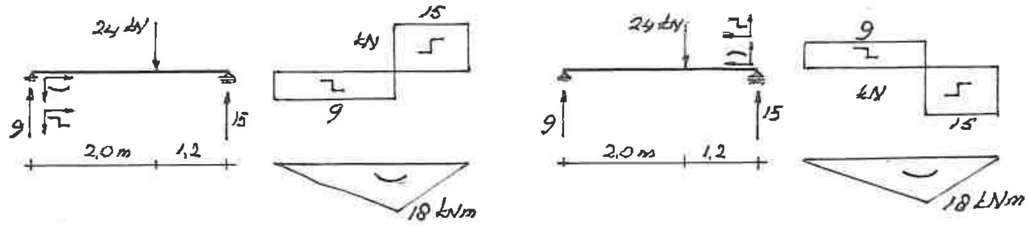
Shear Force and Bending Moment diagrams **without** Sign Conventions.

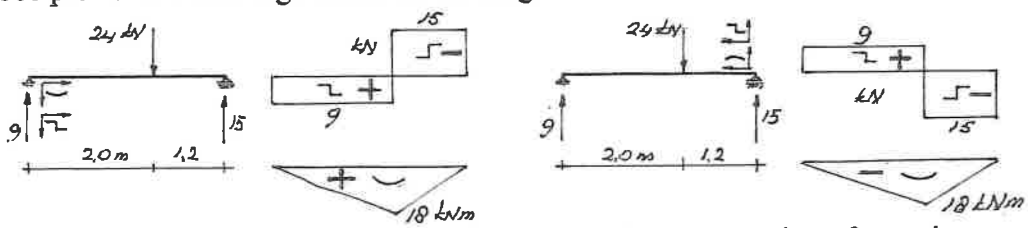
Calculation of shear force and bending moment and drawing the diagrams is not difficult when applying the assumed

'beam axis systems' and .

Shear force sign and bending moment sign of these socalled beam axis systems determine the way how shear force and bending moment are calculated, without Sign Conventions! There are two possibilities depending at which beam end the beam axis systems are placed.
The diagrams are drawn like shown here below, an example.



After the diagrams are drawn the values on both sides of the zero line can be distinguished by adding two different colors, two different letters, or just a plus and minus sign.
Could be e.g. as follows, as an agreement,
a plus sign + belonging to and , and
a minus sign – on the other side of the zero line.
See plus and minus sign added in the diagrams here below.



The two cases show the shear force diagrams with the same shear force signs, with plus and minus signs,
the bending moment diagrams are the same, with the same bending sign,
but the left diagrram with a plus sign and the right diagram with a minus sign, to distinguish the values on both sides of the zero line.

This all will be explained in detail on the following pages. After a while one gets used to this new approach, confusions due to usual Sign Conventions will disappear....for sure.

Ed van Rotterdam

The Netherlands

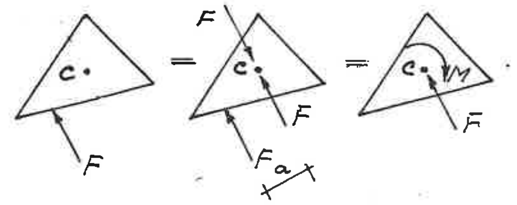


Fig.1

∑ hor.=0

∑ vert.=0

∑ mom.=0

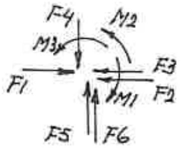


Fig.2.

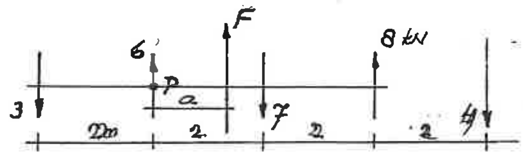


Fig.3a.

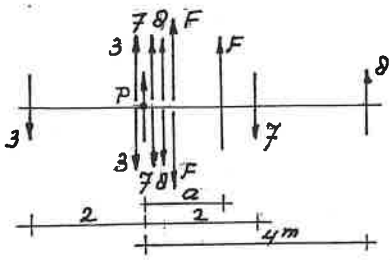


Fig.3b.

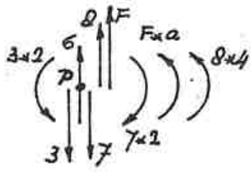


Fig.3c.

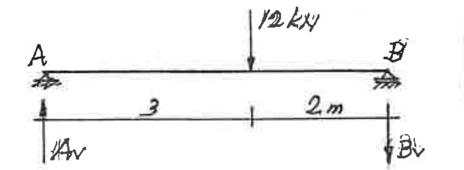


Fig.4a.

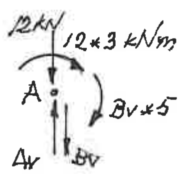


Fig.4b.

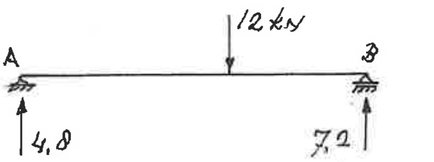


Fig.4c.

STRENGTH OF MATERIALS WITHOUT SIGN CONVENTIONS.

Fig.1.
Force F is resolved into a force F through centre of gravity C plus a couple of forces with moment M=F*a.

Fig.2.
With more forces can be done the same. They can be resolved into forces throught C plus couples of forces with moments M1, M2 and M3.
The forces are resolved into perpendicular directions, here horizontal forces F1, F2 and F3, and vertical forces F5, F6 and F7.
For equilibrium the sum of horizontal forces, vertical forces, and of moments of couples must be zero to solve three unknowns.

∑ hor.=0, two possible equations.
To the right minus to the left =0.   F1-F2-F3=0
To the left minus to the right =0.   F2+F3-F1=0

∑ vert.=0, two possible equations.
Upward minus downward= 0.   F5+F6-F4=0
Downward minus upward= 0.   F4-F5-F6=0

∑ mom.=0, two possible equations.
To the right minus to the left =0.   M1-M2-M3=0
To the left minus to the right =0.   M2+M3-M1=0

Fig.3a to 3c.
Four given vertical forces. Force F in equilibrium with them to be calculated. Assumed upward at a m on the right of P.

Fig.3a.
∑ vert.=0, two possible equations.
F+6+8-3-7=0   F+14-10=0   F=-4 kN   or
3+7-F-6-8=0   10-F-14=0   F=-4 kN

∑ mom.P=0, two possible equations.
7*2-3*2-(-4)*a-8*4=0   4a-24=0   a=6 m   or
3*2+(-4)*a+8*4-7*2=0   -4a+24=0   a=6 m

F=-4 kN, negative so not directed as assumed, thus downward. If drawn downward then with value 4, not minus, -4.
In fig.3a with the drawn force F upward, one could write there F=-4 kN. The minus sign meaning assumed direction wrong, so opposite directed, that's downward.
Distance a=6 m, positive answer, as assumed on the right of P.
Fig. 3b and 3c are drawn to show what is really done: resolving forces into forces and couples of forces. P can be any point.

Fig.4a.
A beam, 2 support reactions Av and Bv to be solved. The direction of the reactions are assumed arbitrarily. Suppose Av upward and Bv downward and draw them as assumed.

Fig.4b.
To calculate Bv with sum of moments w.r.t. A is zero. (Point A like C and P just shown.)
∑ mom. A=0   12*3+Bv*5=0   Bv=36/5=-7,2 kN   or
0-Bv*5-12*3=0   Bv=36/5=-7,2 kN

Going on with the same figure!
∑ vert.=0
Av-12-Bv=0   Av-12-(-7.2)=0   Av=4,8 kN   or
12+Bv-Av=0   12+(-7.2)-Av=0   Av=4,8 kN

Fig.4c.
Bv a negative answer, thus not directed as assumed, so to be drawn upward instead of downward. Av positive answer, thus directed upward as assumed.

Shear force and bending moment.

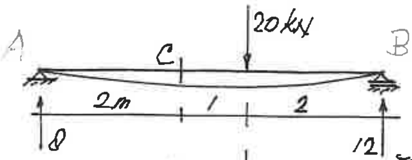


Fig. 5a.

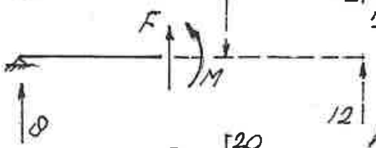


Fig. 5b.

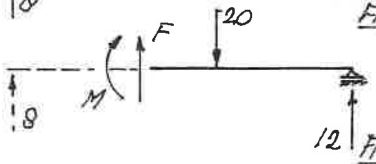


Fig. 5c.

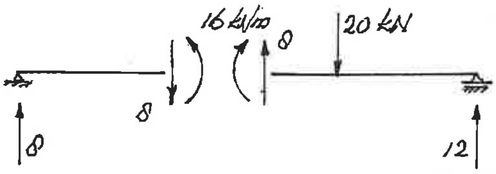


Fig. 5d.

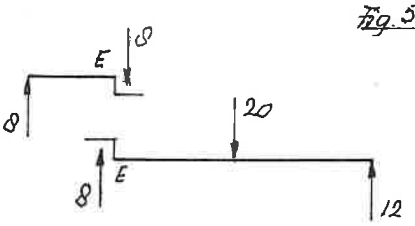


Fig. 6a.

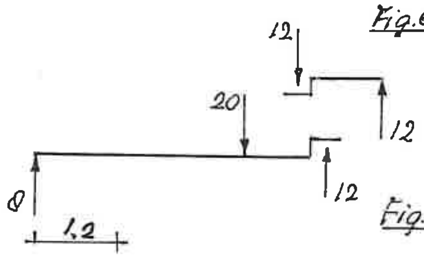


Fig. 6b.

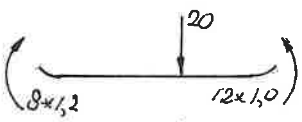


Fig. 6c.

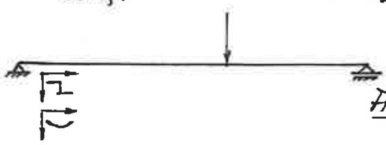


Fig. 7a.

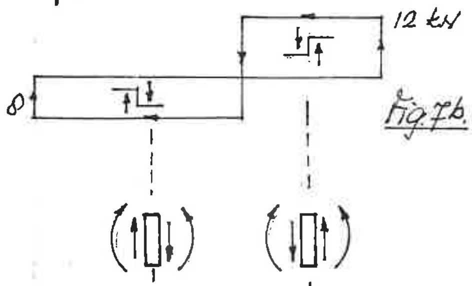


Fig. 7b.

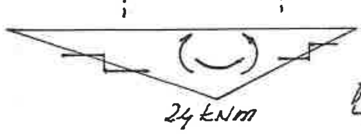


Fig. 7c.

Fig.5a.
A simple beam. Calculation of shear force and bending moment in cross-section C. Reactions 8 and 12 kN.
Fig.5b. Left part.
The beam is cut into two parts. On C act from right onto left shear force F and bending moment M, drawn with arbitrarily assumed directions. F and M resultants of 20 and 12 kN.
Fig.5c. Right part.
F and M as large as but opposite directed, acting on beam end C of the right part, resultants of 8 kN.
Left part.
F assumed upward means that the sum of forces upward is larger than the sum of forces downward, therefore resultant
F↑=12-20=-8 kN, a negative answer, direction not as assumed upward, but downward.
M assumed to the left means that the sum of moments to the left is larger than the sum of moments to the right, therefore resultant
M ⟯=12*3-20*1=16 kNm, positive answer, direction as assumed to the left.
Or calculation with equilibrium equations for left and right part.
Fig.5d.
Forces and moments drawn with their real directions. Put the parts together, then F and M 'disappear', see fig.5a.

Shear force diagram and bending moment diagram.

Fig.6a and 6b.
Like above shear forces act on sections E of the two separated parts. The two drawn 'steps' at each section form the shear force sign applied in the shear force diagram of fig.7b.
Fig.6c.
Bending moments act on the sections at both ends of the loosened part the way like found above. The little curves show half of the bending moment sign to appear in the bending moment diagram of fig.7c.

Assumptions.

Fig.7a.
A simple horizontal beam.
Beam axis systems are ↑‿ and ↑⌐⌙ placed at an end of the beam, always called the left end of the beam.
Fig.7b.
The shear force diagram, D-diagram, is drawn starting at the right end of the beam. Here with 12 kN up, going to the left, jump down at the point load of 20 kN, going to the left and up with 8 kN at the left end.
Fig.7c.
The bending moment diagram, M-diagram, with moments at the point load, 8*3=24 kNm ⟮ to the right and 12*2=24 kNm ⟯ to the left.
(D- and M- diagram drawn this was belong mathematically together. Surface 8*3=24 of D-diagram equals bending moment of 24 kNm of M-diagram. Both a positive answer. Slopes in M-diagram correspond with shear force sign.)

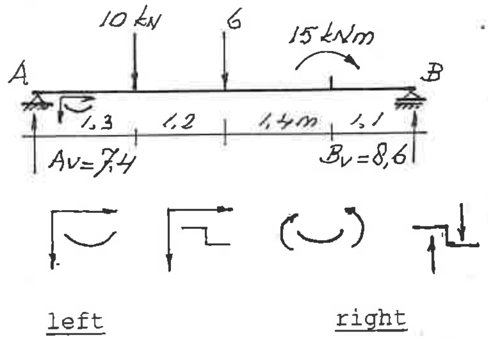


Fig.8a.

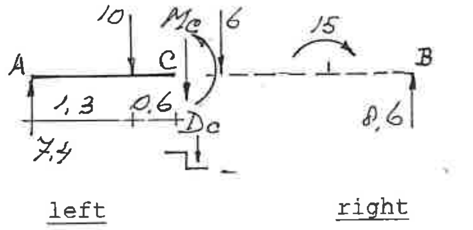


Fig.8b.

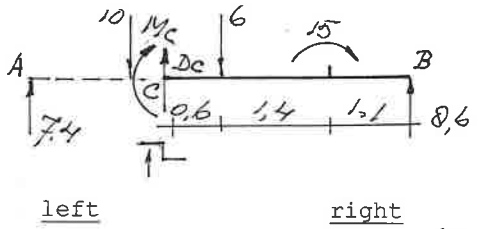


Fig.8c.

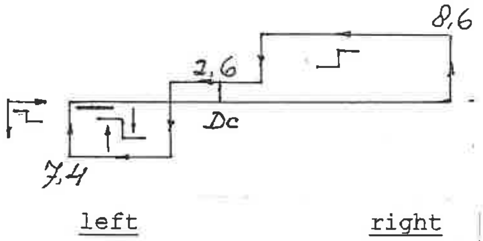


Fig.8d.

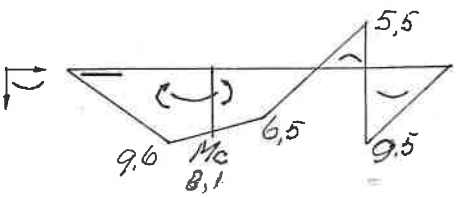


Fig.8e.

Example.

Fig.8a.
Reactions Av and Bv.
$\sum$ mom.A=0   10*1,3+6*2,5+15-Bv*5=0   Bv= 8,6 kN
$\sum$ vert.=0   Av-10-6+8,6=0   Av= 7,4 kN

The 'beam axis system' is placed at beam end A, determining the way of writing equations.
The beam is divided into two parts AC and CB.

Calculation of shear force Dc.

Fig.8b and 8d. Part AC.
Calculation of Dc from 'right onto left'.
According to the assumed shear force sign acts on section C shear force Dc downward.
$\sum$ vert.=0   7,4-10-Dc=0 ↓Dc = -2,6 kN or
Dc+10-7,4=0 ↓Dc = -2,6 kN.

Or, resultant Dc downward of the forces of the right part CB = forces downward minus upward.
Dc↓ = 6-8,6= -2,6 kN

Fig.8c and 8d. Part CB.
Calculation of Dc from 'left onto right'.
According to the assumed shear force sign acts on section C shear force Dc upward.
$\sum$ vert.0   8,6-6+Dc=0 ↑Dc = -2,6 kN or
6-8,6-Dc=0 ↑Dc = -2,6 kN.

Or, resultant Dc upward of the forces of the left part AC = forces upward minus downward.
Dc↑ = 7,4-10= -2,6 kN like above!

A negative answer thus not ⌐_ but _⌐ and plotted above the zero line of the shear force diagram.

Calculation of bending moment Mc.

Fig.8b and 8e. Part AC.
Calculation of Mc from 'right onto left'.
According to the assumed bending moment sign acts on C bending moment Mc to the left.
$\sum$ mom.C=0 part AC.
7,4*1,9-10*0,6-Mc=0   Mc) = 8,1 kNm or
Mc-10*0,6+7,4*1,9=0   Mc) = 8,1 kNm.

Or resultant Mc to the left of part CB = moments to the left minus moments to the right.
Mc) = 8,6*3,1-6*0,6-15= 8,1 kNm

Fig.8c and 8e. Part CB.
Calculation of Mc from 'left onto right'.
According to the assumed bending moment sign acts on C bending moment Mc to the right.
$\sum$ mom.C=0 part CB.
Mc-8,6*3,1+6*0,6+15=0   Mc (= 8,1 kNm or
8,6*3,1+6*0,6+15-Mc=0   Mc (= 8,1 kNm.

Or, resultant Mc to the right of part AC = moments to the right minus moments to the left.
Mc (= 7,4*1,9-10*0,6= 8,1 kNm

A positive answer thus as assumed ⌣ so plotted below the zero line of the bending moment diagram.

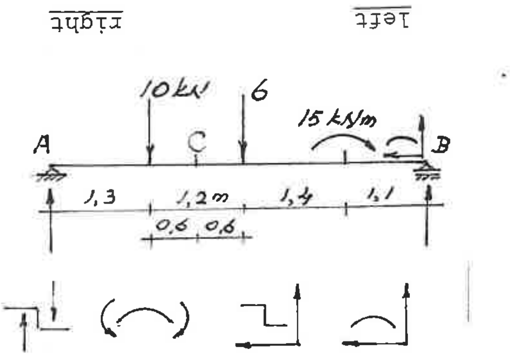


Fig. 9a.

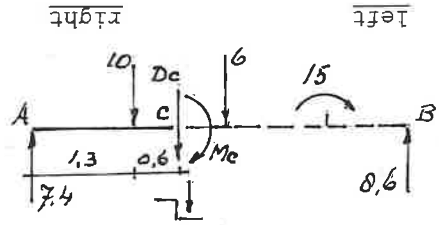


Fig. 9b.

