Delft Applied Mechanics Course:
Statics

AE1-914-I

January 26, 2007, 14:00–17:00

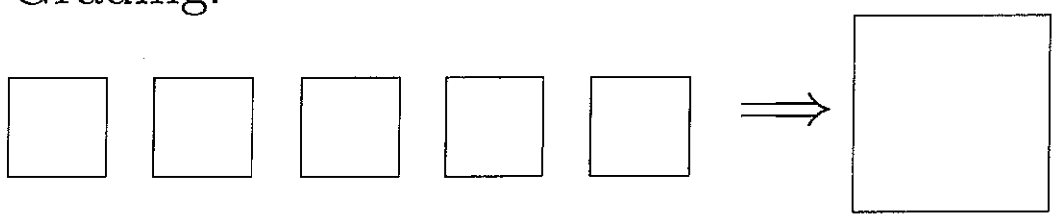
ANSWER SHEETS

Student number:

Name:

Please do not write below this line

Grading:



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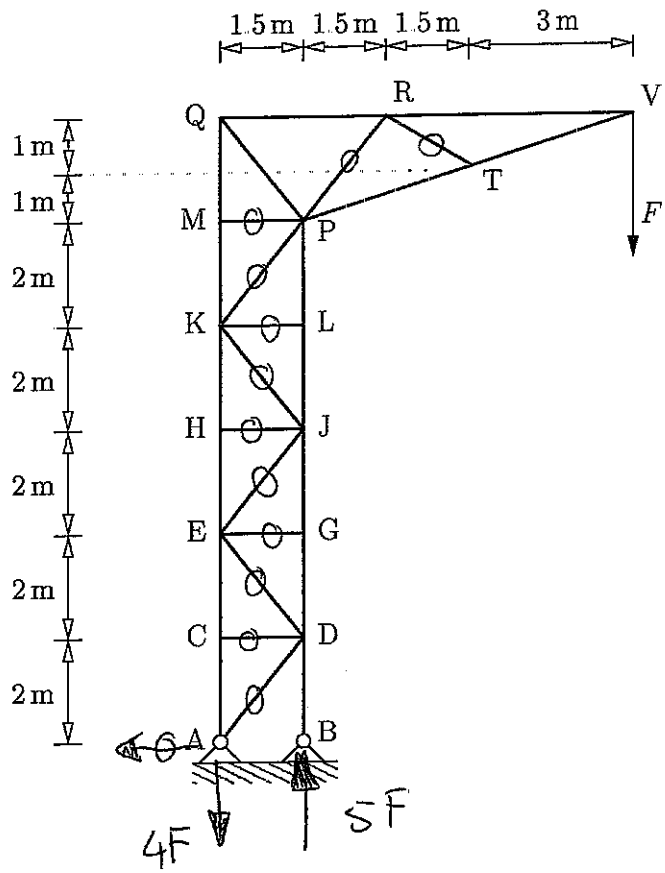
Problem 1 (Weight 1.5, approx. 30 min.)

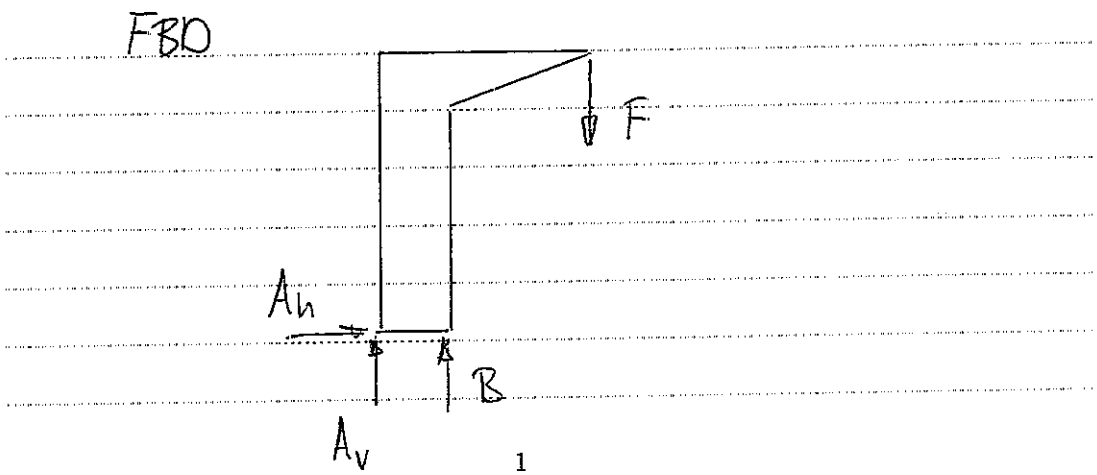
The crane in the figure is loaded by a vertical force F in joint V. It can be assumed that the crane is a truss.



