u>, <u>PV(4)=0 Enter</u> and
<u>SV(5)=12 Enter</u>, <u>PV(5)=0 Enter</u>.

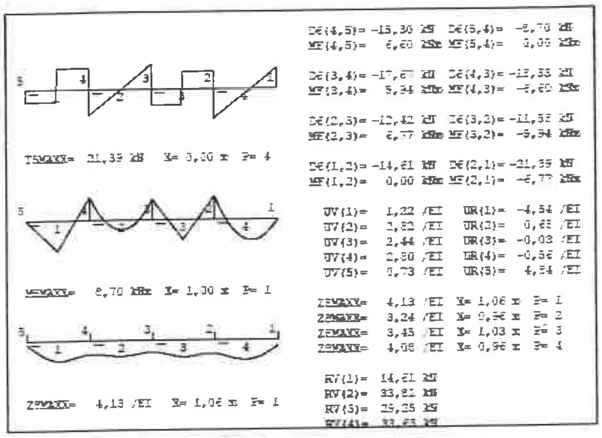
<u>Again</u>, <u>Calculate</u>, <u>DrawT5M5ELC</u> etc.

Joint/support 3.



Beam end forces D6(,) assumed downward.
D6(3,4)= -17,67 kN and D6(3,2)= -11,58 kN
RV(3)= <u>29,25 kN</u> is 17,67+11,58

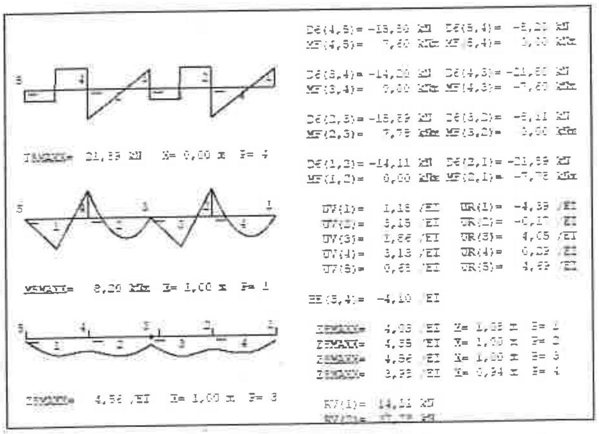
RV(3)= UV(3)*SV(3)= (2,44/EI)*12EI= <u>29,28 kN</u> ok



<u>Example EX2d</u> after a click on EX2c.

Like fig.3. With <u>a hinge</u> at support 3.
Going on with EX2c.
With CSE=1 in TSTRING <u>NL(2)=1 Enter</u>.
<u>Again</u> etc. second print.

MF(3,4)=0 kNm and MF(3,2)=0 kNm.
HE(3,4)= -4,10/EI and UR(3)= 4,05/EI

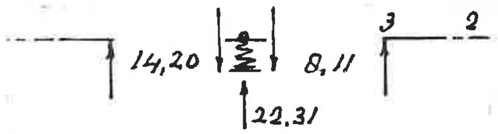


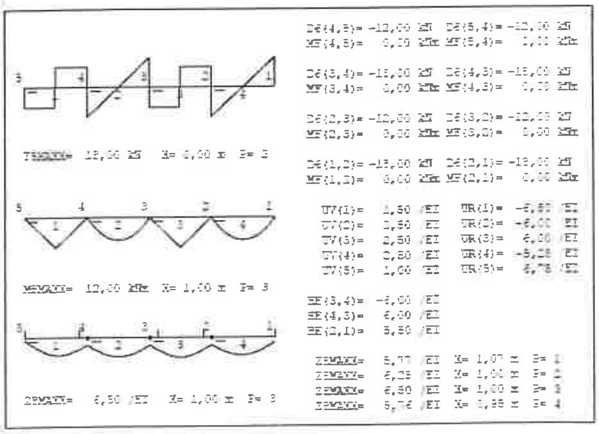
<u>Example EX2e</u> after a click on EX2d.