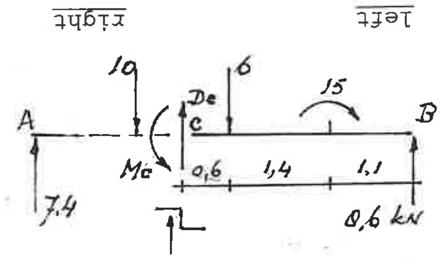


Fig. 9c.

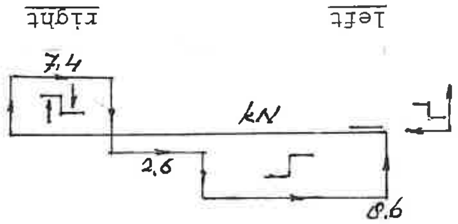


Fig. 9d.

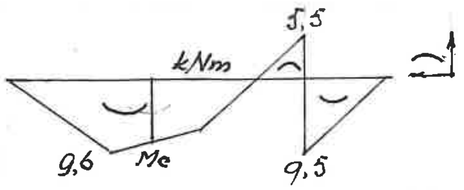


Fig. 9e.

Now with the 'beam axis system' at beam end B.

Fig.9a is figure 8a preceding page upside down. Looking from top down then 'left' is at B and 'right' is at A.

Order of figures like on the preceding page.

Calculation of shear force Dc.

Fig.9b and 9d. Part AC.
Calculation of Dc from 'left onto right'.
According to the assumed shear force sign acts on section C shear force Dc downward.
∑ vert.0   7,4-10-Dc=0   Dc ↓ = -2,6 kN   or
Dc+10-7,4=0   Dc ↓ = -2,6 kN.

Or, resultant Dc downward of the forces of the left part CB = forces downward minus upward.
Dc ↓ = 6-8,6= -2,6 kN

Fig.9c and 9d. Part CB.
Calculation of Dc from 'right onto left'.
According to the assumed shear force sign acts on section C shear force Dc upward.
∑ vert.=0   Dc-6+8,6=0   Dc ↑ = -2,6 kN   or
6-Dc-8,6=0   Dc ↑ = -2,6 kN.

Or, resultant Dc upward of the forces of the right part CA = forces upward minus downward.
Dc ↑ = 7,4-10= -2,6

A negative answer thus not   but   and plotted below the zero line of the shear force diagram.

Calculation of bending moment Mc.

Fig.9b and 9e. Part AC.
Calculation of Mc from 'left onto right'.
According to the assumed bending moment sign acts on C bending moment Mc to the right.
∑ mom.C=0 part AC.
7,4*1,9-10*0,6+Mc=0   Mc) = -8,1 kNm   or
10*0,6-7,4*1,9-Mc=0   Mc) = -8,1 kNm.

Or resultant Mc to the right of part CB = moments to the right minus moments to the left.
Mc) = 6*0,6+15-8,6*3,1= -8,1 kNm

Fig.9c and 9e. Part CB.
Calculation of Mc from 'right onto left'.
According to the assumed bending moment sign acts on C bending moment Mc to the left
∑ mom.C=0 part CB.
Mc+8,6*3,1-6*0,6-15=0   Mc(= -8,1 kNm   or
6*0,6+15-8,6*3,1-Mc=0   Mc(= -8,1 kNm.

Or, resultant Mc to the left of part AC = moments to the left minus moments to the right.
Mc(= 10*0,6-7,4*1,9= 6-14,1= -8,1 kNm

A negative answer not as assumed ⌒ but ⌣ so plotted below the zero line of the bending moment diagram.

So two ways of calculating shear force and bending moment without! 'sign conventions' but with assumptions and .

Example.

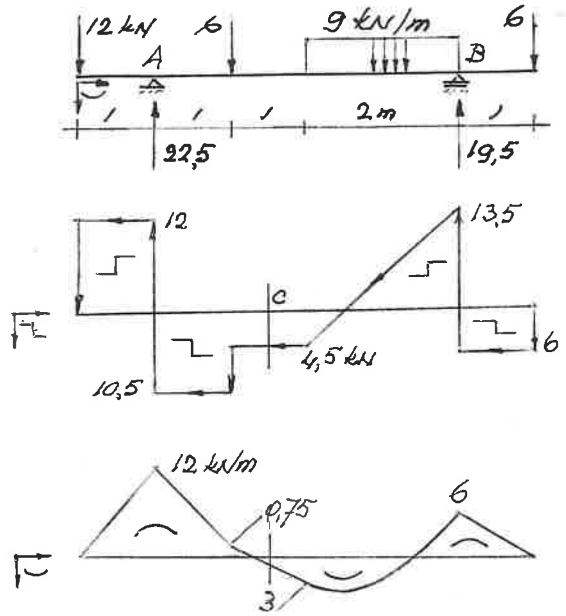
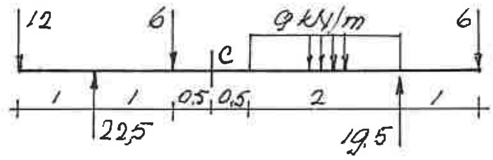


Fig. 8.

Fig.8.
A simple beam with two overhanging parts.
Support reactions are calculated. The beam axis system is put at left end, the shear force diagram drawn starting on right end following the forces from right to left.
Calculation of shear force Dc and bending moment Mc in/at cross-section C as follows.
The beam is cut in C into two parts.
Since shear force doagram and bending moment diagram are drawn, and their shear force sign and bending moment sign are known one knows how shear force and bending moment are directed.

Left part.



left part

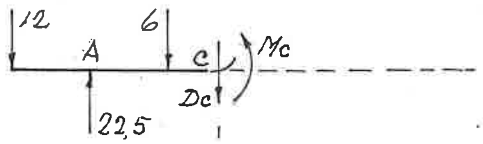


Fig. 8a.

Fig.8a.
For 'right onto left', shear force Dc downward ↓ and bending moment Mc to the left) .

Equilibrium of left part.

∑ vert.=0 Dc+12+6-22,50=0 Dc= 4,50 kN or
22,50-Dc-12-6=0 Dc= 4,50 kN

Positive answer, Dc is directed downward as drawn.

∑ mom. A=0 Dc*1,5+6*1-12*1-Mc=0
(4,50)*1,5+6-12-Mc=0
6,75-6-Mc=0 Mc= 0,75 kNm or
12*1-6*1-Dc*1,5+Mc=0
6-6,75+Mc=0 Mc= 0,75 kNm

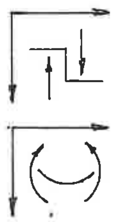
Positive answer, moment Mc is directed to the left as drawn.

Or, calculation of resultants Dc and Mc.

Resultant Dc ↓ of the vertical forces on the right of cross-section C.
Dc downward = downward minus upward.
Dc ↓ = 9*2+6-19,5=24-19,5= 4,50 kN
Positive answer, Dc directed as drawn/assumed.

Resultant Mc) at C of the moments of the forces on the right of cross-section C.
Mc to the left = to the left minus to the right
Mc) =19,5*(2,5)-2*9*(1,5)-6*3,5
=48,75-27,00-21,00= 0,75 kNm
Positive answer, Mc directed as drawn/assumed

Right part.



right part

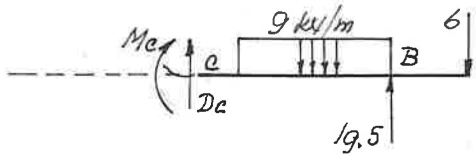


Fig. 8b.

Fig.8b.
For left onto right, shear force Dc upward and bending moment Mc to the right (.

Equlibrium of right part.

∑ vert.=0 Dc+19,5-9*2-6=0 Dc= 4,50 kN or
9*2+6-Dc-19,5=0 Dc= 4,50 kN

∑ mom. B=0 Mc+Dc*2,5+6*1-9*2*1=0
Mc+11,25+6-18=0 Mc= 0,75 kNm or
9*2*1-Dc*2,5-6*1-Mc=0
18-11,25-6-Mc=0 Mc= 0,75 kNm

Resultant Dc of forces on the left of C.
Dc ↓ =22,5-12-6= 22,5-18= 4,50 kN
Resultant Mc of moments on the left of C.
Mc (=22,5*1,5-12*2,5-6*0,5=
=33,75-30-3= 0,75 kNm

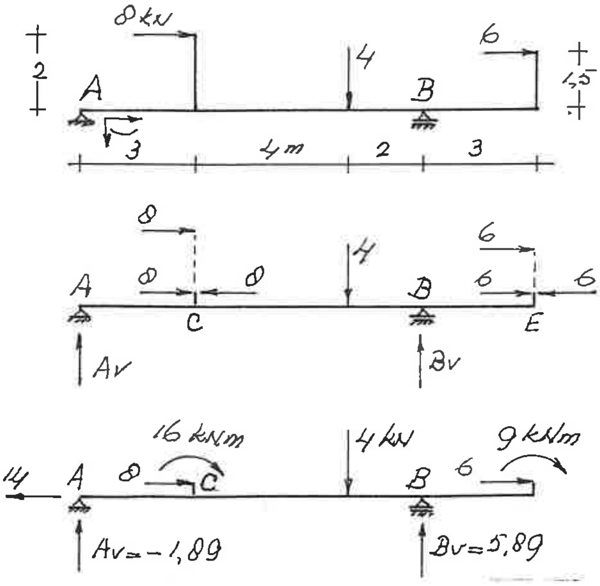


Fig. 9.

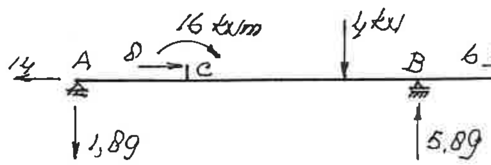


Fig. 9a.

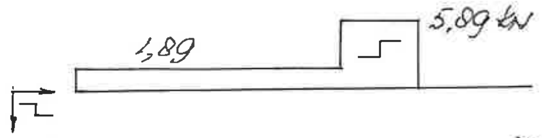


Fig. 9b.

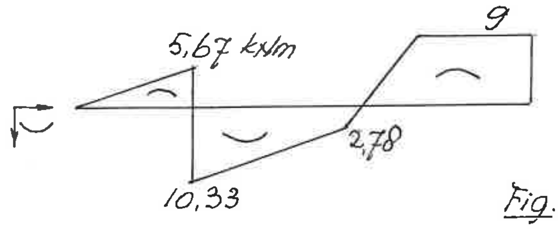


Fig. 9c.

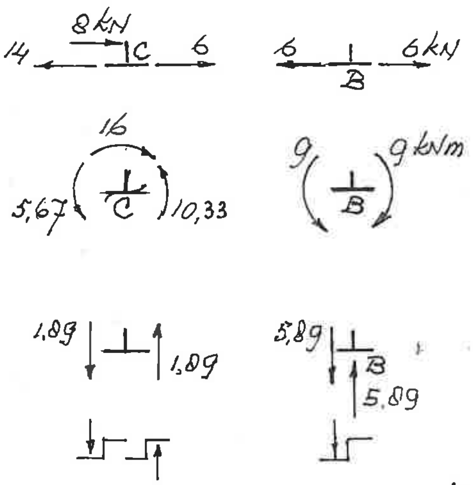


Fig. 10.

Example.

Fig. 9. The first three figures.
The horizontal force of 8 kN is resolved into a horizontal force of 8 kN at C plus a couple of forces of 8 kN with a moment of 8*2=16 kNm to the right.
The same is done with the force of 6 kN giving a horizontal force at E plus a couple of forces of 6kN with a moment of 6*1,5=9 kNm.
∑ hor.=0 gives at support A a horizontal reaction of 8+6=14 kN to the left.
Reactions Av and Bv are assumed to be directed upward, thus drawn upward.

Calculation of reaction Bv.
∑ mom.A=0 To the right minus to the left=0.
16+9+4*7-Bv*9=0 Bv=53/9= 5,89 kN,
or to the left minus to the right=0.
Bv*9-16-9-4*7=0 Bv=53/9= 5,89 kN.

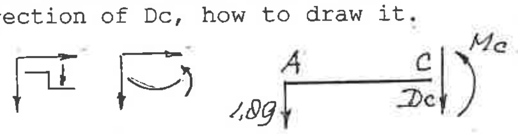
Calculation of reaction Av.
∑ vert.=0 Upward minus downward=0.
Av+Bv-4=0 Av+5,89-4=0 Av=-1,89 kN,
or downward minus upward=0
4-Av-Bv=0 4-Av-5,89=0 Av=-1,89 kN.
Or with ∑ mom.B=0 etc.

Fig.9a.
The reactions drawn with their real directions, 1,89 kN at A downward, 5,89 kN at B upward.
Going on with this figure.

Fig.9b.
The shear force diagram drawn following the forces from right to left.

Fig.9c and 10.
To draw the bending moment diagram some bending moments are calculated.

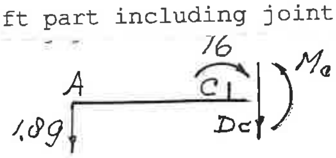
Equilibrium left part of joint C.
The assumed shear force sign determines the direction of Dc, how to draw it.



∑ vert.=0 Dc+1,89=0 Dc=-1,89 kN,

Bending moment Mc on the cross-section of the left part, Mc).
∑ mom.A=0 Mc-Dc*3=0 Mc-(-1,89)*3=0
Mc=-5,67 kNm
Dc neative answer thus not as assumed but opposite directed, Mc negative answer thus not as assumed but opposite directed.

Left part including joint C.



∑ vert.=0 Dc+1,89=0 Dc=-1,89 kN,
Bending moment Mc on the right of joint C.
∑ mom.A=0 Mc-Dc*3-16=0 Mc-(-1,89)*3-16=0
Mc=10,33 kNm, positiv answer, thus directed as assumed.

Example.

Fig.11 and 11a.

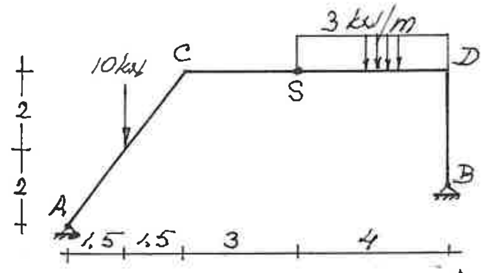


Fig. 11.

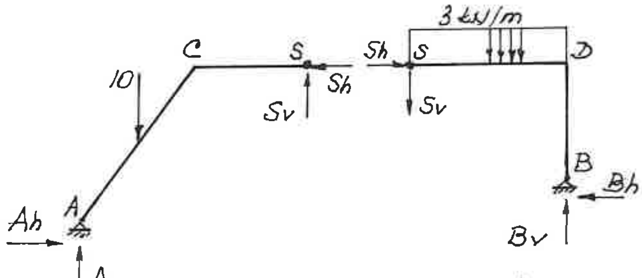


Fig. 11a.

The direction of the reaction forces at the supports A and B are (arbitrarily) assumed and drawn.
Of the separated left part the direction of the hinge forces Sh and Sv are (arbitrarily) assumed and drawn.
At the hinge of the right part act forces Sh and Sv as large as but opposite directed.

Calculation of Sh and Sv.

Left part, ∑ mom.A=0 10*1,5-Sh*4-Sv*6=0,
right part, ∑ mom.B=0 Sh*3-Sv.4-3*4*2=0.

4Sh+6Sv= 15		4,0Sh+6Sv= 15
3Sh-4Sv= 24	*1,5	4,5Sh-6Sv= 36 +
		8,5Sh = 51 Sh= 6,0 kN

4*6+6Sv= 15   6Sv=15-24   6Sv= -9   Sv=-1,5 kN

Going on with these results to calculate the reactions at A and B, see the separated two parts.

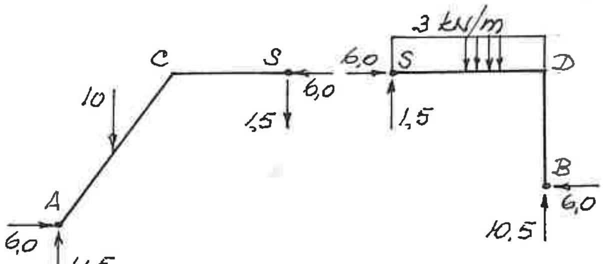


Fig.11b.

Left part.

∑ hor.=0	Ah-Sh=0	Ah-6,0=0	Ah= 6,0 kN
∑ vert.=0	Av-10+Sv=0		
	Av-10+(-1,5)=0		Av= 11,5 kN

Right part.

∑ hor.=0	Sh-Bh=0	6,0-Bh=0	Bh= 6,0 kN
∑ vert.=0	Bv-3*4-Sv=0		
	Bv-12-(-1,5)=0		Bv= 10,5 kN

Five positive answers, the concerning forces have the assumed directions. One negative answer, Sh= -1,5 kN, the assumed direction was wrong, thus opposite directed.

Fig.11b.
Reaction forces and hinge forces drawn with their real directions. Note how the vertical hinge forces are drawn with value 1,5 kN.

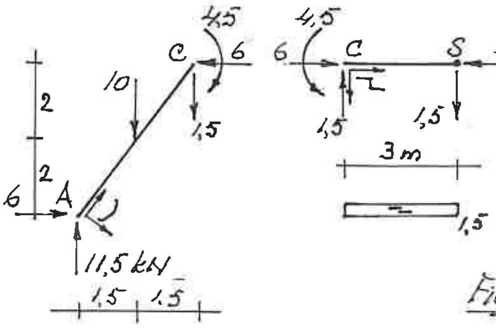


Fig.12a.

Fig.12a.
The left part of the hinge frame is cut into two parts, left A-C and right C-S.

Equilibrium of right part C-S.

At S the calculated shear and normal force of 1,5 and 6 kN. With the equilibrium equations for this part follow at C
a shear force of 1,5 kN upward ↑,
a normal force of 6,0 kN to the right ⟶, and
a bending moment of 4,5 kNm to the left ↶.

At C of left part A-C act forces and moment as large as but opposite directed.

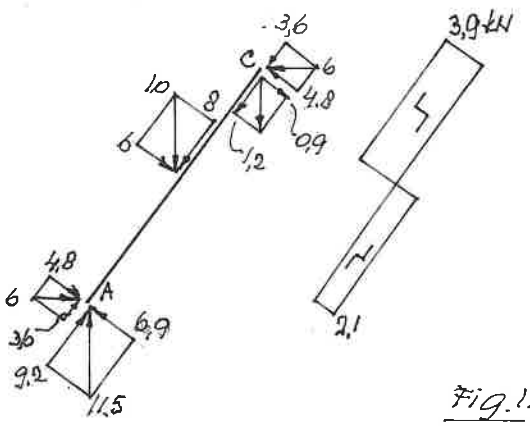


Fig.12b.