Question a

Calculate the reaction forces in the supports A and B and draw them in the figure as they act on the structure in reality.

Answer



Since BD is a two-force member, the reaction in B is aligned with BD: there is no horizontal component in B.

$\sum T_A \overset{\curvearrowleft +}{:}$ $\quad 1.5\,B - 7.5\,F = 0 \qquad B = 5F$

$\sum F_y \overset{\uparrow +}{:}$ $\quad A_v + B - F = 0 \qquad A_v = F - B = -4F$

$\sum F_x \overset{\rightarrow +}{:}$ $\quad A_h = 0$

Check:

$\sum T_B \overset{\curvearrowleft +}{:}$ $\quad -1.5\,A_v - 6F = 0 \qquad 6F - 6F = 0$ ✓

Question b

How many zero-force members does this structure have? Indicate the zero-force members in the figure

Answer

12, see figure.

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Question c

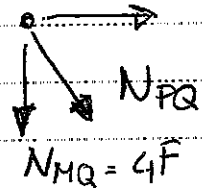
A maintenance man measures the force acting in member PQ. He discovers the member is loaded in compression and that the normal force in the member is equal to 20 kN. Determine the magnitude of the external load F on joint V

Answer

Because of all zero-force-members, the force N_{MQ} is equal to the force N_{AC} which is equal to.

$N_{MQ} = 4F$ (tension).

Equilibrium of node Q



$\Sigma F_y \uparrow : -N_{MQ} - \frac{4}{5} N_{PQ} = 0$

$\frac{5}{4} N_{MQ} = -N_{PQ}$

Since $N_{PQ} = -20$ kN. and $N_{MQ} = 4F$

$5F = 20$

$F = 4$ kN.

Alternative solution / check:

Work your way up to node Q from node V.

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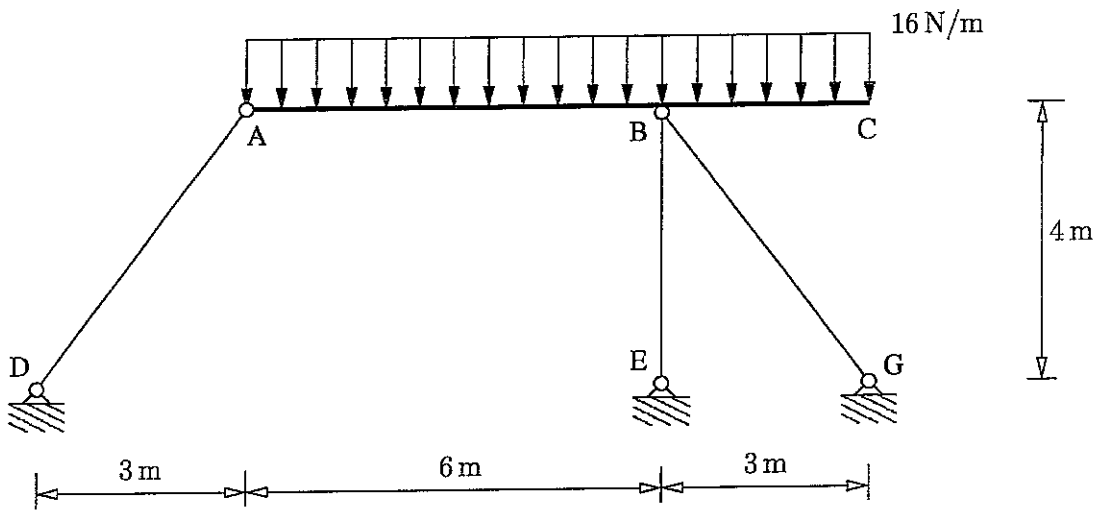
Problem 2 (Weight 2.5, approx. 45 min.)