Adding more hinges. Going on with EX2d.
With CSE=1 <u>NH(2)=1 Enter</u> and <u>NH(4)=1 Enter</u>.
<u>Again</u> etc. third print.

Third print.
D6(3,4)= -14,20 kN   D6(3,2)= -8,11 kN
RV(3)= <u>22,31 kN</u> is 14,20+8,11= 22,31 ok

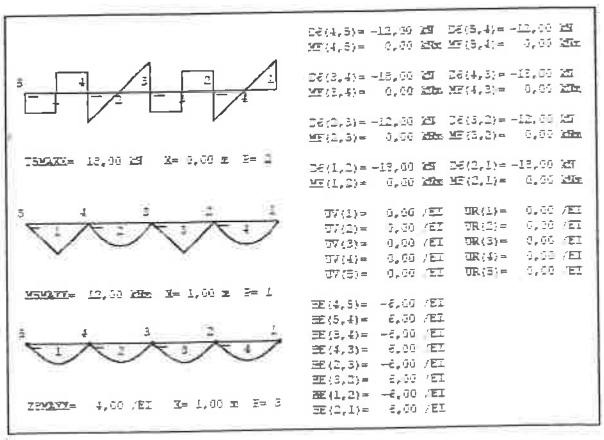
RV(3)= (1,86/EI)*12EI= <u>22,32 kN</u> ok





<u>Example EX2f</u> after a click on EX2e.

All supports with hinges, 'full' hinges.
<u>NH(1)=1 Enter</u>, <u>NL(1)=1 Enter</u>,
<u>NH(3)=1 Enter</u>, <u>NL(3)=1 Enter</u> and
<u>NL(4)=1 Enter</u>.
<u>Again</u>, <u>Calculate</u>, <u>DrawT5M5ELC</u> etc. 4th print.



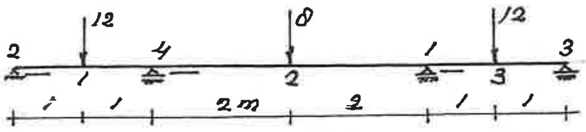
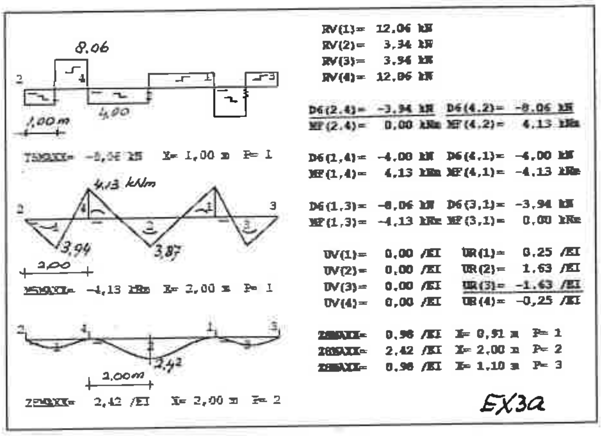


Fig.1.