Fig.12b.
The shear force diagram of part A-C. The beam/member end forces at C and A are resolved into forces perpendicular to and along the member. (For the force 1,5 kN, small, drawn too large. With the beam axis system ⌐⌣ at A the diagram is drawn going from C to A.

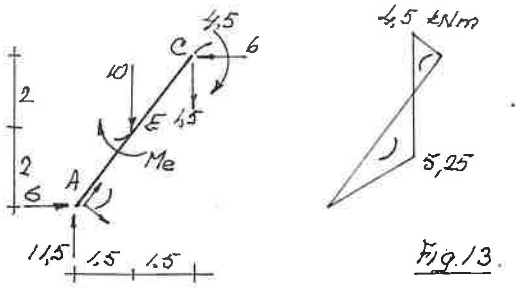


Fig.13.

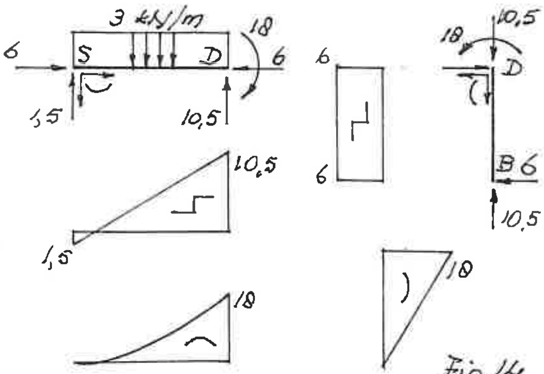


Fig.14.

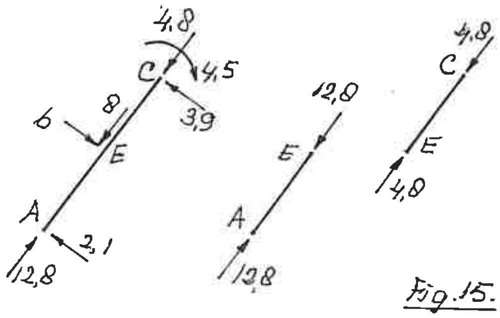


Fig.15.

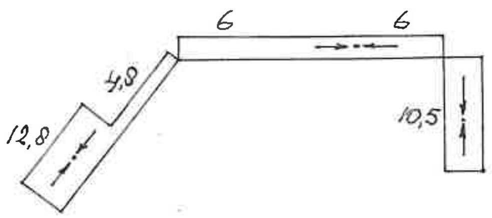


Fig.16.

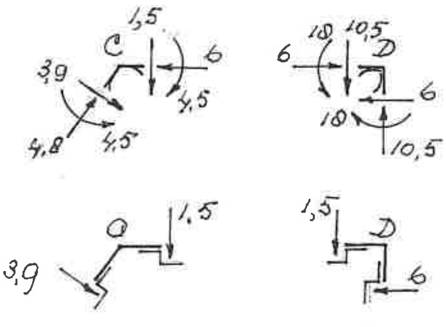


Fig.17.

Example.

Fig.13. See prec. page.

The bending moment diagram of part A-C.
The beam axis system is drawn at member end A. (Not really necessary when knowing the assumed bending signs like on both sides of the zero line.)
At C 4,5 kNm to the right, half of the bending sign due to that moment can be drawn thus knowing where to plot in the diagram.
The bending moment at E, suppose Me like drawn then Me =11,5*1,5-6*2= 5,25 kNm, pos. answer, direction as assumed, half of the bending sign follows, so knowing where to plot it.
Or from the other side of E, assuming Me to the left, then
Me =6*2-1,5*1,5-4,5=12-6,75= 5,25 kNm, etc.

Fig.14.

Part S-D-B is cut into S-D and D-B. With the three equations of equilibrium shear force, normal force and bending moment can be found, drawn at D with their real directions.
Beam axis system at S, shear force diagram starting drawing the diagram at the right end with 10,5 kN and going to the left.
Beam axis system at D of part D-B, 'left end', then starting with 6 kN at 'right end' B etc.
The figure shows the normal force in S-D is compression of 6 kN, in D-B compression as well 10,5 kN.

Fig.15.

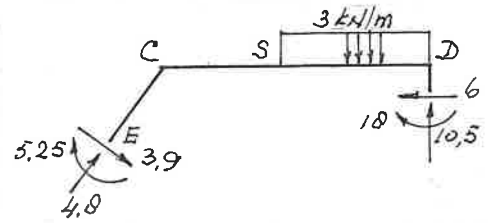
Member A-C cut into two parts, cut at both sides of E. Like above shear force and bending moment diagram can be drawn.
Part A-E, equilibrium along the member axis gives 12,8 kN at E, compression in A-E 12,8 kN, part C-E gives compression 4,8 kN in C-E.

Fig.16.

The normal force diagrams, compression indicated with →,←. On which side of the zero line of no importance.
In case of tension, indicated with ←-→.

Fig.17.

Joints C and D separated from the beams/members with forces and moments acting on them. These are as large as those acting on the corresponding member ends but opposite directed.



Every separated part must be in equilibrium. A check is simplier if shear force and normal force are resolved into horizontal and vertical components

Continuous beam with internal hinge.

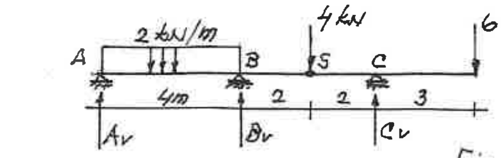


Fig.18a.

Fig.18a.
Two equations, $\sum$ vert.=0 and $\sum$ mom.=0, three unknowns, Av, Bv and Cv.

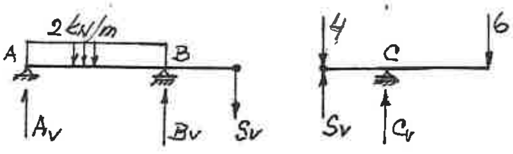


Fig.18b.

Fig.18b.
Cut into two parts at hinge S.
Direction of hinge forces assumed. Here Sv on the left part assumed downward, in that case on the right part as large as but opposite directed, thus upward.
The load force on the hinge of 4 kN is put on the right part, or on the left part, or e.g. 1 kN on the right and 3 kN on the left part.
Support reactions assumed upward.

Part on the right.
$\sum$ mom.S=0   6*5-Cv*2=0   Cv=15 kN   or
                  Cv*2-6*5=0   Cv=15 kN
$\sum$ vert.=0   4+6-Sv-15=0   Sv=-5 kN   or
                  -15-4-6-Sv=0   Sv=-5 kN
Cv positive answer, directed as assumed. Sv negative answer, not directed as assumed, but going on with assume Sv with Sv=-5 kN.
Part on the left.
$\sum$ mom.A=0   2*4*2-Bv*4+Sv*6=0   16-Bv*4+Sv*6=0
                  16-Bv*4+(-5)*6=0
                  -14-Bv*4=0   Bv=-3,5 kN
               or Bv*4-16-(-5)*6=0   Bv=-3,5 kN
$\sum$ vert=0.   2*4-Av-Bv+Sv=0
                  8-Av-(-3,5)+(-5)=0   Av= 6,5 kN
               or Av+(-3,5)-8-(-5)=0   Av= 6,5 kN
Bv negative answer, not directed as assumed, Av positive answer, thus directed as assumed.

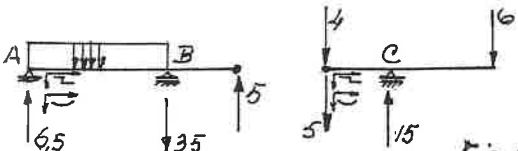


Fig.18c.

Fig.18c.
Both beam parts with forces drawn with their real directions. Beam axis systems at left beam ends.

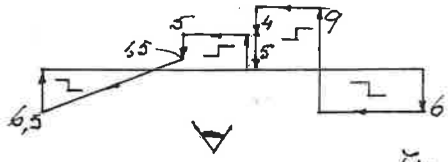


Fig.18d.

Fig.18d.
The shear force diagram is drawn from 'right to left'.

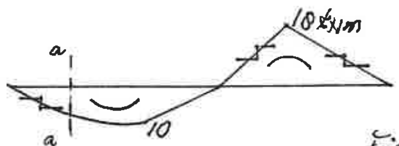


Fig.18e.

Fig.18e.
The bending moment diagram with corresponding bending signs.

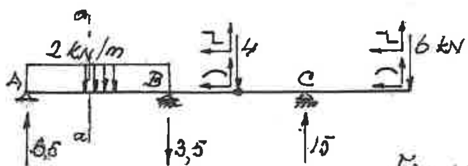


Fig.19a.

Fig.19a.
Here the axis systems are placed at left end of the beams when looking at them from above.

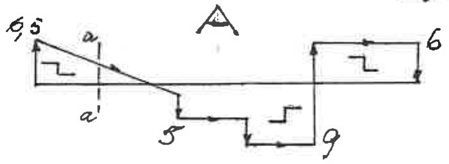


Fig.19b.

Fig.19b.
Also now drawing the shear force diagram starting at A which is 'on the right' of the beam. Comparing with fig. 8d this diagram is mirrored, the shear signs are the same, of course.

The bending moment diagram is like that of fig. 8e, bending signs the same.

Shear sign and bending sign.

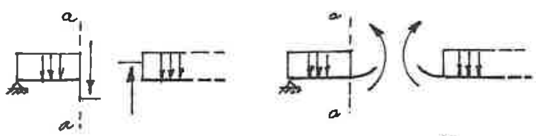


Fig.19c.

Fig.19c.
With these signs one knows at once how shear force and bending moment act on 'both sides' of a cross-section, how they are directed. And, as large as but opposite directed.

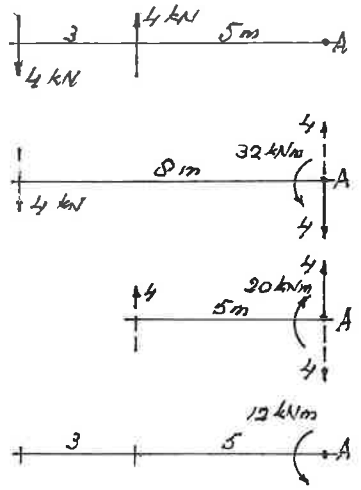


Fig.1a.

1b.

1c.

1d.

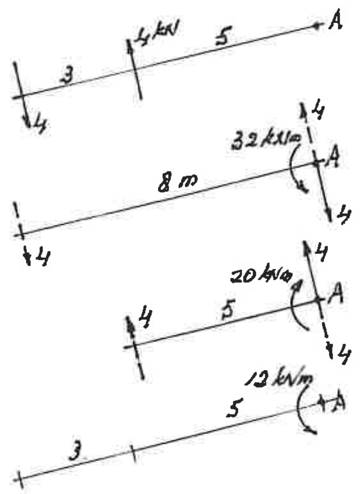


Fig.2a.

2b.

2c.

2d.

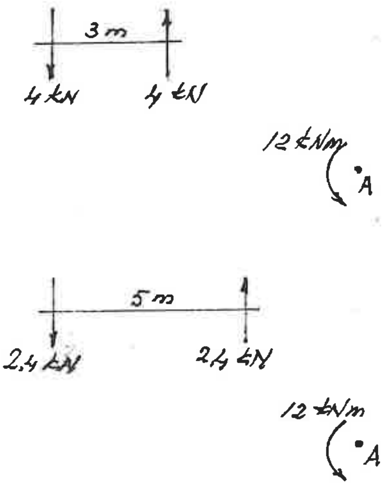


Fig.3.

Couples of forces.

Fig.1a.
A couple of forces of 4 kN at distances from A with a moment of 4x3= 12 kNm to the left.

Each of the forces can be resolved into a force through A and a couple of forces, see page 1.

Fig.1b.
4 kN at 8 meter from A into a downward force of 4 kN through A plus a couple of forces of 4 kN with moment 4x8= 32 kNm to the left.

Fig.1c.
4 kN at 5 meter from A into an upward force of 4 kN through A plus a couple of forces of 4 kN with a moment of 4x5= 20 kNm to the right.

Fig.1d.
The two opposite directed forces of 4 kN are together zero. The two moments of couples can be added,

32 - 20 = 12 kNm to the left.
Force and arm of this couple are unknown.

Fig.2a.
The same couple of forces with moment 4x3= 12 kNm to the left in another position.

These forces can be resolved into a force and a couple like done here above.

Fig.2b.
4 kN at 7 m from A into 4 kN through A plus a couple with forces 4 kN with moment 4x7= 28 kNm to the left.

Fig.2c.
4 kN at 4 m from A into 4 ikN through A plus a couple with forces 4 kN with a moment of 4x4= 16 kNm to the right.

Fig.2d. The two opposite forces of 4 kN are in equilibrium. The two moments can be added,

28 - 16 = 12 kNm to the left.
Force and arm of this couple are unknown.

Fig.1a and fig.2a give same result.

Fig.3.
Couple force and distance of the couple moment of 12 kNm can be changed keeping the moment of the couple the same, 12 kNm.

4x3=12 kNm   E.g.   Fx5=12   F=12/5= 2,4 kN

These forces of 2,4 kN can be resolved into forces through A plus a couple with a moment of 12 kNm, like done here above.

Moments of couples indicated with to the right, or to the left, can be added. Their sum means always a couple of forces of which force and arm can be changed as wanted.

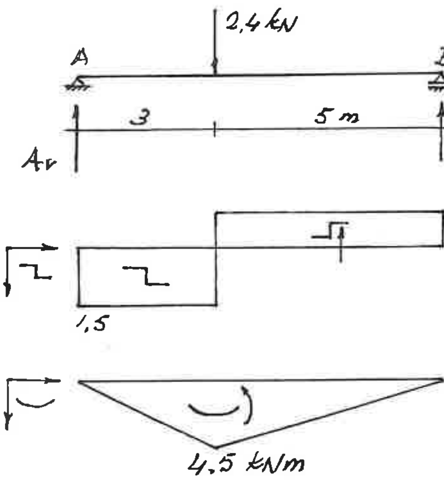


Fig.4.

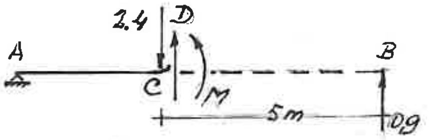


Fig.5.

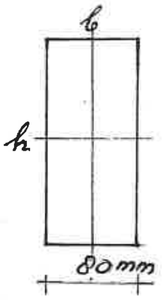


Fig.6a

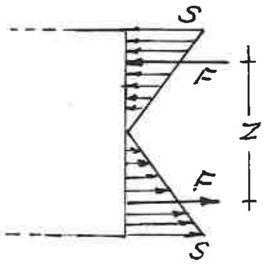


Fig.6b.

Calc. of allowable bending moment.

Moment of inertia

I= (1/12)*80*180^3 = 38,9 *10^6 mm^4,

moment of resistance W= I/90) or

W= (38,9*10^6)/90= 432*10^3 mm^3

Stress S= M/W N/mm^2= Nmm/mm^2

With assumed allowed stress S= 12 N/mm2

follows 12= M/432*10^3 or

M=12*432*10^3= 5,2*10^6 Nmm, then is

the allowable maximum bending moment

with 1 kNm= 10^6 Nmm is M=5,2 kNm.

Fig.4.
A simple beam length 8 m loaded with 2,4 kN at 3 m from the left.

$\sum$ mom. A=0
2,4*3 -Bv*8=0 Bv=7,2/8= 0,9 kN
$\sum$ vert.=0
Av -2,4 +Bv=0 Av-2,4+0,9=0 Av= 1,5 kN

Shear force diagram and bending moment diagram drawn according to the assumed shear force and bending moment axis systems.

Fig.5.
The beam is cut just on the right of 2,4 kN. Considering the left part, the influence of Bv=0,9 kN on the right of 2,4 kN.

Force Bv=0,9 kN is resolved into a vertical force of 0,9 kN, shear force D, at C plus a couple of forces with moment M= 0,9*5= 4,5 kNm to the left ↶ at C.

M ◡) = Bv*5= 0,9*5= 4,5 kNm.

D ⌐↑ = Bv= 0,9 kN.

Fig.6a.
Suppose a rectangular cross-section 80x180 mm.

At C arise at the upper part compression stresses and at the lower part tensile stresses.

Fig.6b.
180 mm= 180*10^-3 m
Stresses are forces per unit area, like N/mm^2.

These forces added give forces F together a couple with moment
M = F*(2/3)*180*10^-3= F*(120*10^-3)= 4,5 kNm

F= 4,5/(120*10^-3)= 37,5 kN

This way the couple with forces 0,9 kN and arm 5 m with moment 0,9*5= 4,5 kNm
is changed into a couple with forces 37,5 kN and arm 0,12 m with moment 37,5*0,12= 4,5 kNm.

Calculation of stress S with M= 4,5 kNm.

F= 37,5 kN with 0,09 m and 0,08 m is

37,5= (S*0,09*0,08)/2 = 0,0036*S

S=37,5/0,0036= 10,4*10^3 kN/m^2

= 10,4*10^3* 10^3 N/10^6 mm^2

S = 10,4 N/mm^2

(With timber allowable tensile and compressive stress will not be the same.)

Moment of resistance W= b*h^2/6=
(80*180^2)/6= 432*10^3 mm^3

M= 4,5 kNm = 4,5*10^3*10^3= 4,5*10^6 Nmm,

S= M/W= (4,5*10^6)/(432*10^3)= 10,4 N/mm^2

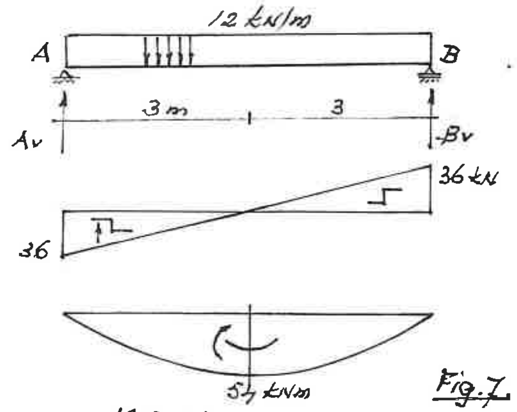


Fig.7.