Beam ABC in the figure is loaded by a uniform distributed load of 16 N/m and is supported by the 3 two-force members AD, BE and BG.

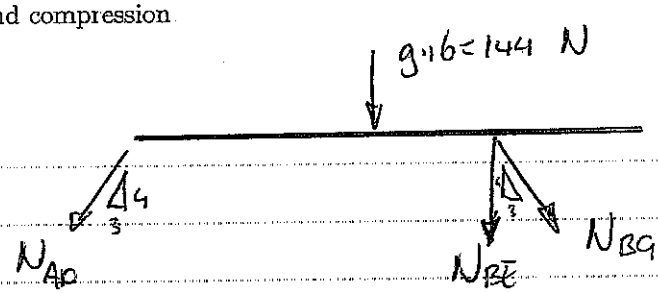


Question a

Determine the normal forces in the two-force members AD, BE and BG. Use the correct sign for tension and compression.

Answer *)

FBD



$\curvearrowright^{+} \Sigma T_B: \quad 1{,}5 \cdot 144 + 6 \cdot \frac{4}{5} N_{AD} = 0$

$N_{AD} = -45 \text{ N}$

$\xrightarrow{+} \Sigma F_x: \quad -\frac{3}{5} N_{AD} + \frac{3}{5} N_{BG} = 0$

$N_{BG} = -45 \text{ N}.$

$\Sigma F_y \uparrow^+ : -\frac{4}{5} N_{AD} - \frac{4}{5} N_{BG} - N_{BE} - 144 = 0$

$N_{BE} = 36 + 36 - 144 = -72\ N$

*) Note that all forces acting on the beam are drawn in the direction that corresponds to a tensile force in the members. The forces in these members are

$N_{AD} = -45\ N$

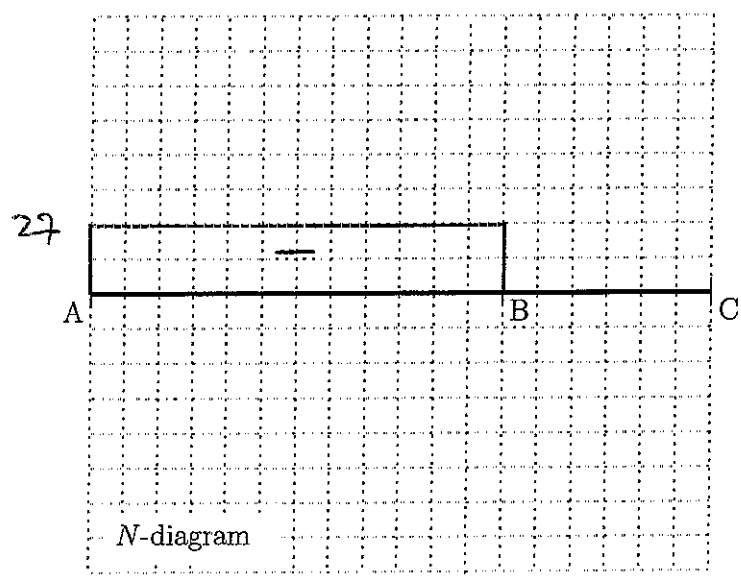
$N_{BG} = -45\ N$ Check: $\Sigma T_A \circlearrowleft^+ = 0$ §

$N_{BE} = -72\ N$

Question b

Draw the normal force diagram (N-diagram) of the beam and use the correct deformation signs. Mention all relevant values.