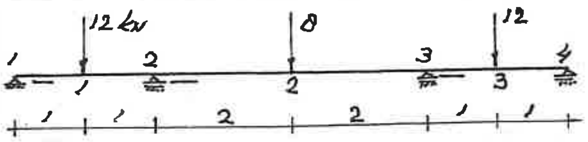
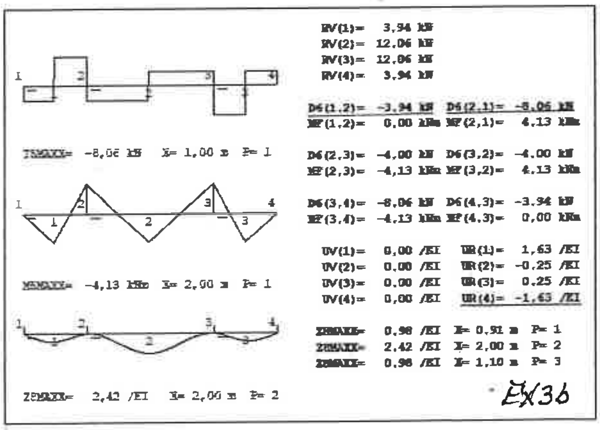
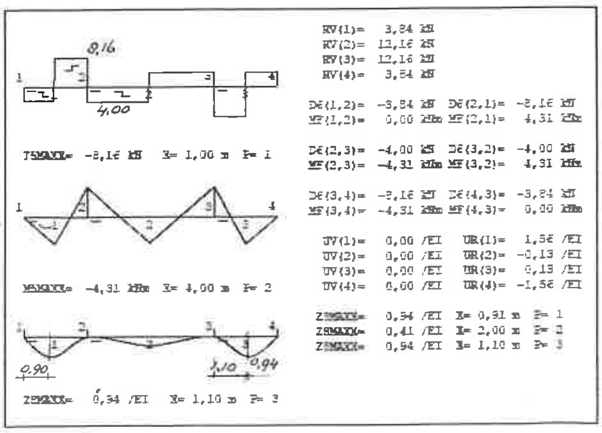


Fig.2.




```
M5= -4,13 kNm X= 0,00 m P= 2
M5=  0,04 kNm X= 1,04 m P= 2
M5=  3,87 kNm X= 2,00 m P= 2
M5=  0,00 kNm X= 2.97 m P= 2
M5= -4,13 kNm X= 4,00 m P= 2
```



Click examples EX3a to EX3e.

Example EX3a after a click on EX3.

Fig.1.
Statically 3-fold undetermined.
Joints are regularly numbered, 2 4 1 3, beams are regularly numbered, 1 2 3.

N9=4 joints.

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	6	0	0	0	0
2	0	1	0	0	0	0	0	0	0
3	0	1	0	0	8	0	0	0	0
4	0	1	0	0	2	0	0	0	0

P9=3 beams.

P	LL	HH	NL	NH	BA	EI
1	2	4	0	0	2	1
2	1	4	0	0	4	1
3	1	3	0	0	1	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	1	1	12	1
2	1	1	8	2
3	1	1	12	1

A click on EX3 gives the diagrams, next Reactions and Results to get the print shown on the left.

Example EX3b after a click on EX3a.

Fig.2.
Like fig.1 but now the joints are regularly numbered as well, 1 2 3 4.

N9=4 joints. With changed X1(I).

I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	1	0	0	2	0	0	0	0
3	0	1	0	0	6	0	0	0	0
4	0	1	0	0	8	0	0	0	0

P9=3 beams. With changed LL(P), HH(P), BA(P).

P	LL	HH	NL	NH	BA	EI
1	2	4	0	0	2	1
2	1	4	0	0	4	1
3	1	3	0	0	1	1

P	NFB(P)	I	F22(P,I)	L22(P,I) No changes.
1	1	1	12	1
2	1	1	8	2
3	1	1	12	1

Reactions, Results, the final results are the same, see some underlined values.

Going on with EX3b.

Suppose the bending stiffness of beam 1 becomes 5EI instead of 1EI.
Then with CSE=1 in TSTRING EII(1)=5 Enter.
Again, Calculate, DrawT5M5ELC, etc.

Z8MAXX was 2,42/EI and now 0,94/EI.
The largest displacement determines how the deformation line is drawn. First time 2,42/EI and the second time 0,94/EI.

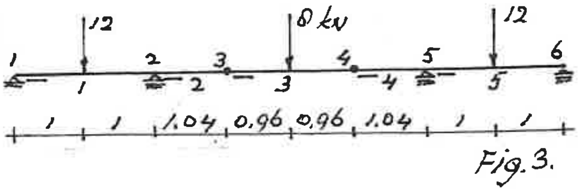


Fig. 3.