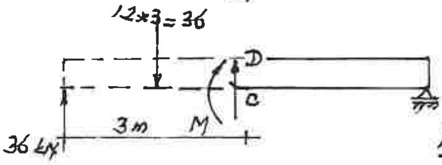


Fig.8.

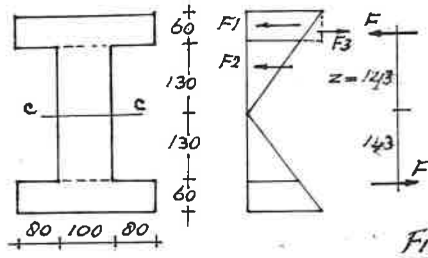


Fig.9a.

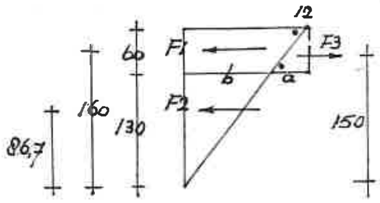


Fig.9b.

Calculation of the moment of inertia I.

(1/12)*100*260^3 = 146,5 *10^6 mm^4

2*((1/12)*260*60^3)= 9,4 *10^6 mm^4

2*(260*60)*(160^2) = 798,7 *10^6 mm^4

moment of inertia I= 934,6 *10^6 mm^4

moment of resistance W= I/190) or

W= (934,6*10^6)/190= 5,0*10^6 mm^3

Stress S= M/W N/mm^2= Nmm/mm^2

With allowed stress S= 12 N/mm2 follows

12= M/5,0*10^6 or

M=12*5,0*10^6= 60,2*10^6 Nmm, then is the allowable maximum bending moment with 1 kNm= 10^6 Nmm M= 60,2 kNm.

Fig.7.
A beam loaded with a uniformly distributed load of 12 kN/m
∑ mom. A=0
(12*6)*3 -Bv*6=0 Bv=216/6= 36 kN
∑ vert.=0
Av -72 +Bv=0 Av= 72 -36= 36 kN

Or, Av=Bv= (12*6)/2= 36 kN.

Fig.8.
The beam is cut just on the left of the middle. Considering the right part, the influence of Av=36 kN and (12*3) of the distributed load,

Av=36 kN is resulved into 36 kN upward at C plus a couple with moment 36*3= 108 kNm ↶ , (12*3) is resolved into 12*3=36 kN downward at C plus a couple with moment (12*3)=36 kNm ↷ .

Both forces at C 36-36=0 kN, both moments of the couples 108 - 54 is 54 kNm ↶ .

M ↶ = Av*3 -(12*3)*1,5= 108-54= 54 kNm

D ⇅ = Av -(12*3)= 36-36=0 kN.

Fig.9a and 9b.
An assumed cross-section. Assumed allowable stress 12 N/mm^2.(Happened to be same number like 12 of the distributed load...) Calculation of allowable maximum bending moment.

a/60= 12/190 a=60*(12/190)= 3,8 N/mm^2

b= 12,0-3,8= 8,2 N/mm^2

F1= 12*60*260 = 187,2 *10^3 N
\+
F2=((8,2*130)/2)*100 = 53,3 *10^3 N +
240,5 *10^3 N
\-
F3=((3,8*60)/2)*260 = 29,6 *10^3 N -

F = F1 +F2 -F3 = 210,9 *10^3 N

Moments w.r.t. line c.

F1*160 = 187,2*10^3 *160 = 29,95 *10^6 Nmm
\+
F2*(2/3)*130= 53,3*10^3 *86,7= 4,62 *10^6 Nmm
34,57 *10^6 Nmm
\-
F3*150 = 29,6*10^3 *150 = 4,45 *10^6 Nmm

F*z= 210,9 *10^3 *z= 30,12 *10^6 Nmm

z= (30,12*10^6)/(210,9*10^3)= 143 mm

Couple forces 210,9*10^3 N, arm 2*143= 286 mm,

moment F*284= 210,9*10^3*286= 60,3*10^6 Nmm,

M= 60,3 kNm > 54 kNm.

On the left applying moment of inertia I and moment of resistance W to calculate the allowable maximunt bending moment with 12=M/W.

<u>Examples applying beam axis systems.</u>

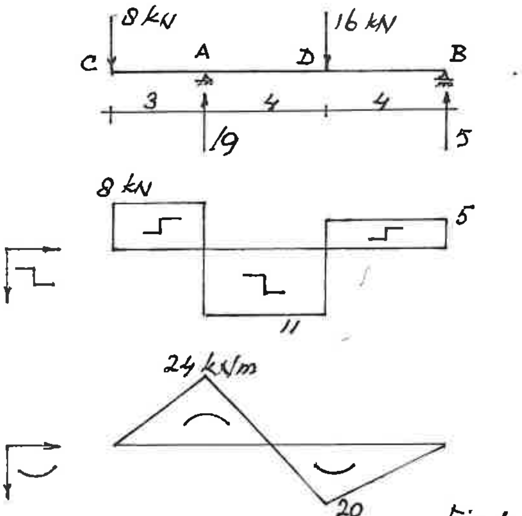
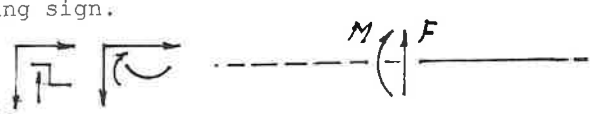


Fig. 1.

Fig. 1.
Reactions are calculated, shear force and bending moment diagram drawn.

<u>First case.</u>
Shear force F and bending moment M acting from '<u>left onto right</u>' according to shear force and bending sign.



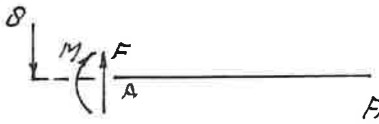


Fig. 2a

Fig. 2a.
Just on the left of A.
F = 0-8 = -8 kN, neg. answer, so ,
see the shear force diagram, 8 kN above the zero line.
M = 0-8*3= -24 kNm neg. answer, so ,
see the bending moment diagram, 24 kNm above the zero line.

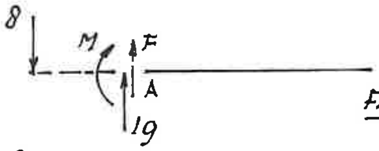


Fig. 2b.

Fig. 2b.
Just on the right of A.
F = 19-8= 11 kN, pos. answer, so ,
11 kN below the zero line.
M = 19*0-8*3= -24 kNm, neg. answer, so ,
24 kNm above the zero line.

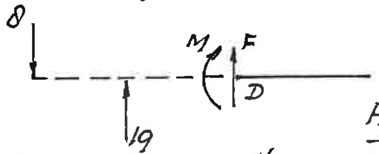


Fig. 2c.

Fig. 2c.
Just on the left of D.
F = 19-8= 11 kN, pos. answer, so ,
11 kN below the zero line.
M = 19*4-8*7= 76-56= 20 kNm, pos. answer,
so , 20 kNm below the zero line.

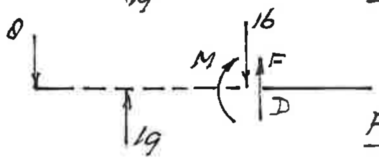


Fig. 2d.

Fig. 2d
Just on the right of D.
F = 19-8-16= -5 kN, neg. answer, so ,
5 kN above the zero line.
M = 19*4-8*7-16*0= 76-56-0= 20 kNm, so ,
20 kNm below the zero line.

<u>Second case.</u>
Shear force F and bending moment M acting from '<u>right onto left</u>' according to shear force and bending sign.

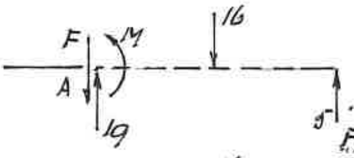


Fig. 3a.

Fig. 3a.
Just on the left of A.
F = 16-5-19= -8 kN, neg. answer, so ,
8 kN above the zero line.
M = 5*8-16*4+19*0= -24 kNm, neg. answer,
so , 24 kNm above the zero line.

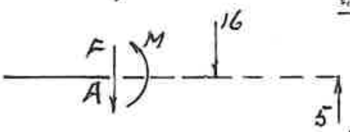


Fig. 3b.

Fig. 3b.
Just on the right of A.
F = 16-5= 11 kN, pos. answer, so ,
11 kN below the zero line.
M = 5*8-16*4= -24 kNm, neg. answer, so ,
24 kNm above the zero line.

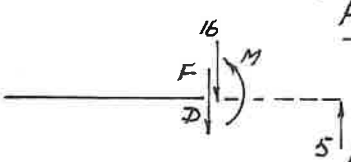


Fig. 3c.

Fig. 3c.
Just on the left of D.
F = 16-5= 11 kN, pos. answer, so .
M = 5*4-16*0= 20 kNm, pos. answer, so .

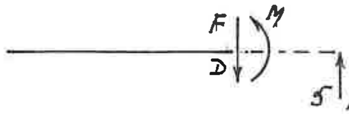


Fig. 3d.

Fig. 3d.
Just on the right of D.
F = 0-5= -5 kN, neg. answer, so .
M = 5*4= 20 kNm, pos. answer, so .

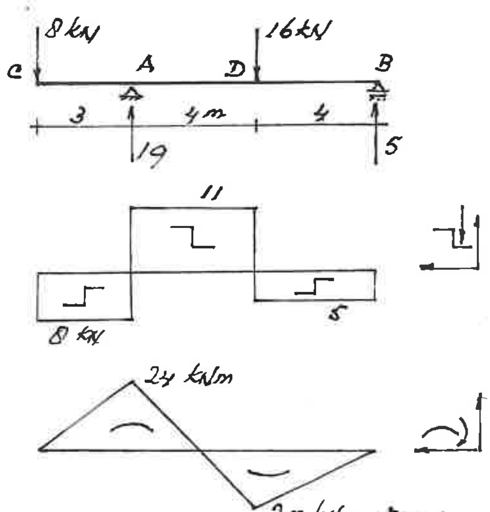


Fig.4.

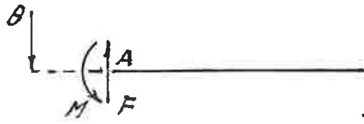


Fig.5a.

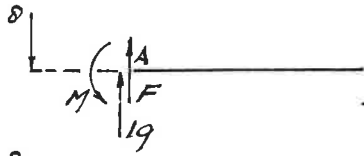


Fig.5b.

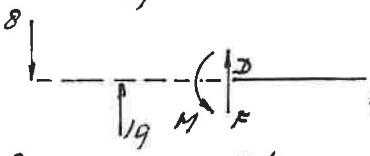


Fig.5c.

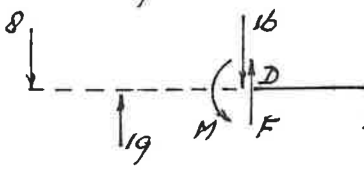


Fig.5d.

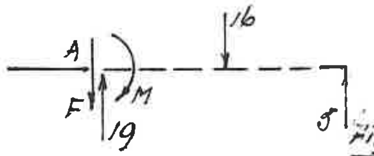


Fig.6a.

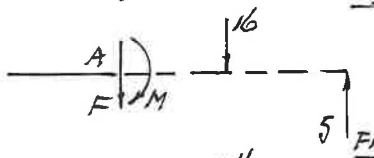


Fig.6b.

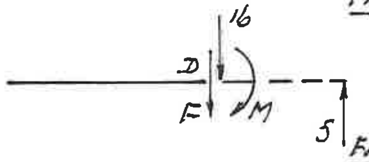


Fig.6c.

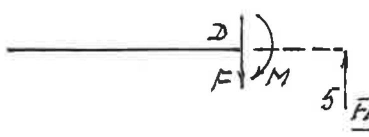


Fig.6d.

Fig.4.
Beam axis systems on the other beam end.

First case.
Like done before on the preceding page for cases 'left onto right'.

Fig.5a.
Just on the left of A.
F = 0-8= -8 kN, neg. answer, so ,
8 kN below the zero line.
M = 8*3= 24 kNm, pos. answer, so ,
24 kNm above the zero line.
Fig.5b.
Just on the right of A.
F = 19-8= 11 kN, pos. answer, so ,
11 kN above the zero line.
M = 8*3-19*0= 24 kNm, pos. answer, so ,
24 kNm above the zero line.

Fig.5c.
Just on the left of D.
F = 19-8= 11 kN, pos. answer, so ,
11 kN above the zero line.
M = 8*7-19*4= 56-76= -20 kNm, neg. answer, so , 20 kNm below the zero line.
Fig.5d.
Just on the right of D.
F = 19-8-16= -5 kN, neg. answer, so ,
5 kN below the zero line.
M = 8*7-19*4-16*0= 56-76= -20 kNm, neg. answer, so , 20 kNm below the zero line.

Second case.
Shear force F and bending moment M acting from 'right onto left' according to shear force and bending sign.

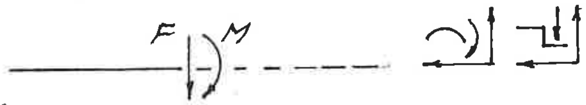


Fig.6a.
Just on the left of A.
F = 16-5-19= -8 kN, neg. answer, so ,
8 kN below the zero line.
M = 16*4-5*8-19*0= 24 kNm, pos. answer,
so , 24 kNm above the zero line.
Fig.6b.
Just on the right of A.
F = 16-5= 11 kN, pos. answer, so ,
11 kN above the zero line.
M = 16*4-5*8= 24 kNm, pos. answer, so ,
24 kNm above the zero line.

Fig.6c.
Just on the left of D.
F = 16-5= 11 kN, pos. answer, so ,
11 kN above the zero line.
M = 16*0-5*4= -20 kNm, neg. answer, so ,
20 kNm below the zero line.
Fig.6d.
Just on the right of D.
F = 0-5= -5 kN, neg. answer, so ,
5 kN below the zero line.
M = 0-5*4= -20 kNm, so ,
20 kNm below the zero line.

Fig. 1.
A beam with two load moments (being the moments of two couples of forces).

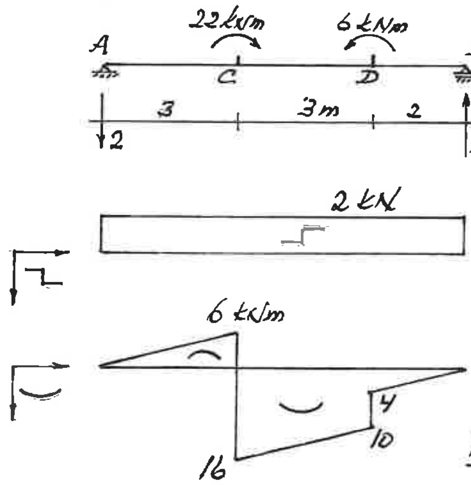


Fig.1.

<u>First case</u>.
Like done before on the preceding page, shear force F and bending moment M acting from '<u>left onto right</u>'.

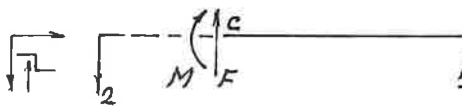


Fig.2a.

Fig.2a.
Just on the left of C.
F↑ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 0-2*3= -6 kNm, neg. answer, so ,
6 kNm above the zero line.

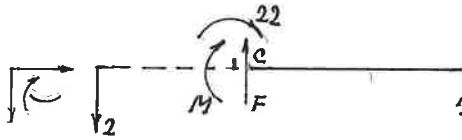


Fig.2b.

Fig.2b.
Just on the right of C.
F↑ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 22-2*3= 16 kNm, pos. answer, so ,
16 kNm below the zero line.

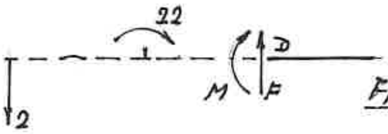


Fig.2c.

Fig.2c.
Just on the left of D.
F↑ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 22-2*6= 10 kNm, pos. answer, so ,
10 kNm below the zero line.

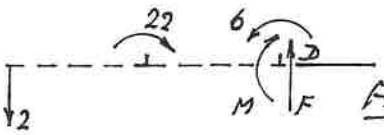


Fig.2d.

Fig.2d.
Just on the right of D.
F↑ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 22-6-2*6= 16-12= 4 kNm, pos. answer,
so , 4 kNm below the zero line.

<u>Second case</u>.
Shear force F and bending moment M acting from '<u>right onto left</u>' according to shear force and bending moment sign.

(Comparing with page , the four steps in reversed order.)

Fig.3a.

Fig.3a.
Just on the right of D.
F↓ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 2*2= 4 kNm, pos. answer, so ,
4 kNm below the zero line.

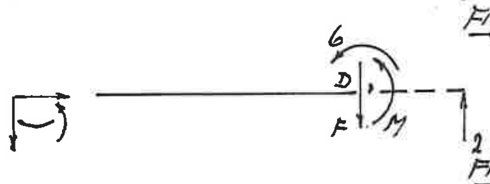


Fig.3b.

Fig.3b.
Just on the left of D.
F↓ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 2*2+6= 10 kNm, pos. answer, so ,
10 kNm below the zero line.

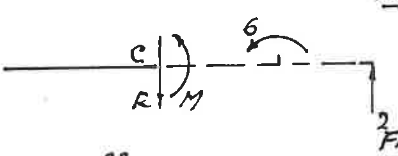


Fig.3c.

Fig.3c.
Just on the right of C.
F↓ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 2*5+6= 16 kNm, pos. answer, so ,
16 kNm below the zero line.

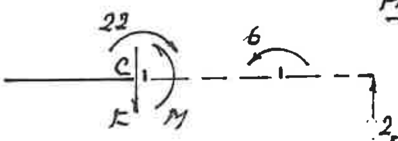
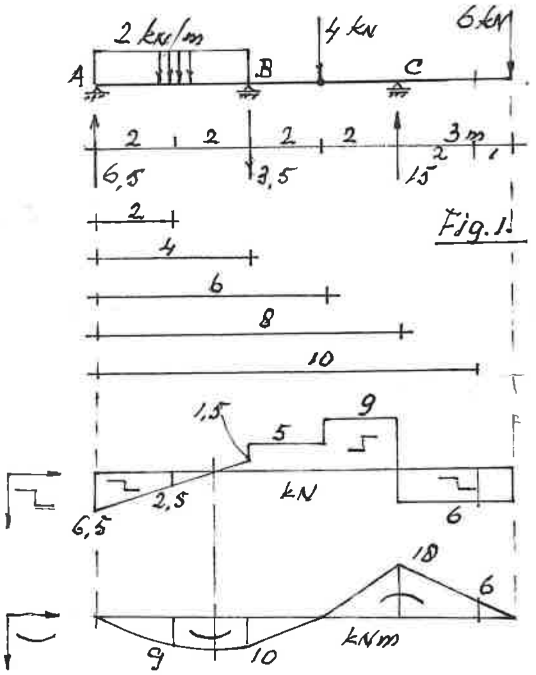


Fig.3d.