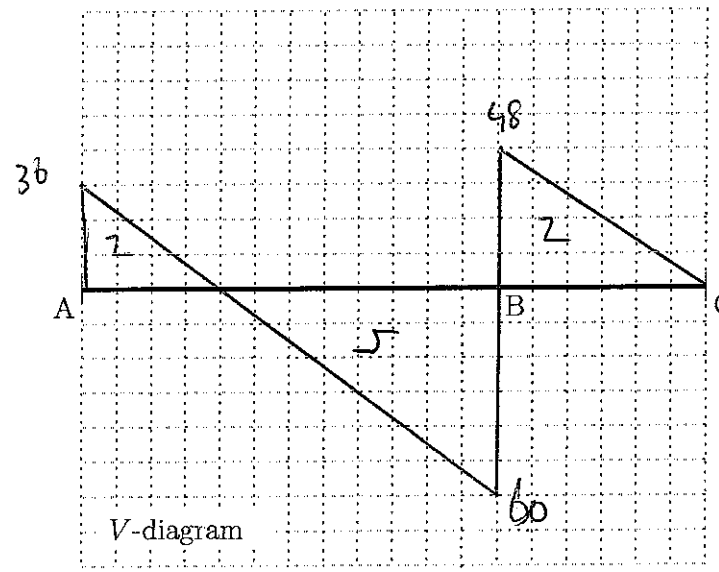
Answer



Question c

Draw the shear force diagram (V-diagram) of the beam and use the correct deformation signs. Mention all relevant values.