Example EX3c after a click on EX3b.

Fig.3, see fig.2.
The continuous beam is made statically determined by placing two hinges at the place of moment zero points of beam 2 found by M5MaxZero of EX3a.

N9=6 joints.

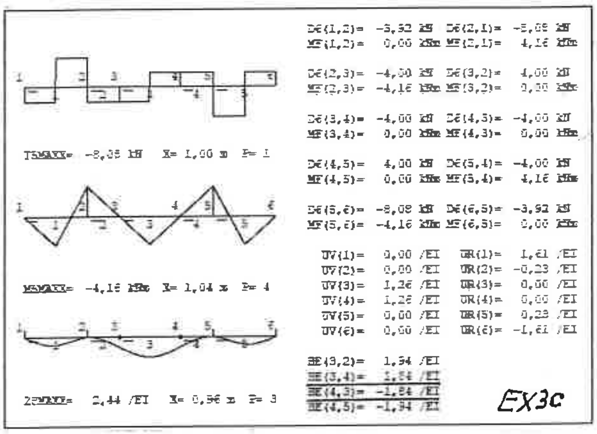
I	FY	PV	UV	SV	X1	MZ	PR	UR	SR
1	0	1	0	0	0	0	0	0	0
2	0	1	0	0	2	0	0	0	0
3	0	0	0	0	3.04	0	0	0	0
4	0	0	0	0	4.96	0	0	0	0
5	0	1	0	0	6	0	0	0	0
6	0	1	0	0	8	0	0	0	0

P9=5 beams.

P	LL	HH	NL	NH	BA	EI
1	1	2	0	0	1	1
2	2	3	0	1	2	1
3	3	4	1	1	3	1
4	4	5	1	0	4	1
5	5	6	0	0	5	1

P	NFB(P)	I	F22(P,I)	L22(P,I)
1	1	1	12	1
3	1	1	8	0.96
5	1	1	12	1

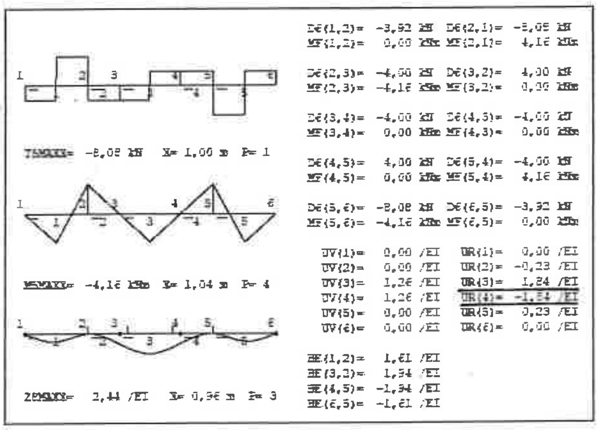
No changes.



RV(1)= 3,92 kN
RV(2)= 12,08 kN
RV(3)= 0,00 kN
RV(4)= 0,00 kN
RV(5)= 12,08 kN
RV(6)= 3,92 kN

Click Results, double click PrF to get the screen print shown on the left. (Ah, not enough space for Z8MAXX results.) The bold dots indicate the hinges, separately calculated HE(,). Shear force and bending moment diagram equal those of the second case EX3b of the preceding page, but the deformation line is different.