Fig.3d.
Just on the left of C.
F↓ = 0-2= -2 kN, neg. answer, so ,
2 kN above the zero line.
M = 2*5+6-22= -6 kNm, neg. answer, so ,
6 kNm above the zero line.



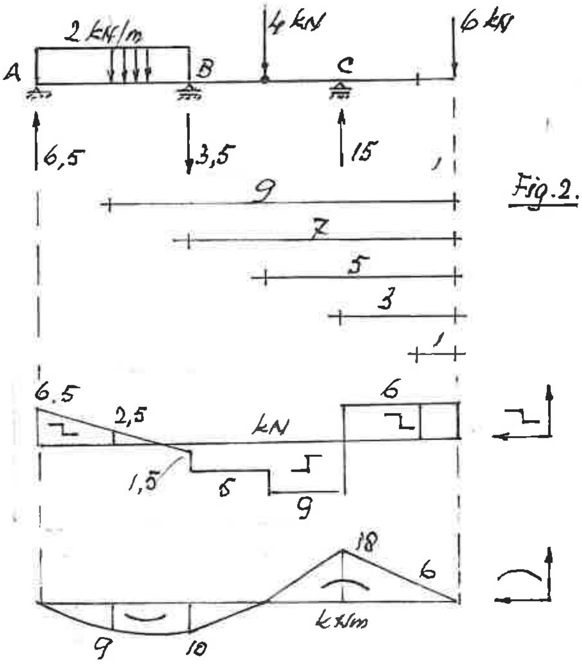
Continuous beam with internal hinge, page 9 .
First case, 'from left onto right'.

Fig.1.
X= 0 m F ↑ = 6,5 kN M= 0 kNm
X= 2 m
F ↑ = 6,5-2*2= 2,5 kN, so .
M = 6,5*2-4*1= 9 kNm, so .
X= 4 m
F ↑ = 6,5-2*4= -1,5 kN, so .
M = 6,5*4-2*4*2= 10 kNm, so .
X= 4 m
F ↑ = 6,5-4*2-3,5= -5 kN, so .
M = 6,5*4-2*4*2= 10 kNm, so .
x= 6 m
F ↑ = 6,5-2*4-3,5= -5 kN, so .
M = 6,5*6-8*4-3,5*2= 0 kNm
x= 6 m
F ↑ = 6,5-2*4-3,5-4= -9 kN, so .
M = 6,5*6-8*4-3,5*2-4*0= 0 kNm
x= 8 m
F ↑ = 6,5-4*2-3,5-4 = -9 kN, so .
M = 6,5*8-8*6-3,5*4-4*2= -18 kNm, so .
x= 8 m
F ↑ = 6,5-2*4-3,5-4+15 = 6 kN, so .
M = 6,5*6-8*4-3,5*4-4*2+15*0= -18 kNm, .
x= 10 m
F ↑ = 6,5-2*4-3,5-4+15= 6 kN, so ,
M = 6,5*10-8*8-3,5*6-4*4+15*2= -6 kNm, .
X= 11 m
F ↑ = 6 kN M= 0 kNm

First case.			Second case.		
X	F	M	X	F	M
0	6,5	0	11	6,5	0
2	2,5	9	9	2,5	-9
4	-1,5	10		-1,5	-10
	-5,0	10	7	-5,0	-10
6	-5,0	0		-5,0	0
	-9,0	0	5	-9,0	0
8	-9,0	-18		-9,0	18
	6,0	-18	3	6,0	18
10	6,0	-6	1	6,0	6
11	6,0	0	0	6,0	0

Second case, 'from right onto left'.

Fig.2.
X= 11 m F ↓ = 6,5 kN M= 0 kNm
x= 9 m
F ↓ = 6-15+4+3,5+2*2= 2,5 kN, so .
M = 6*9-15*6+4*4+3,5*2+4*1= -9 kNm, so .
x= 7 m
F ↓ = 6-15+4+3,5= -1,5 kN, so .
M = 6*7-15*4+4*2+3,5*0= -10 kNm, so .
x= 7 m
F ↓ = 6-15+4= -5 kN, so .
M = 6*7-15*4+4*2= -10 kNm, so .
x= 5 m
F ↓ = 6-15+4= -5 kN, so .
M = 6*5-15*2+4*0= 0 kNm
x= 5 m
F ↓ = 6-15= -9 kN, so .
M = 6*5-15*2= 0 kNm
X= 3 m
F ↓ = 6-15= -9 kN, so .
M = 6*3-15*0= 18 kNm, so .
X= 3 m
F ↓ = 6 kN, so .
M = 6*3= 18 kNm, so .
X= 1 m
F ↓ = 6 kN, so .
M = 6*1= 6 kNm, so .
X= 0 m F ↓ = 6 kN M= 0 kNm



Second case given with distances in reversed order to compare both easier. Final results ending with same shear force and bending moment sign. Values of shear force in both cases the same, values of bending moment of second case are opposite to those of first case.

More with the example of page 7 .

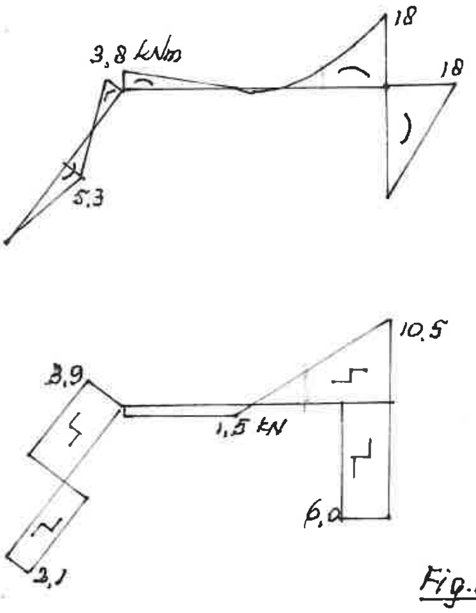


Fig.1.

Fig. 1
Shear force and bending moment diagram drawn completed according to the assumed member end places of the axis sytems and .

Fig.2a.
Calculation from 'left onto right' of shear force F and bending moment M at section E between S and D at 2 m from S.

Force F is the resultant of the vertical forces of the left part on the left of E.
F = 11,5-10,0-6,0= -4,5 kN, so .

M is the resultant moment of the moments of the couples.
M = 11,5*8-6,0*4-10*6,5-3*2*1=
92,0 -24,0 -65,0 -6,0=
92,0-95,0= -3,0 kNm, so .

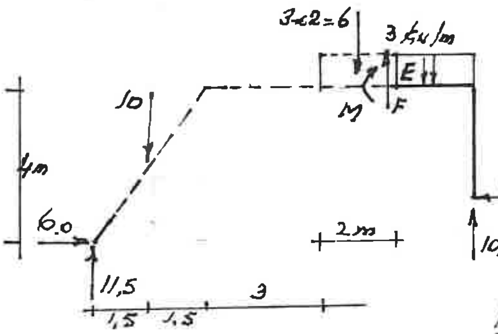


Fig.2a.

Fig.2b.
Calculation from 'right onto left' of sear force F and bending moment M at section E.

Force F is the resultant of the vertical forces of the right part on the right of E.
F = 3*2-10,5= -4,5 kN, so .

Moment M is the resultant monent of the moments of the couples of forces.
M = 10,5*2 -6,0*3 -6*1=
21,0 -18,0 -6,0= -3,0 kNm, so .

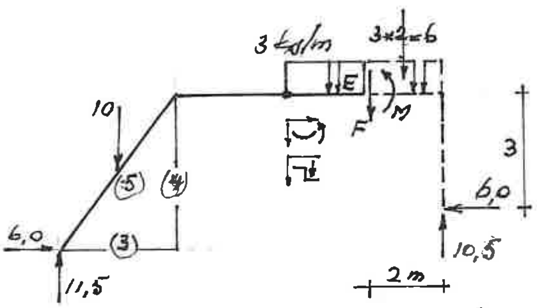
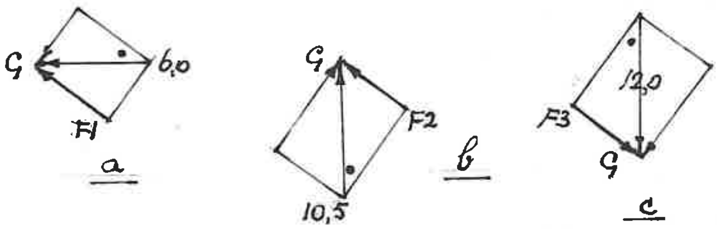


Fig.2b.

Fig.2c.
Section G on the right of the vertical load force of 10 kN.

Three forces are resolved into forces at G plus the moemnts of the couples of the concerning forces. These three forces at G are resolved into shear forces and normal forces.



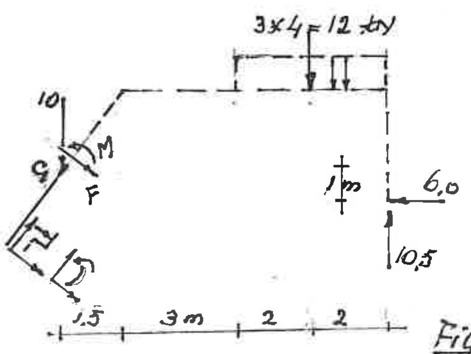


Fig.2c.

Calculation of shear force F .
a) F1/6,0= 4/5 F1 = 6,0*4/5= 4,8 kN

b) F2/10,5= 3/5 F2 =10,5*3/5= 6,3 kN

c) F3/12,0= 3/5 F3 =12,5*3/5= 7,2 kN

F = F3-F2-F1= 7,2-6,3-4,8= -3,9 kN, so .

Calculation of bending moment M due to the moments of the couples of forces.
a) M1 =6,0*1= 6,0 kNm

b) M2 = 10,5*8,5= 89,3 kNm

c) M3 = 12,0*6,5= 78,0 kNm

M = 89,3-6,0-78,0= 5,3 kNm, so . Etc.

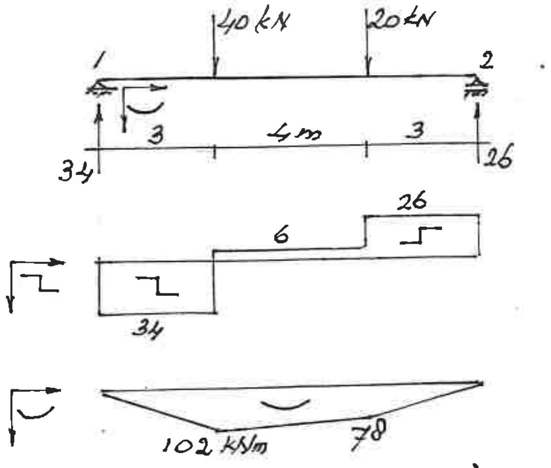


Fig.3.

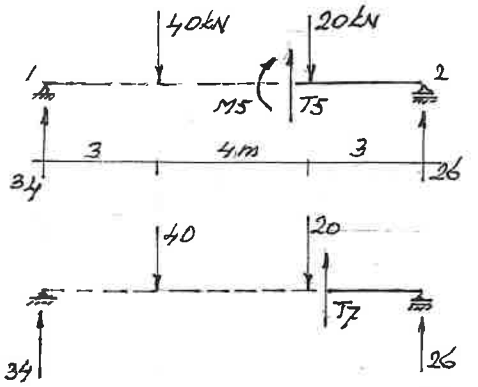


Fig.4.

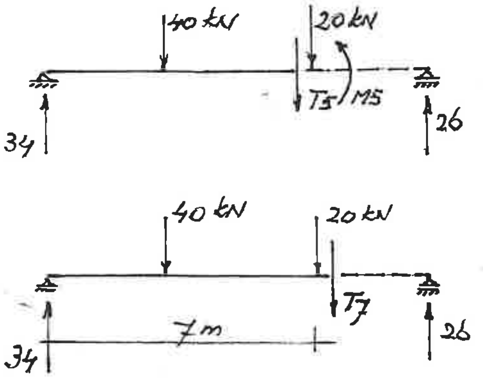


Fig.5.

member P= 1 L1(1)= 10,000 m

X m	T5 kN	T7 kN	M5 kNm
0,00	34,00		0,00
1,50	34,00		51,00
3,00	34,00	-6,00	102,00
4,50	-6,00		93,00
6,00	-6,00		84,00
7,00	-6,00	-26,00	78,00
7,50	-26,00		65,00
9,00	-26,00		26,00
10,00	-26,00		0,00

Example.

First possibility.

Fig.3.
With ↓⌣ and ↓⌐L at right beam end. Shear force and bending moment diagram are drawn. Calculation from 'left to right' of shear force T5 left of 20 kN and T7 right of 20 kN.

Fig.4.
Shear force sign ⌐L determines the direction of T5 and T7.

T5 ⌐L = 34-40= -6 kN, negative answer, so not ⌐L as assumed but _⌐.

T7 ⌐L = 34-40-20= -24 kN, thus ⌐L.

M5 ⌣ = 34*7-40*4= 238-160= 78 kNm, positive answer, so as assumed ⌣.

Suppose calculation with the given shear sign _⌐ of the diagram left and right of 20 kN, here both the same, but they can be different as well.

T5 _⌐ = 40-34= 6 kN, positive answer, so _⌐ as assumed.

T7 _⌐ = 40+20-34= 26 kN, so as assumed _⌐.

M5 ⌣ like here above.

Fig.5.
Calculation from 'right to left' of shear force T5 on the left of 20 kN and T7 on the right of 20 kN.

T5 ⌐L = 20-26= -6 kN, not ⌐L but _⌐.

T7 ⌐L = 0-26= -26 kN, not ⌐L but _⌐.

M5 ⌣ = 26*3= 78 kNm, positive answer so ⌣ as assumed.

Or with the given shear sign in the diagram as assumed sign.

T5 _⌐ = 26-0= 26 kN, so _⌐ as assumed.

T7 _⌐ = 26-20= 6 kN, so _⌐ as assumed.

With a program. When T5, T7 and M5 calculated each meter, and printed, with a calculation, starting from the place of the beam axis system. with the assumed shear force and bending moment signs, ↓⌣ and ↓⌐L.

At the force of 20 kN at 7 m from the left follow

T5= -6,00 kN and T7= -26,00 kN, negative answers, so not ⌐L but _⌐, and

M5= 78,00 kNm, positive answer and thus ⌣ as assumed.

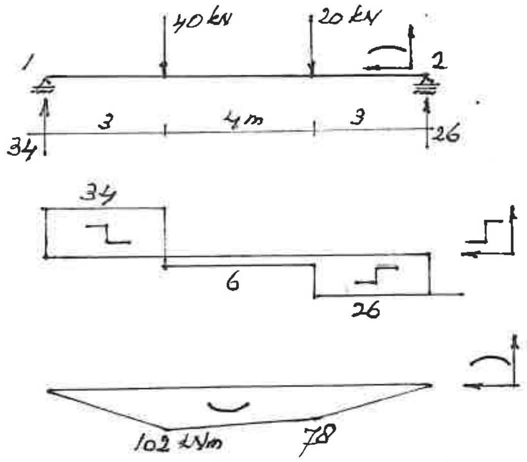


Fig. 6.

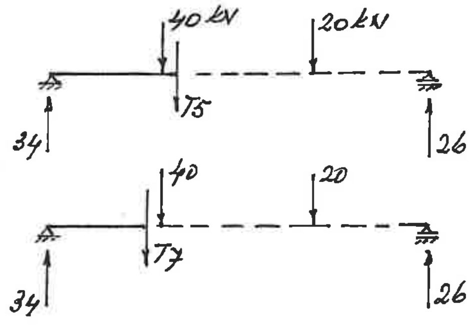


Fig. 7.

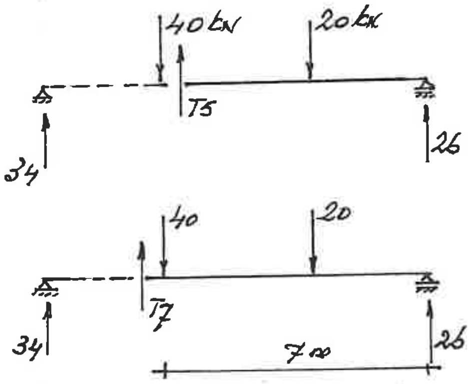


Fig. 8.

member P= 1   L1(1)= 10,000 m

X m	T5 kN	T7 kN	M5 kNm
0,00	-26,00		0,00
1,50	-26,00		-39,00
3,00	-26,00	-6,00	-78,00
4,50	-6,00		-87,00
6,00	-6,00		-96,00
7,00	-6,00	34,00	-102,00
7,50	34,00		-85,00
9,00	34,00		-34,00
10,00	34,00		0,00

<u>The second possibility.</u>
Fig. 6.
With ⌒↑ and ⌐L↑ at right beam end.
With calculated reactions shear force and bending moment diagram are drawn.
Calculation from 'right to left' of shear force T5 right of 40 kN and T7 left of 40 kN.

Fig. 7.
Shear force sign ⌐L determines the direction of T5 and T7.

T5 ⌐↓L = 20-26= -6 kN, negative answer, so not

⌐L as assumed but _Γ .

T7 ⌐↓L = 40+20-26= 34 kN, thus ⌐L .

M5 ⌒) = 20*4-26*7= 80-182= -102 kNm, negative

answer, so not ⌒ as auuned but ‿ .

Suppose calculation with the given shear signs _Γ and ⌐L of the diagram right and left of 40 kN, two different cases.

T5 _↑Γ = 26-20= 6 kN, so _Γ as assumed.

T7 ⌐↓L = 40+20-26= 34 kN, so as assumed ⌐L .

M5 ‿ like here above.

Fig. 8.
Calculation from 'left to right' of shear force T5 on the right of 40 kN and T7 on the left of 40 kN.

T5 ↑⌐L = 34-40= -6 kN, not ⌐L but _Γ .

T7 ↑⌐L = 34 kN, as assumed ⌐L .