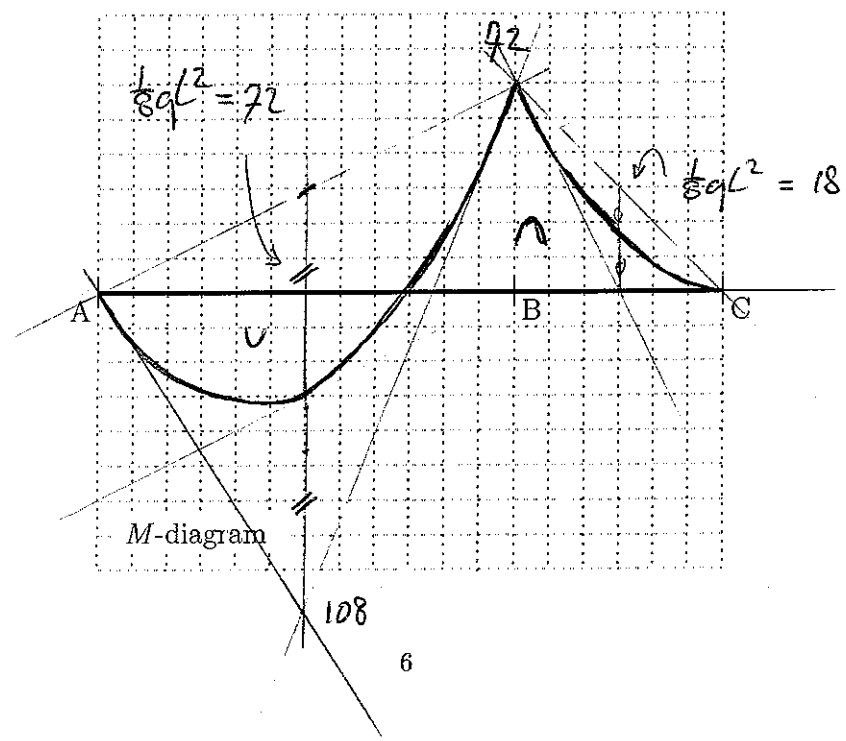
Answer



Question d

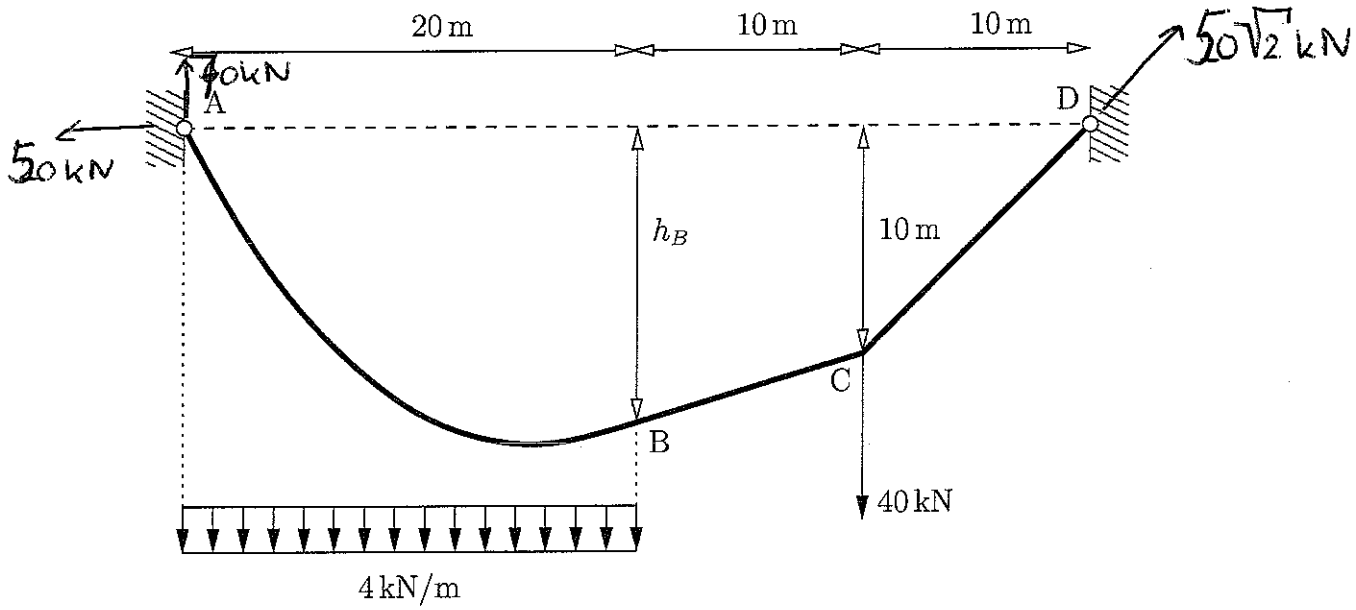
Draw the moment diagram (M-diagram) of the beam and use the correct deformation signs. Mention all relevant values and draw tangents where neccesary.

Answer



Opgave 3 (2.0 punten, ongeveer 30 min.)

De kabel ABCD in de figuur is belast door een verdeelde belasting van 4 kN/m over het gedeelte AB en een puntlast van 40 kN in C. De doorzakking van dit punt C is 10 meter



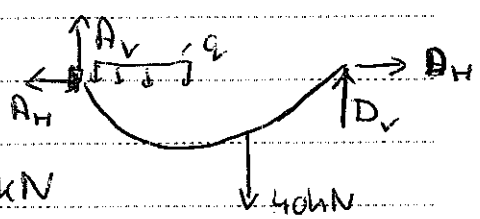
Vraag a

Bepaal de reactiekrachten in de punten A en D. Teken ze zoals ze in werklijkheid op de kabel werken.

Antwoord

Equilibrium of joint D gives $D_H = D_V$

$\Sigma T_A \circlearrowleft : 0 = 4 \cdot \frac{20^2}{2} - D_V \cdot 40 + 40 \cdot 30$



$\rightarrow D_V = 50$ kN, $D_H = 50$ kN $\Big\}$ $D = 50\sqrt{2}$ kN

$\Sigma F_x \rightarrow : 0 = D_H - A_H = 0 \Rightarrow A_H = 50$ kN

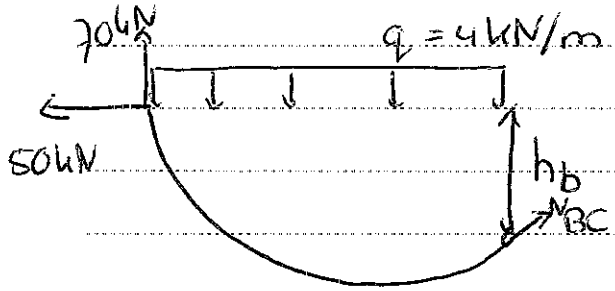
$\Sigma F_y \uparrow : 0 = A_V + D_V - 4 \cdot 20 - 40 \Rightarrow A_V = 70$ kN $\Big\}$ $A = 10\sqrt{74}$ kN

Vraag b

Bepaal de doorzakking h_B van punt B.