HE(3,2)= 1,94/EI
HE(3,4)= 1,84/EI
HE(4,3)= -1,84/EI
HE(4,5)= -1,94/EI



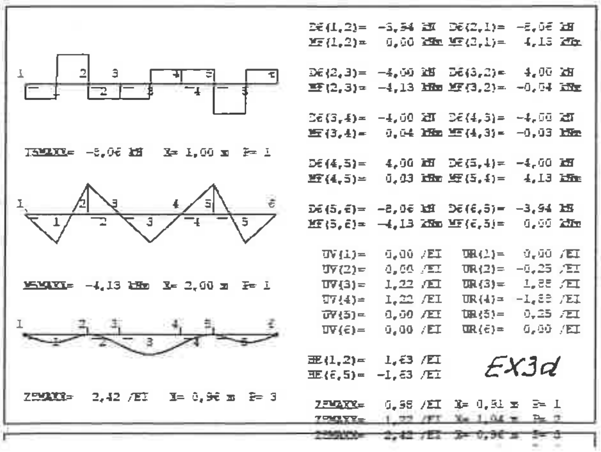
Second print on the left.
Suppose beam ends 3 and 4 of beam 3 are 'real joints', then with CSE=1 to type in TSTRING NL(3)=0 Enter and NH(3)=0 Enter.

And beam end 1 of beam 1 and beam end 6 of beam 5 seen as hinges, then in TSTRING NL(1)=1 Enter and NH(5)=1 Enter.

Again, Calculate, DrawT5M5ELC and Results.

HE(3,4)= 1,84/EI is replaced by UR(3)= 1,84/EI,
HE(4,3)=-1,84/EI is replaced by UR(4)=-1,84/EI.

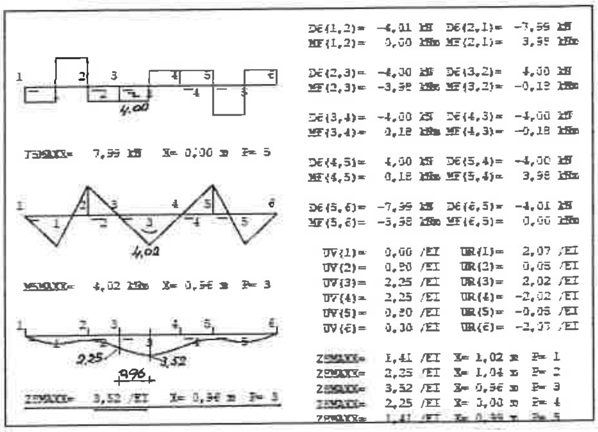
UR(1)= 1,61/EI is replaced by HE(1,2)= 1,61/EI,
UR(6)=-1,61/EI is replaced by HE(6,5)=-1,61/EI.



Example EX3d after a click on EX3c, or going on with EX3d.

One may remove the hinges, with CSE=1,
NH(2)=0 Enter and NL(4)=0 Enter,
NH(3)=0 Enter and NL(3)=0 Enter.

Again, Calculate, DrawT5M5ELC and Results to get the third print. See the short stripes, the two hinges are gone, the construction has become 2-fold statically undetermined.



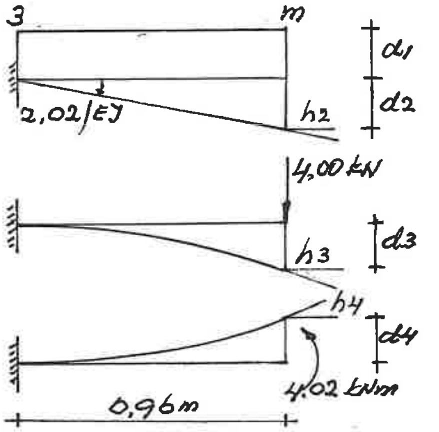
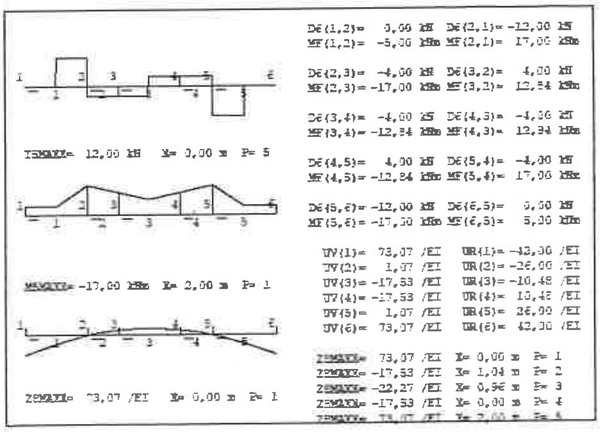
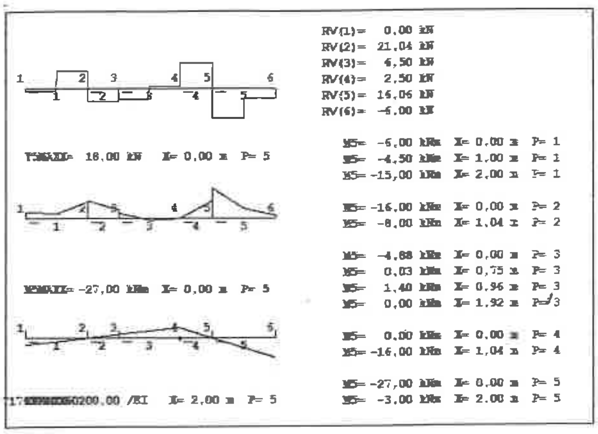