M5 (⌒ = 0-34*3= -102 kNm, negative answer so

not ⌒ as assumed but ‿ .

Or with the given shear signs _Γ and ⌐L in the diagram as assumed sign.

T5 ↓_Γ = 40-34= 6 kN, so _Γ as assumed.

T7 ↑⌐L = 34 kN, so ⌐L as assumed.

With a program. When T5, T7 and M5 calculated each meter, and printed, with a calculation, starting from the place of the beam axis system. with the assumed shear force and bending moment signs, ⌒↑ and ⌐L↑ .

At the force of 40 kN at 7 m from the right follow

T5= -6,00 kN and T7= 34 kN, with _Γ and ⌐L .

M5= -102 kNm, negative answer, not ⌒ as assumed but ‿ .

<u>Comparing the two possibilities</u>, the final results are the same, see the shear force and bending moment signs.

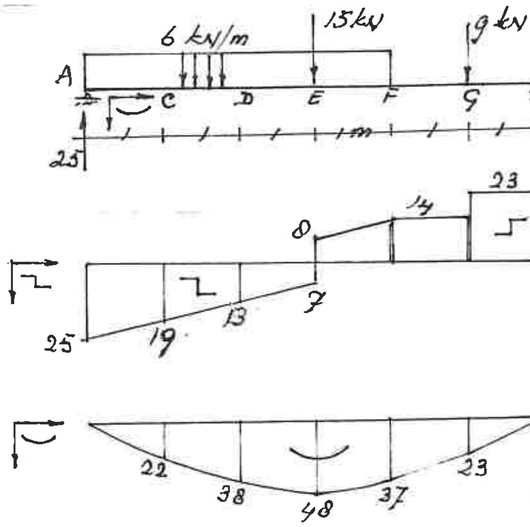


Fig 9.

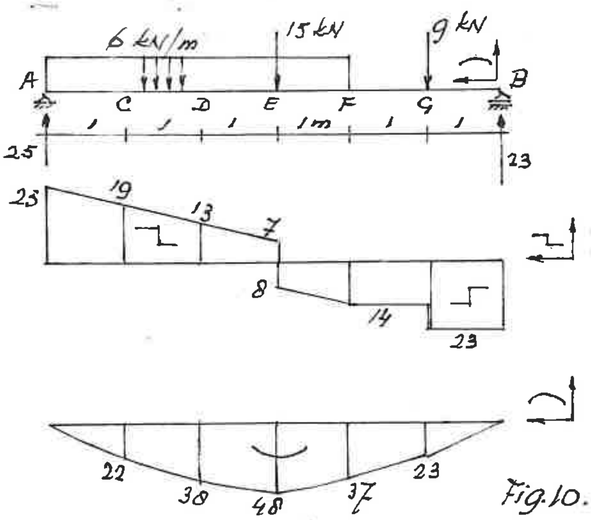


Fig.10.

First possibility with at A.

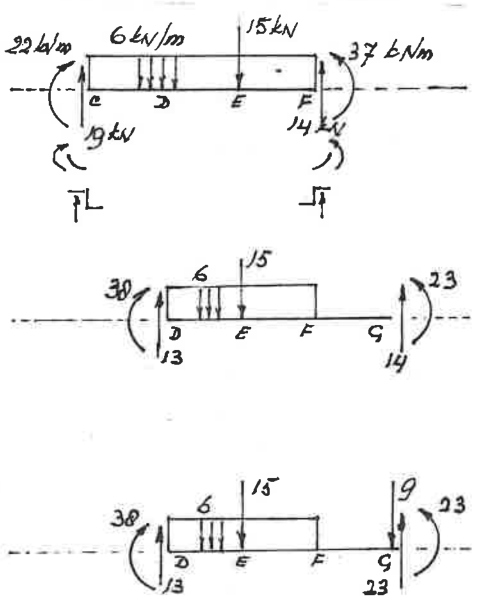


Fig. 11.

Second possibility with at B.

Example.

Fig. 9.

First possibility with beam axis system at the left beam end. Calculation of shear force F and bending moment M, from 'left onto right', and .

A	F	=	25	kN
C	F= 25-6*1	=	19	kN
D	F= 25-6*2	=	13	kN
E	F= 25-6*3	=	7	kN
	F= 25-6*3-15	=	-8	kN
F	F= 25-6*4-15	=	-14	kN
G	F= 25-6*4-15	=	-14	kN
	F= 25-6*4-15-9	=	-23	kN
B	F= 25-6*4-15-9= 25-48	=	-23	kN

A	M=	=	0	kNm	A
C	M= 25*1-6*1*0,5	=	22	kNm	C
D	M= 25*2-6*2*1	=	38	kNm	D
E	M= 25*3-6*3*1,5= 75-27	=	48	kNm	E
F	M= 25*4-6*4*2-15*1= 100-48-15	=	37	kNm	F
G	M= 25*5-6*4*3-15*2	=	23	kNm	G
B	M= 25*6-6*4*4-15*3-9*1	=	0	kNm	B

From 'right onto left', and , with the same results, ofcourse.

B	F= 0-23	=	-23	kN
G	F= 0-23	=	-23	kN
	F= 9-23	=	-14	kN
F	F= 9-23	=	-14	kN
E	F= 9+6*1-23	=	-8	kN
	F= 9+15+6*1-23	=	7	kN
D	F= 15+9+6*2-23	=	13	kN
C	F= 15+9+6*3-23	=	19	kN
A	F= 15+9+6*4-23	=	25	kN

B	M=	=	0	kNm	B
G	M= 23*1	=	23	kNm	G
F	M= 23*2-9*1	=	37	kNm	F
E	M= 23*3-9*2-6*1*0,5	=	48	kNm	E
D	M= 23*4-9*3-15*1-6*2*1	=	38	kNm	D
C	M= 23*5-9*4-15*2-6*3*1,5	=	22	kNm	C
A	M= 23*6-9*5-15*3-6*4*2	=	0	kNm	A

Fig. 10.

Second possibility with beam axis system at the right beam end.
From 'right onto left', and .

B	F= 0-23	=	-23	kN
G	F= 0-23	=	-23	kN
	F= 9-23	=	-14	kN
F	F= 9-23	=	-14	kN
E	F= 9+6*1-23	=	-8	kN
	F= 9+15+6*1-23	=	7	kN
D	F= 15+9+6*2-23	=	13	kN
C	F= 15+9+6*3-23	=	19	kN
A	F= 15+9+6*4-23	=	25	kN

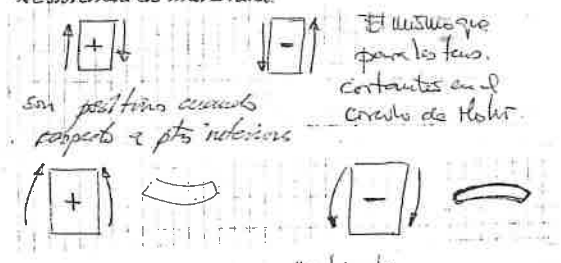
B	M=	=	0	kNm	B
G	M= 0-23*1	=	-23	kNm	G
F	M= 9*1-23*2	=	-37	kNm	F
E	M= 9*2+6*1*0,5-23*3	=	-48	kNm	E
D	M= 15*1+9*3+6*2*1-23*4	=	-38	kNm	D
C	M= 15*2+9*4+6*3*1,5-23*5	=	-22	kNm	C
A	M= 15*3+9*5+6*4*2-23*6	=	0	kNm	A

And from 'left onto right', and , the same results as from 'right onto left'.

Fig. 11.

Some separated parts. Direction of shear forces and bending moments acting at the part ends follow with the shear and bending signs.

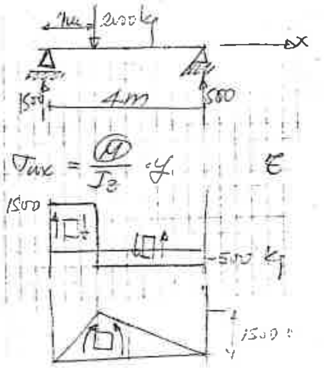
Example V- and M-diagrams. Spanish course notes of a student at the university of Madrid. 'Resistencia de materiales.'



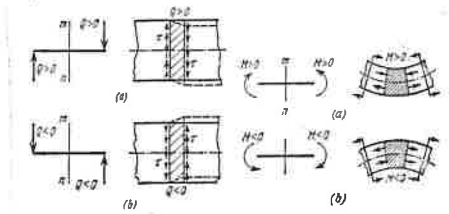
This is amazing! Just a little step to go and they would have shear signs and bending signs.

Here they use in fact V and M.

Spanish I can't read, so I could not discover the 'conventions' for drawing V- and M-diagrams of frames like shown below.



Example V- and M-diagrams. Russian book. English edition. 1st edition in Russia 1938 (Very extensive) 1st edition in English 1979 'Strength of materials' N.M. Belyaev (1890-1944) No frames etc. dealt with in this book.



The used 'language' to explain the sign convention is rather difficult. Also using 'clockwise anti-clockwise.'

Example V- and M-diagrams. French book. 1979 'Resistance des matériaux.' Basquin / Lemasson. In the book only horizontal beams are dealt with.

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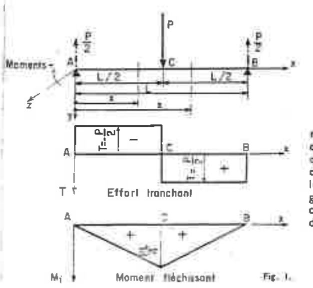


Fig. 1.

Effort tranchant.

De A à C :

$$T = -R_A = -\frac{P}{2}$$

De C à B :

$$T = -R_A + P = \frac{P}{2}$$

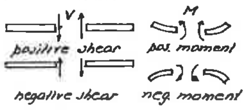
Soulignons la différence existant entre ce cas de flexion et celui que nous avons étudié au cours de la précédente leçon : sur toute la longueur de la poutre nous constatons la présence d'un effort tranchant.

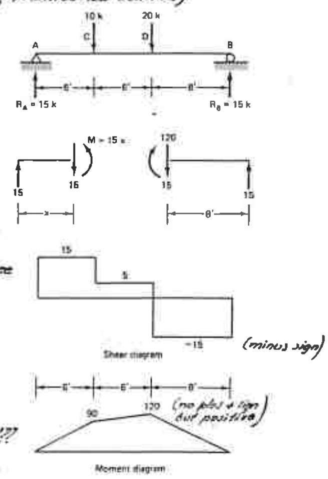
Moment fléchissant.

De A à C :

$$\mathcal{M}_f = R_A \cdot x = \frac{P}{2} \cdot x$$

Example V- and M-diagrams. American book. 'Structural Analyses' Alexander Chajes (University of Massachusetts; Prentice-Hall edition)





From the book: "As indicated, a shear force is considered to be positive if it produces a clockwise moment about a point in the free body on which it acts. Conversely, a negative shear force produces a counter clockwise moment about a point in the free body on which it acts."
(This suggests, in general 'clockwise is positive'; should be avoided!)
"The bending moment is positive if it causes compression in the upper fibers of the beam and tension in the lower fibers." Etc. But why!! this assumptions!??
It is almost 'funny.' The ben-

Example V and M-diagrams. German book. 1958/74 'Baustatik - in Beispielen und Aufgaben' Bötzl/Martin. Volume I. A very extensive book.

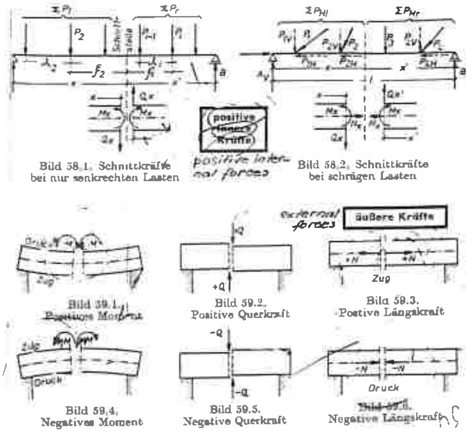


Bild 58.1. Schnittkräfte bei nur senkrechten Lasten

Bild 58.2. Schnittkräfte bei schrägen Lasten

Bild 59.1. Positives Moment

Bild 59.2. Positive Querkraft

Bild 59.3. Postive Längskraft

Bild 59.4. Negatives Moment

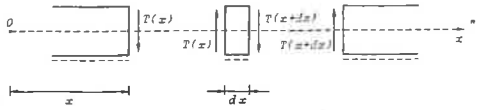
Bild 59.5. Negative Querkraft

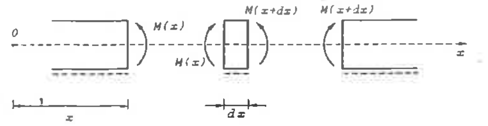
Bild 59.6. Negative Längskraft

Example V- and M-diagrams. Italian book. University of Milan, department of architecture. 600 pages. A very theoretical book; not practical book for students to learn something about statics. (A student, having finished her studies, said "I did not understand much of it" and "Oh, why your manuals are not in Italian!".

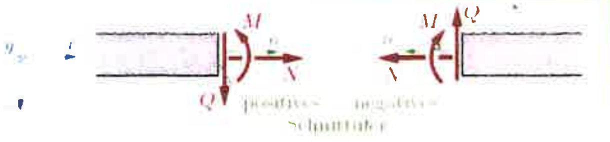
"Lezioni di Statica." Grandori/Buccino/Caretti/Molina. 1983.

vu definito il concetto di sinistra e di destra in tutti i casi in cui l'asse dell'asta non è orizzontale;di solito ciò viene precisato tratteggiando il lembo che si considera "inferiore"





Vorzeichenkonvention



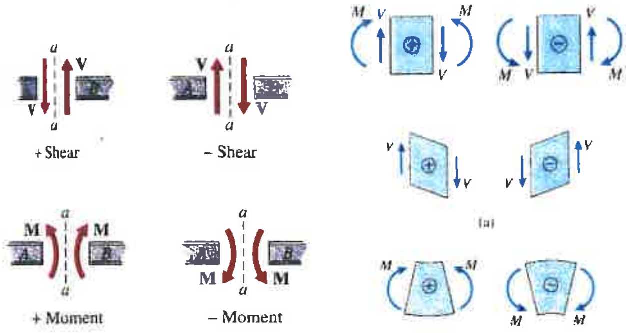
Vorzeichenkonvention:

***Positive* Schnittgrößen** zeigen am *positiven* Schnittufer in *positive* Koordinatenrichtungen.

***Positive* Schnittgrößen** zeigen am *negativen* Schnittufer in *negative* Koordinatenrichtungen.

LEHRSTUHL FÜR BAUSTATIK — UNIVERSITÄT SIEGEN

Shear Forces and Bending Moments in Beams
Sign Convention



X [Fig. 3.7(b)] the whole loading is equivalent to an unbalanced vertical force F acting upward and a moment M [Fig. 3.7(c)] in the clockwise direction acting in the plane of X. Similarly if the equilibrium of the right hand portion of the beam is considered, the loading is reduced to an unbalanced vertical forces F, acting downwards and a moment M acting in the anticlockwise direction as shown in Fig. 3.7(d).

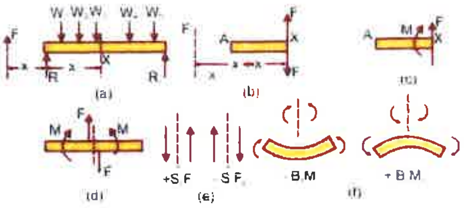
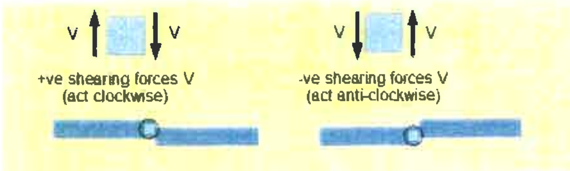


Fig 3.7

(https://civilengineering.blog/2017/09/10/basic-concepts/7-2/)

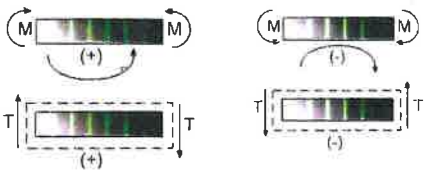


In subsequent tutorials we always consider sections of beams originating at the le
face at the right hand end of the section Hence the sign of the shearing force V is
the force shown on the **right hand face** of the elements above.

**Note that the direction of V on the right hand face of the elements above is t
convention for forces where upward forces are +ve**

This difficulty regarding the sign of shearing forces can be avoided by reversing the sign convention
intuitive and prefer to reverse the sign of V.

**Note that the sign conventions for bending moment M and shearing force V
bending and shear as defined above are universally adopted and must not b**

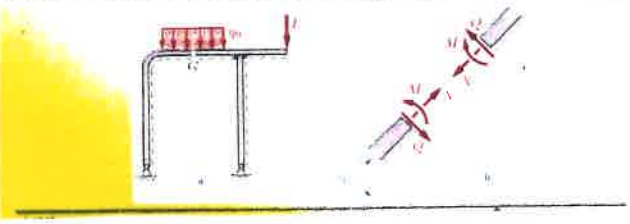


If the bending moment are positive, forces at the left of mn cross-section have CW and forces on the right of mn have CCW moment directions.

Gestrichelte Faser

Gestrichelte Faser:

Beim Rahmen und Bogen wird zur Festlegung der Vorzeichen der Schnittgrößen eine Seite jedes Tragwerksteils durch eine gestrichelte Linie eingeführt. Diese gestrichelte Linie wird häufig als **gestrichelte Faser** bezeichnet



In subsequent tutorials we always consider sections of beams originating at the left hand
face at the right hand end of the section Hence the sign of the bending moment M is dete
of the moment shown on the **right hand face** of the elements above.

**Note that the rotational direction of M on the right hand face of the elements above
normal sign convention for moment loads where clockwise moments are +ve and a
moments are -ve.**

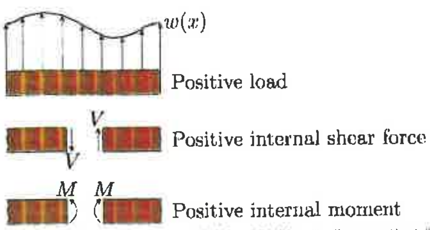
This difficulty regarding the sign of bending moments can be avoided by taking sections from the right hand en
the +ve direction of the x axis. I find this counter intuitive and prefer to reverse the sign of M.

Positive and negative shearing forces

Vertical loads and resultant reaction forces generate vertical **shearing forces** in a beam. T
definitions of +ve and -ve shear.