Antwoord

Consider equilibrium of AB



$\Sigma T_B \circlearrowleft^{+} : 0$

$\Rightarrow 70\,20 - q\frac{20^2}{2} - 50\,h_b = 0$

$\Rightarrow h_b = 12\ m$

Vraag c

In welk punt van de kabel is de kabelkracht het grootst? Hoe groot is de kabelkracht in dit punt?

Antwoord

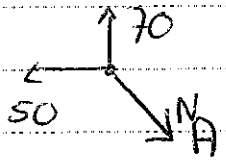
Cable force has a maximum at max slope

slope at AB: $70/50 = 1.4$ → largest slope

slope at BC: 0,2

slope at CD: 1

equil of joint A:



$N_A = \sqrt{50^2 + 70^2} = 10\sqrt{74}$ kN or $\sqrt{7400}$ kN ≈ 86 kN

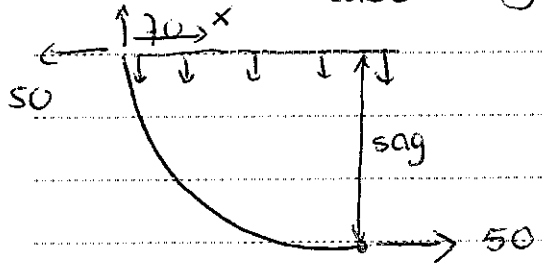
Vraag d

In welk punt van de kabel is de kabel doorzakking maximaal? Hoe groot is de doorzakking in dit punt?