Fig.4.





Example EX3e after a click on EX3d.

When going on with EX3d.
Joints 2 and 5 will be supported by springs with spring constant 15EI.
With CSE=1 to type in TSTRING
SV(2)=15 Enter and SV(5)=15 Enter,

NL(1)=0 Enter and NH(5)=0 Enter and
PV(1)=1 Enter and PV(5)=1 Enter to remove the 'beam end hinges'.

Again, Calculate, DrawT5M5ELC etc. 1st print.

Fig.4.

Calculating the displacement dm of the middle of beam 3, startng with beam end 3.
Section just left of the load force of 8 kN.

The shear force sign determines the direction of 4,00 kN, that's downward.
the bending moment sign determines the direction of 4,02 kNm, that's to the left.

Joint 3 displaces 2,25/EI is d1 ↓ = 2,25/EI.

d2 ↓ = (2,02*0,96/EI= 1,94/EI

d3 ↓ = (4,00*0,96^3)/3EI= 1,18/EI

d4 ↑ = (4,02*0,96^2)/2EI= 1,85/EI

displacement of beam end 3 of beam 3

dm ↓ = (2,25+1,21-1,85+1,94)/EI= 3,52/EI ok

Slope deflection, angle hm in the middle.

h2 = 2,02/EI

h3 = (4,00*0,96^2)/2EI= 1,84/EI

h4 = (2,02*0,96)/EI= 3,86/EI

hm = (2,02+1,84-3,86)/EI= 0 ok

Example EX3f after a click on EX3e.

Going on with EX3e.
Supports 1 and 6 will be removed, with CSE=0 to type in TSTRING

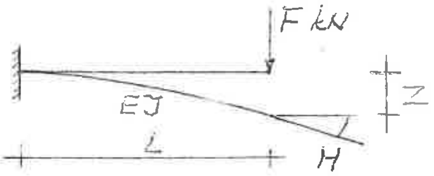
PV(1)=0 Enter and PV(6)=0 Enter.

And beam end load moments added at beam end 1 (5 and beam end 6 5).

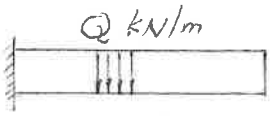
MZ(1)=-5 Enter and MZ(6)=5 Enter.
Again, Calculate etc. second print.

Suppose a hinge at beam end 4 of beam 3 and 4,
NH(3)=1 Enter and NL(4)=1 Enter,

Again, Calculate etc., third print... collapse!