- simply supported, cantilevered, overhanging, statically indeterminate

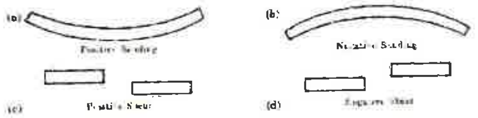
Knowing about the loads and supports will enable you to sketch a *qualitative* V-M diagram, and then a statics analysis of the free body will help you determine the quantitative description of the curves. Let's start by recalling our sign conventions.



These sign conventions should be familiar. If the shear causes a counterclockwise rotation, it is positive. If the moment bends the beam in a manner that makes the beam bend into a "smile" or a U-shape, it is positive. The best way to recall these diagrams is to work through an example. Begin with this cantilevered beam – from here you can progress through more complicated loadings.

SIGN CONVENTIONS

Due to the magnitude, type and location of loading, beams tend to bend in upward or downward direction.
Figure (a): Concave bending (say in direction of gravity) of the beam . Positive bending leads to produce Positive Bending.
Figure (c): Left portion of the beam is sheared upwards with respect to right portion is "Positive Shear"



BEAMS IN BENDING

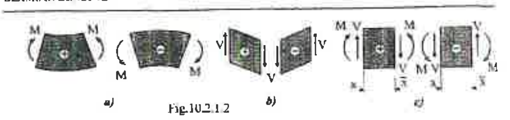


Fig.10.2.1.2

Internal Force and Moment Conventions.

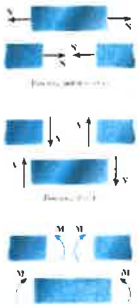


Figure 10 shows the widely accepted deformation sign conventions for normal and shear forces and bending moments. The deformation conventions are focused on the way the forces and moments deform the material, not on their directions.

Positive normal forces act normal to the face and are tensile forces (pointing away from the face) -stretching the material. Their directions can be upward, downward, leftward, or rightward.

Positive shear forces slice the material in a downward direction and have negative directional signs. They tend to turn the material in a clockwise direction. Positive shear forces are plotted on the positive y-axis.

Positive bending moments act to bend the material in upwardly concave –creating "smiley faces". Positive bending moments are plotted on the positive y-axis.

n: Normalenvektor

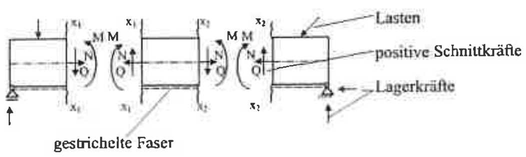
Schnittufer:

Positives Schnittufer:	Schnittufer, dessen Normalenvektor in *positive* x-Richtung zeigt
Negatives Schnittufer:	Schnittufer, dessen Normalenvektor in *negative* x-Richtung zeigt.

5.5 Schnittkräfte

Nachdem die äußeren Kräfte (einschließlich Auflagerkräfte) bekannt sind, können unter Verwendung der Gleichgewichtsbedingungen die inneren Kräfte berechnet werden. Zur Ermittlung der inneren Kräfte trennt man den Körper durch einen gedachten Schnitt und bestimmt diejenigen Kräfte, die mit den äußeren Kräften des jeweiligen Teils Gleichgewicht ergeben.

Die drei Schnittkräfte sind: N - Normalkraft (in Richtung der Trägerachse)
Q - Querkraft (senkrecht zur Trägerachse)
M - Biegemoment (bezogen auf den Schwerpunkt des Schnittes)



Vorzeichenregeln:

Normalkraft	= positiv bei Zugbeanspruchung = negativ bei Druckbeanspruchung
Querkraft	= positiv, wenn Q den linken Tragwerksteil nach unten und den rechten nach oben verschieben will
Moment	= positiv, wenn an der Unterseite (gestrichelte Faser) Zugspannungen auftreten

Sign Conventions

Sign conventions are a standardized set of widely accepted rules that provide a consistent method of setting up, solving, and communicating solutions to engineering mechanics problems–statics, dynamics, and strength of materials problems. There are two types-static and deformation. Static sign conventions govern the directions of applied and reaction forces and moments, for example, upward or downward. Deformation sign conventions govern the directions of internal forces and moments that deform a body, for example, stretch, compress, twist or bend.

For statically determinate structures, static sign conventions are used to determine external reactions. Both types are used to determine internal forces and moments.

For statically indeterminate structures, both types are needed to find external reactions and internal forces and moments.

Applied and Reaction Force Sign Conventions Are Static Sign Conventions

Applied and reaction forces that are directed toward a positive axis are assigned positive signs. For example, referring to Figure 1, the signs of the components of the various forces are:

1. Force 1: $F1_x$ sign = +, $F1_y$ sign = +;
2. Force 2: $F2_x$ sign = +, $F2_y$ sign = -;
3. Force 3: $F3_x$ sign = -, $F3_y$ sign = -;
4. Force 4: $F4_x$ sign = -, $F4_y$ sign = +

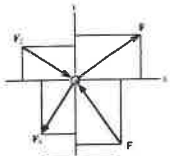


Figure 1.

Note: In some ENGR 2140 worked examples, the + y direction is assumed to be in the direction of the applied force. To illustrate, in worked Ex1-5, the forces P_A and P_B are assumed to be in the + y-direction. In many beam analysis problems, the + y-direction is in the direction of the applied force. The correctness of the result is ok, but the orientation of the + y-axis is downward, not upward.

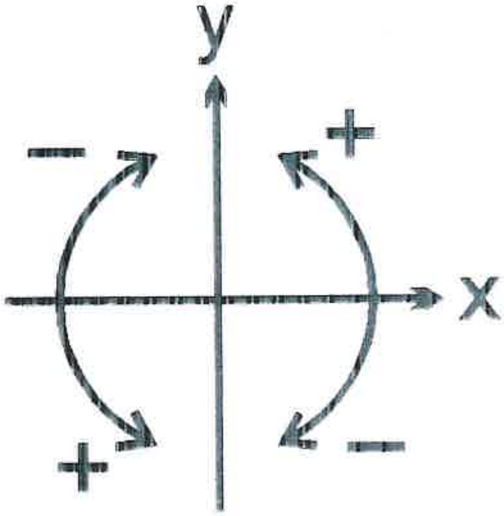


Fig. 1.3 The sign convention for rotation

Note that Newton's Third Law of Motion says that to any force there is an equal and opposite moment to exist in an equilibrium system there must be a counteracting moment to establish tha

A sign convention also applies to forces, and is implicit in diagrams such as Fig. 1§12.1. Usually downwards are negative. Likewise, tension is considered positive while compression is negative

Internal Loading Sign Conventions Are Deformation Sign Conventions

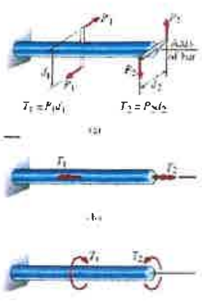


Figure 6 illustrates three sign conventions for torsional structures. The positive z-axis points to the left. Figure 7 illustrates a top-level FBD where T_R is the reaction torque and is shown positive when normal to the face.

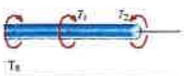
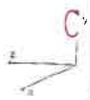


Figure 7 Top=Level

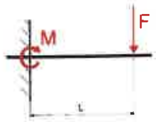


The equilibrium equation is:

$$\sum T = T_R + T_1 - T_2 = 0,\ T_R = T_2 - T_1$$

Always show reaction torque in positive direction.

Die Zeichnung unten zeigt ein Beispiel für ein Moment M, das durch eine Kraft F über den Hebelarm L verursacht wird. Die Kraft wirkt auf einen Stab, der fest in einer Wand verankert ist. Man spricht hier in der "Statik" von einer festen Einspannung. Diese Lagerart kann Lagerkräfte in allen Richtungen und Einspannmomente aufnehmen. Mehr über die verschiedenen Lagerarten ist im entsprechenden Statik-Skript über Lagerarten zu lesen.



Kraft F erzeugt über den Hebelarm L ein Moment M

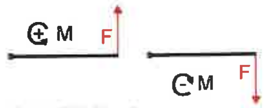
Vorzeichenregelung für Momente

Wichtig beim rechnen mit Momenten in der Statik, ist das Vorzeichen – d.h. die Frage ob es sich um ein positiv oder negativ gerichtetes Moment handelt.

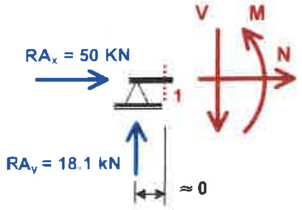
Die Regel für die Vorzeichen bei Drehmomenten lautet:

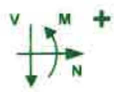
- Bei Drehung gegen den Uhrzeigersinn => positives Moment
- Bei Drehung im Uhrzeigersinn => negatives Moment

Die Vorzeichenregelung für Momente ist in der Grafik unten veranschaulicht.



Vorzeichenregelung für Drehmomente





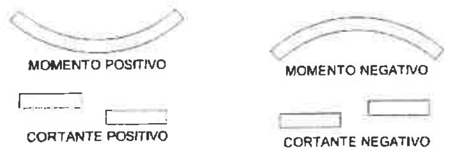
$\Sigma F_N = 0$ → $50 + N = 0$ → $N = -50$ kN

$\Sigma F_V = 0$ → $-18.1 + V = 0$ → $V = 18.1$ kN

$\Sigma M_1 = 0$ → $0 + M = 0$ → $M = 0$ kNm

analizando por un lado o por el otro la magnitud del esfuerzo es la misma). Para analizar el signo de los esfuerzos internos, consideramos un elen situado entre dos secciones rectas adyacentes y tomaremos por convenc que indican en la figura:

El esfuerzo normal será positivo cuando se trate de un esfuerzo de tracció de corte será positivo, cuando tenga un sentido horario de rotación respect interior del cuerpo libre. El momento flector será positivo cuando produzca las fibras inferiores y la compresión de las fibras superiores.



Sign Convention Of Bending Moments

We will also consider a piece of beam that undergoes bending moment. We will define the sign of bending moment according to the behavior of the beam under this moment

Sign conventions of the bending moment on a beam(Image Source: D. K. Singh – Strength of Materials-Springer-2020)

As you see above, there two situations of bending on beams. At the left side, the beam is bent as concave to upward. In this situation, the bending moment is positive. Otherwise which is like the left, bending moment is considered as negative.

tado el diagrama de la figura 4.21b, en la que por claridad visual se han rayado además las zonas cubiertas por la función.

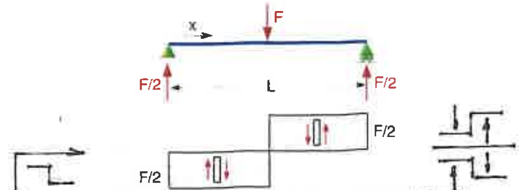


Figura 4.21b: Trazado del diagrama de esfuerzos cortantes. Nótese la discontinuidad en x=L/2

El trazado del diagrama de momentos flectores no presenta ninguna complicación adicional. Se sabe que en el punto x=0 es M_z=0, ya que el apoyo no puede ejercer momento, y no hay ningún otro elemento conectado o acción exterior que pudiera ejercerlo. Por tanto trazamos la línea horizontal que representará M_z=0, y empezamos trazando desde ese valor nulo con pendiente positiva y constante (de valor +F/2, el del cortante en esa zona). Esto es, trazamos una recta hacia abajo, hasta llegar a x=L/2.

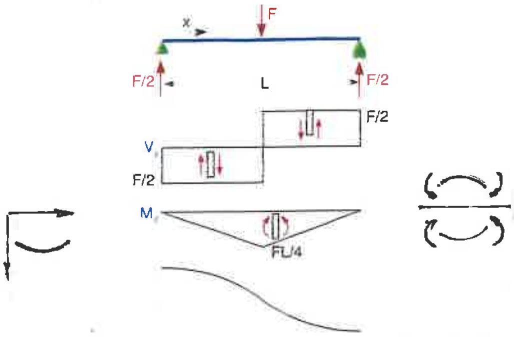
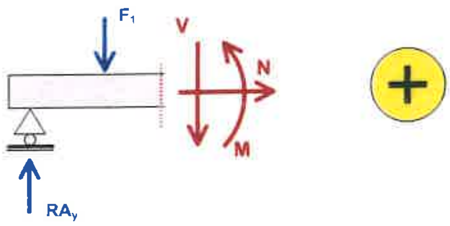


Figura 4.21c: Diagrama de momentos. Diagrama de giros parcialmente dibujado.

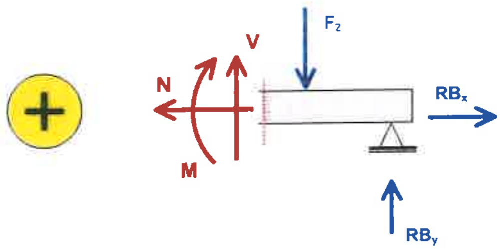
Este problema tiene todas sus condiciones de contorno dadas en desplazamientos (ninguna en

Il existe une convention de signe internationale qui définit pour une partie à gauche ou à droite de la section de coupe, le sens des efforts intérieurs qui seront dits **"positifs"**. Cette convention de signe est aussi valable pour tous les logiciels de calcul informatique.

Partie à gauche de la section de coupe
→ sens positif des efforts intérieurs



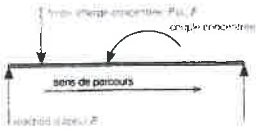
Partie à droite de la section de coupe
→ sens positif des efforts intérieurs



Principales notations et conventions de signes

Les principales notations et conventions de signes rencontrées dans le présent ouvrage sont indiquées ci-après :

Efforts extérieurs

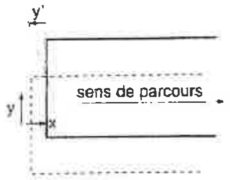


P, F : force, charge concentrée
p : charge répartie
C : couple concentré
c : couple réparti
R : réaction d'appui

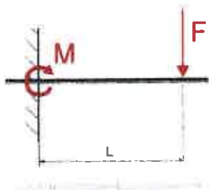
Éléments de réduction des forces de gauche

V : effort, tranchant
N : effort normal
M : moment de flexion
T : moment de torsion

Déformations



x : translation parallèle au sens de parcours
y : translation perpendiculaire au sens de parcours
y' : rotation



Kraft F erzeugt über den Hebelarm L ein Moment M

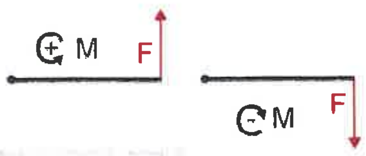
Vorzeichenregelung für Momente

Wichtig beim rechnen mit Momenten in der Statik, ist das Vorzeichen – d.h. die Frage ob es sich um ein positiv oder negativ gerichtetes Moment handelt.

Die Regel für die Vorzeichen bei Drehmomenten lautet:

- Bei Drehung gegen den Uhrzeigersinn => positives Moment
- Bei Drehung im Uhrzeigersinn => negatives Moment

Die Vorzeichenregelung für Momente ist in der Grafik unten veranschaulicht.



Vorzeichenregelung für Drehmomente

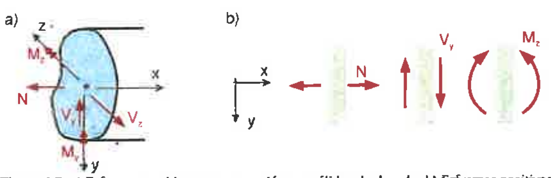


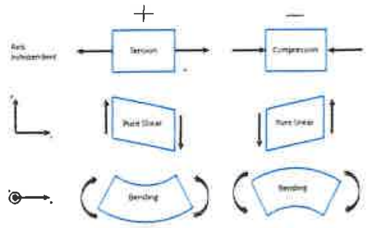
Figura 4.7: a) Esfuerzos positivos en una sección con sólido a la derecha b) Esfuerzos positivos dibujados en una rebanada diferencial de barra

No debe pensarse que lo anterior es una complicación innecesaria introducida por el modelo matemático. El que el esfuerzo cambie de sentido en una misma sección al considerar sólido a uno u otro lado de la misma es consecuencia directa del "principio de acción y reacción", y el que en ambos casos tenga el mismo valor (incluido el signo) es algo útil y pretendido, que por ejemplo hace que exista un sólo valor de un esfuerzo para cada valor de x. Esto es muy conveniente para hacer intervenir los esfuerzos como variables en un modelo matemático.

Force/Moment Convention #forceMomConv

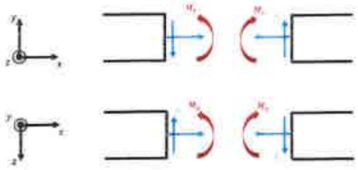
Positive conventions for internal forces and bending moments

- Where + agrees with right-handed coordinate system
- Third direction still matters, directions drawn specify the convention

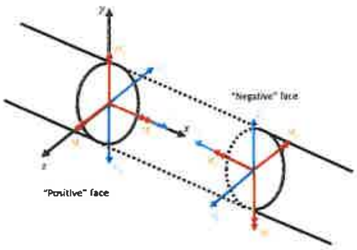


Expanded to 2D cuts

- A positive face is one in which the outward normal aligns with the coordinate axis. A negative face will have the outward normal going against the coordinate axis.



Expanded to 3D cuts



Selection of coordinate axes "x-y-z" is completely arbitrary. This sign convention is true for any right handed coordinate system "1-2-3"

In subsequent tutorials we will use extensively the conditions for static equilibrium ("sum of forces = 0" and "sum of moments = 0"). Be aware of the following error when writing equations for the sum of forces in the example above!

It is **not correct** to state R1 + R2 = - F1 - F2 (for sum of forces on the y axis = 0)

It **is correct** to state R1 + R2 - F1 - F2 = 0 or R1 + R2 = F1 + F2

The incorrect equation makes the mistake of a "double negative". If you are prone to this error (as I am) it helps to put all terms and their signs initially on the LHS.

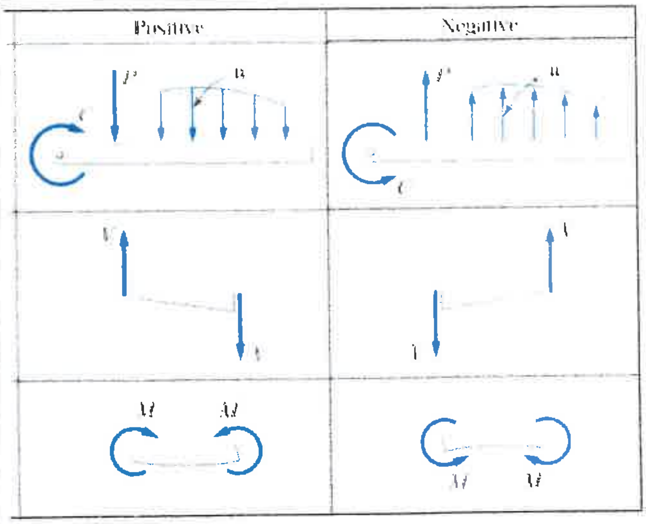
Positive and negative bending

This diagram shows definitions of +ve and -ve bending.

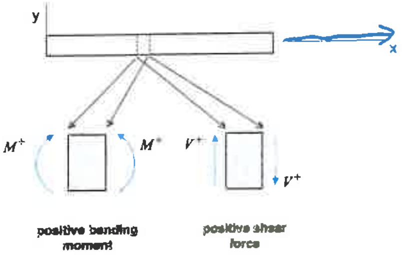
We interpret bending as the consequence of **bending moments** generated by loading.

To viualise this consider an element of a beam and the bending moments that produce positive or negative bending on the element.

In subsequent tutorials we always consider sections of beams originating at the left hand end (x = 0) with the cut face at the right hand end of the section. Hence the sign of the bending moment M is determined by the



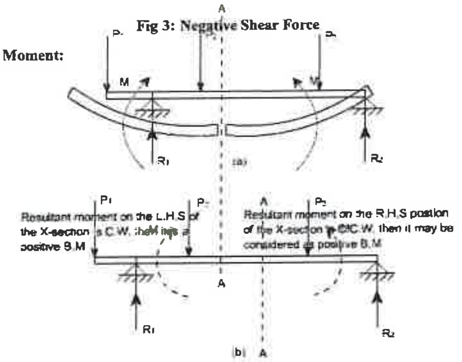
- A positive bending moment M on the left face (negative x-face) of a section is CW. A positive bending moment M on the right face (positive x-face) of a section is CCW. Such a positive bending moment creates a concave curvature in the deflection of the beam.
- A positive shear force V on the left face (negative x-face) of a section is in positive y-direction. A positive shear force V on the right face (positive x-face) of a section is in negative y-direction.



When making a cut through a cross section of the beam, the positive sign conventions for the bending moment and shear force are as shown below:

Bending Moment:

Fig 4



2.1. Shearing force (S.F.) sign convention

Forces upwards to the left of a section or downwards to the right of the section are positive. Thus Figure (4a) shows a positive S.F. system at X-X and Figure (4b) shows a negative S.F. system.

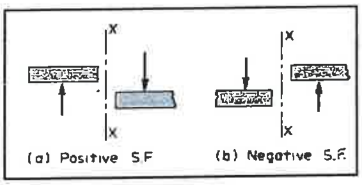
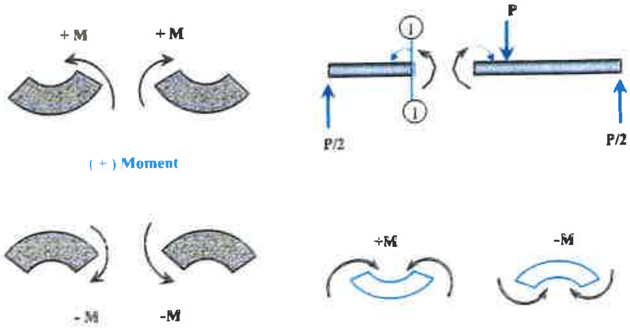


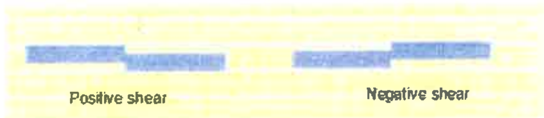
Figure (4) S.F. sign convention

2) **Bending Moment** is considered **Positive** at section when it tends to **bend** the member **Con @ + ve upward**; otherwise it is negative.

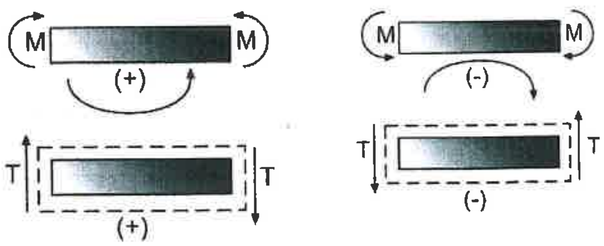


Positive and negative shearing forces

Vertical loads and resultant reaction forces generate vertical **shearing forces** in a beam. This diagram shows definitions of +ve and -ve shear.

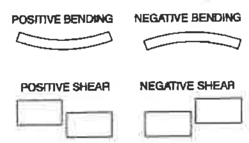


To vlualise this consider an element of a beam and the shearing forces that produce positive or negative shear on the element.



Shearing Force and Bending Moment Sign Conventions

1. The bending moment is *positive* if it produces bending of the beam *concave upward* (compression in top fibers and tension in bottom fibers).
2. The shearing force is *positive* if the *right portion of the beam tends to shear downward with respect to the left.*



If the bending moment are positive, forces at the left of mn cross-section have CW and forces on the right of mn have CCW moment directions.

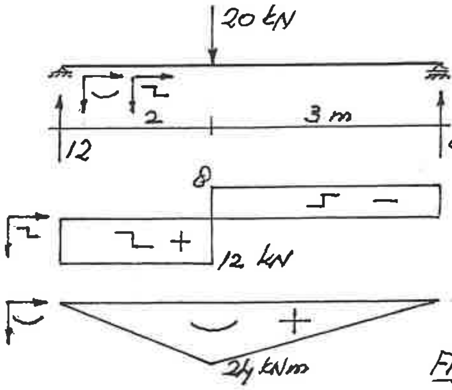


Fig. 1a.

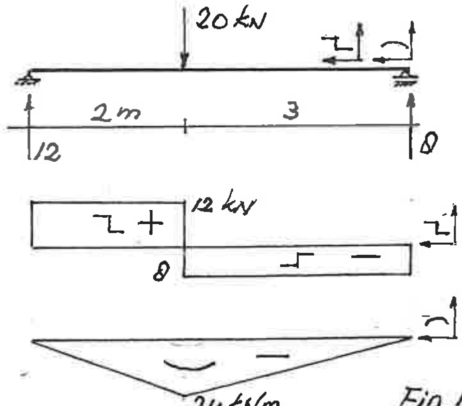


Fig. 1b.

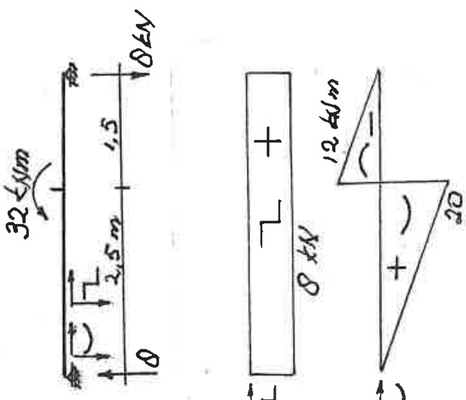


Fig. 2a.

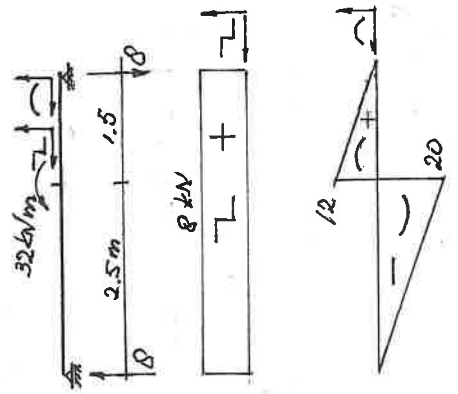


Fig. 2b.

Shear force and bending moment.

Before calculations the beam axis system is placed at arbitrarily chosen beam end.
Next the shear force and bending moment calculations are carried out and diagrams drawn as explained and shown in the preceding pages.

How to distinguish the values of shear force and bending moment at each side of the zero line.

Agreement!
The diagram values at the side of the zero line indicated with the beam axis system are given a plus sign +, the values on on the other side a minus −.
That's not like the usual sign conventions set before calculation and drawing, no, it's an agreement! (Could be − and + i.s.o. + and −, or blue and red, etc.)

Fig.1a and 1b.
Plus and minus signs are added, they correspond with the drawn beam axis systems at the beam ends.
The place of the beam axis systems determine how the diagrams look like.

Comparing fig.1a and 1b.

The shear force diagrams are mirrorred, same values with plus and minus sign.
Fig.1a + sign at of the zero line, − sign at the other side of the zero line.
Fig.1b with same arguments.

The bending moment diagrams are the same, the values however get opposite signs.
Fig.1a bending sign with + sign and
fig.1b bending sign with − sign.

Fig.2a and 2b.
A vertical beam with the same assumptions.
The place of the beam axis system at a beam end determines how shear force and bending moment diagrams look like.

The bending moment diagrams are the same, the values however get opposite signs.

Fig.2a bending sign) with + sign and
bending sign (with − sign.

Fig.2b bending sign (with + sign and
bending sign) with − sign.

These + and − sign are used to give the values on both sides of the zero line a 'name'. When using these names one knows which side of the zero line it concerns.

For any beam, if horizontal, vertical or sloping the given approach makes calculation and drawing shear force and bending moment diagrams clearly and easy. Just choose a beam end to place the beam axis system and carry out the shown way of calculation and drawing.

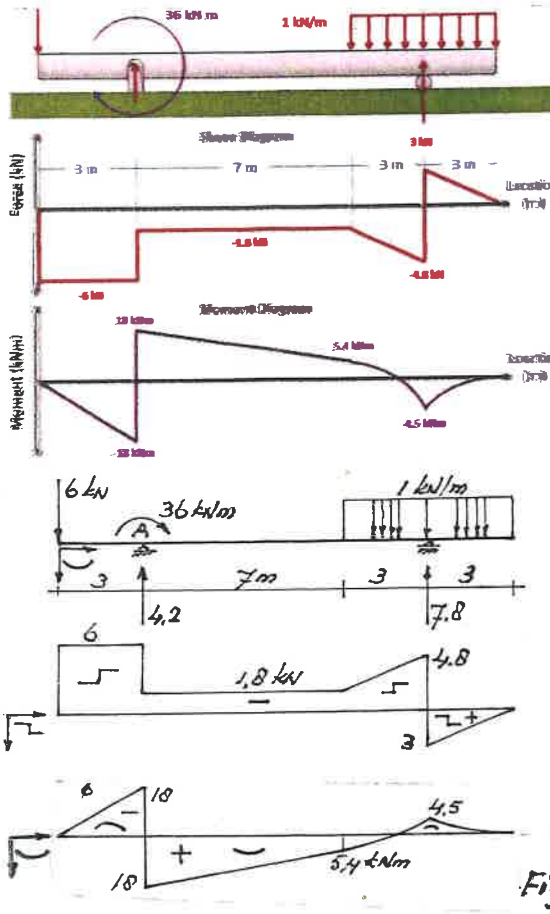


Fig. 1a.

Some examples found on internet.

Fig.1a with (. Bending moment M left of A.
Left onto right,
M(= 0-6*3= -18 kNm, not (but (.

Right onto left,
M) = 0-1*6*10-36+7,8*10= 0-60-36-78= -18 kNm,
not) but) .

Fig.1b with (. Bending moment M left of A.
Left onto right,
M(= 6*3= 18 kNm, (as assumed.

Right onto left,
M) = 1*6*10+36-7,8*10= 60+36-78= 18 kNm,
) as assumed.

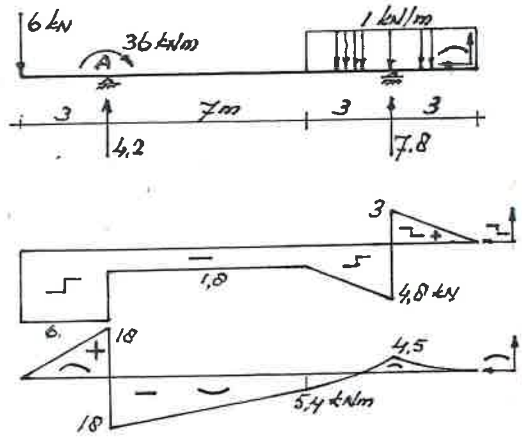


Fig. 1b.

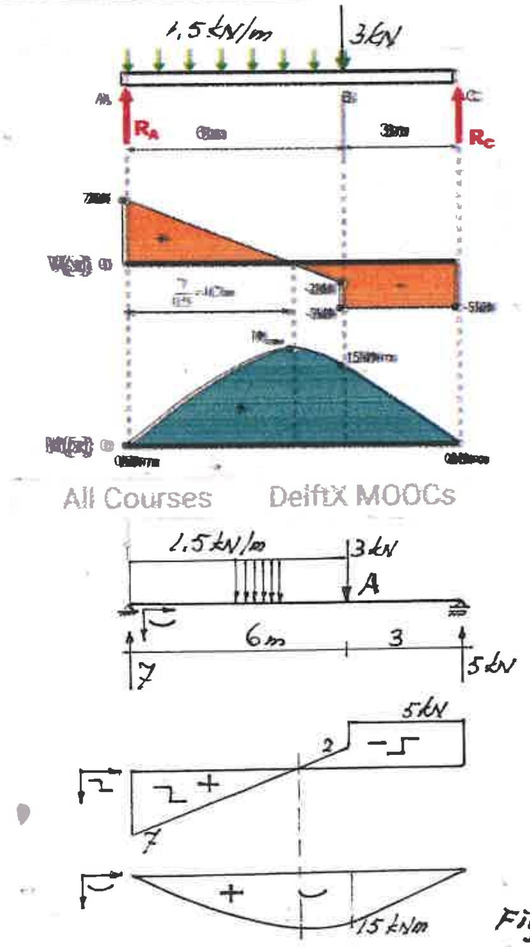


Fig. 2a.

Fig.2a with (. Bending moment M at A.
Left onto right,
M(= 7*6-1,5*6*3= 15 kNm, (as assumed.

Right onto left,
M) = 5*3= 15 kNm,) as assumed.

Fig.2b with (. Bending moment M at A.
Left onto right,
M(= 1,5*6*3-7*6= -15 kNm, not (but (.

Right onto left,
M) = 0-5*3= -15 kNm, not) but) .

Like on the preceding page a + and - sign are added to the diagrams to distinguish the values on both sides of the zero line.

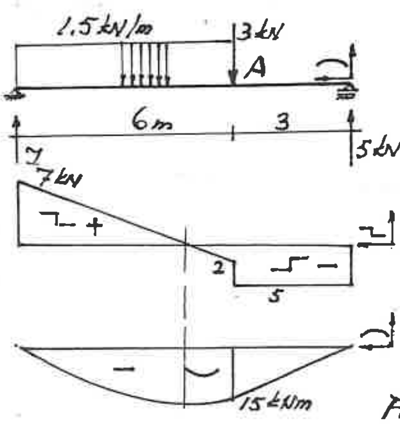


Fig. 2b.

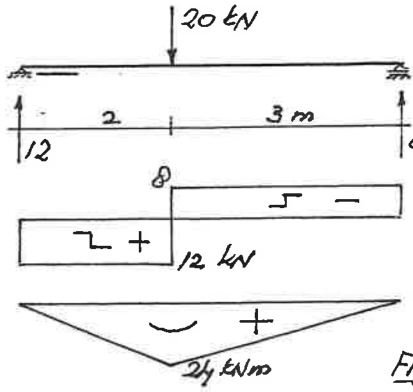


Fig.1a.

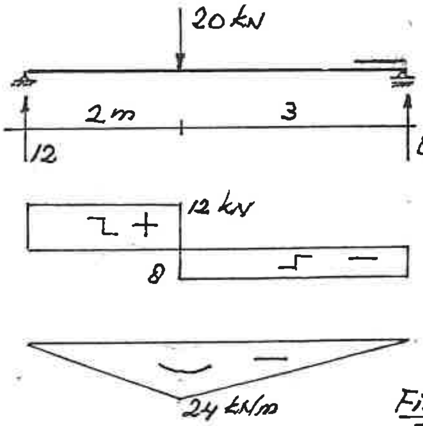


Fig.1b.

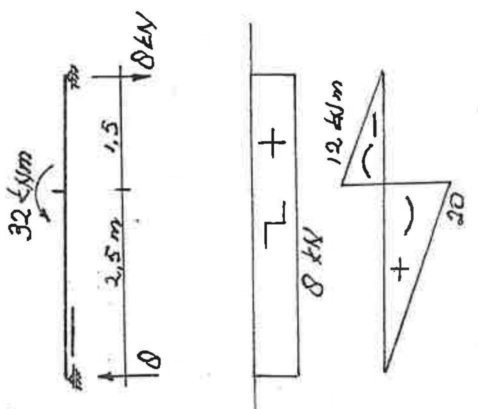


Fig.2a.

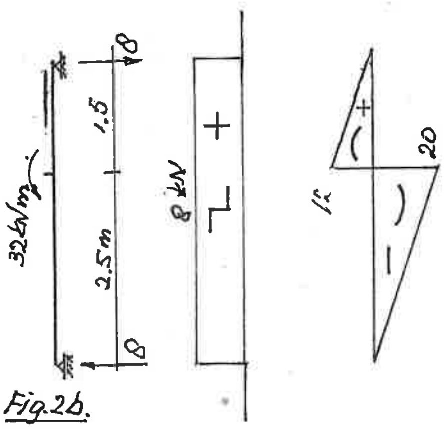


Fig.2b.

Shear force and bending moment.

Just a short line at one of the beam ends can replace the 'beam axis systems'.

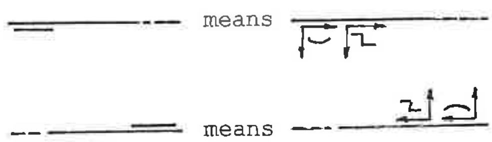


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Fig.1a bending sign ◡ with + sign and
fig.1b bending sign ◠ with - sign.

Fig.2a and 2b.
A vertical beam with the same assumptions.
The place of the beam axis system at a beam end determines how shear force and bending moment diagrams look like.

The bending moment diagrams are the same, the values however get opposite signs.

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bending sign (with - sign.

Fig.2b bending sign (with + sign and
bending sign) with - sign.

These + and - sign are used to give the values on both sides of the zero line a 'name'. When using these names one knows which side of the zero line it concerns.

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