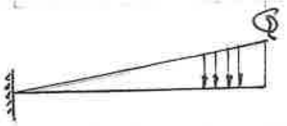


H= F*L^2/(2*EI)   Z= F*L^3/(3*EI)



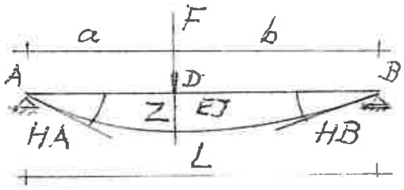
H= Q*L^3/(6*EI)   Z= Q*L^4/(8*EI)

H= Q*L^3/(24*EI)   Z= Q*L^4/(30*EI)



H= Q*L^3/(8EI)   Z= 11Q*L^3/(120EI)

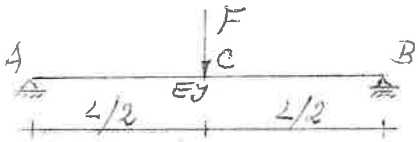
H= M*L/EI   Z= M*L^2/(2*EI)



HA= F*a*b*(L+b)/(6*L*EI)

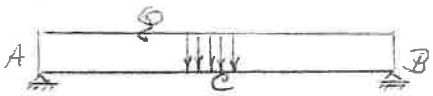
HB= F*a*b*(L+a)/(6*L*EI)

ZD= F*a^2*b^2/(3*L*EI)



HA= HB= F*L^2/(16*EI)

ZC= F*L^3/(48*EI)



HA= HB= Q*L^3/(24*EI)

ZC= 5*Q*L^4/(384*EI)

HA= Q*L^3/(45*EI)

HB= 7*Q*L^3/(360*EI)

ZC= (5*Q*L^4/(384*EI))/2

Standard formulas for simple beams.

E is modulus of elasticity in kN/m^2
EI is bending stiffness, EI is E*I with
I is moment of inertia in m^4

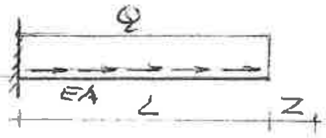
EI is (kN/m^2)*m^4 is kNm^2

EA is strain stiffness, EA is E*A with
A is cross sectial area in m^2

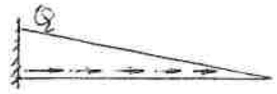
EA is (kN/m^2)*m^2 is kN

Displcement Z in m, angle H in radians

Z=F*L/EA

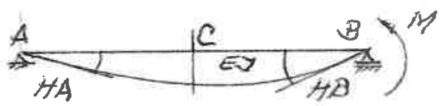


Z=Q*L^2/(2*EA)



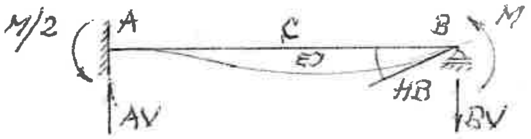
Z=Q*L^2/(6*EA)

Z=Q*L^2/(3EI)



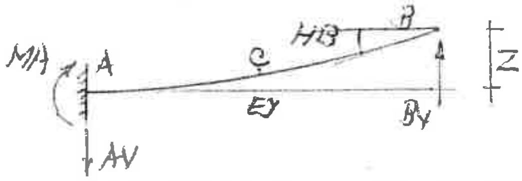
HA= M*L/(6*EI)   HB= M*L/(3*EI)

ZC= M*L^2/(16*EI)



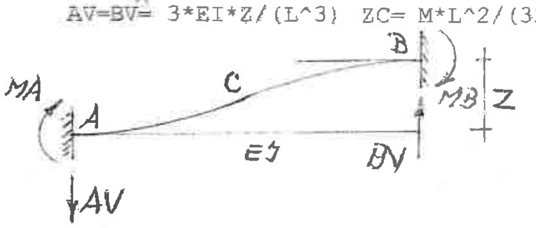
HB= M*L/(4*EI)   ZC= M*L^2/(32*EI)

AV=BV= 3*M/(2*EI)



MA=3*EI*Z/(L^2)   HB= 3*Z/(2*L)

AV=BV= 3*EI*Z/(L^3)   ZC= M*L^2/(32*EI)



MA=MB= 6*EI*Z/(L^2)   ZC= Z/2

AV=BV= 12*EI*Z/(L^3)