Antwoord

max. sag if tangent to cable is horizontal

then also N_{cable} only has horiz comp



$\Sigma F_y \uparrow + : 0 = 70 - q\,x$

max at $x = 17{,}5$ m from A

sag: $\Sigma T_A \circlearrowleft : 0 = q\frac{x^2}{2} - 50 \cdot y$

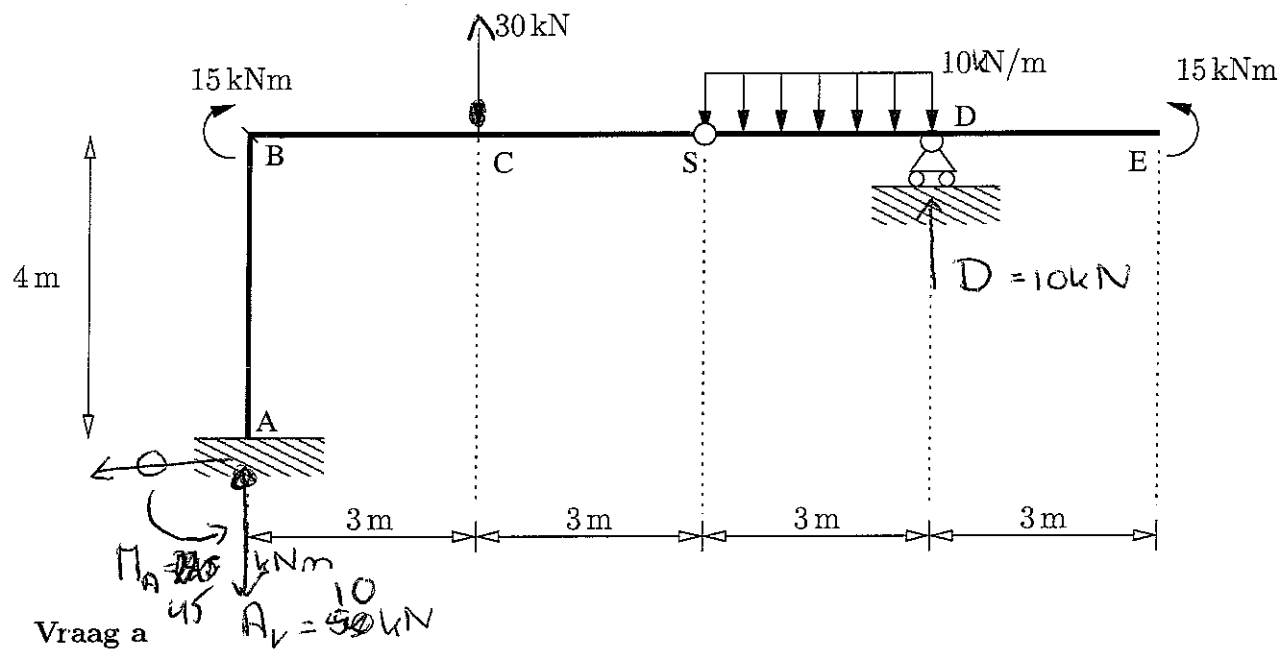
$y = 12{,}25$ m

Examen AE1-914-I Studienummer:

26 januari 2007 Naam: Antwoord model

Opgave 4 (2.5 punten, ongeveer 45 min.)

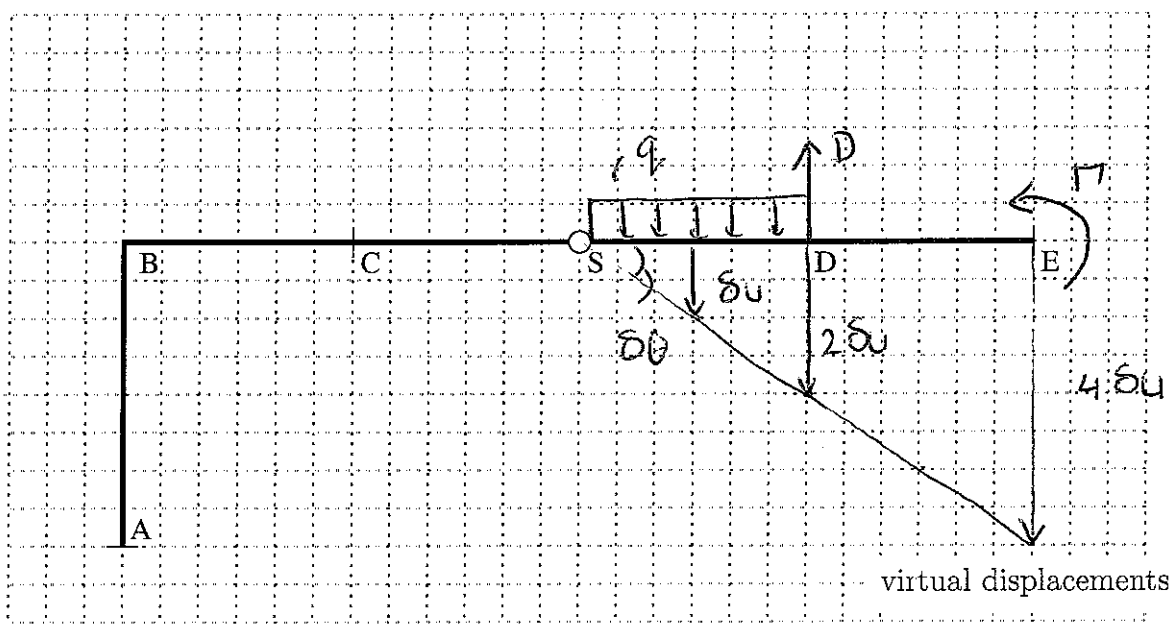
Gegeven de constructie in de figuur. Punt A is ingeklemd, de starre hoek B en het uiteinde E worden belast door een koppel van 15 kNm. Punt C is belast door een vertikale kracht van 30 kN en deel SD door een constant verdeelde belasting van 10 kN/m.



Vraag a

Gebruik het principe van virtuele arbeid en bereken de oplegreactie in punt D. Geef duidelijk aan welk virtueel verplaatsingsveld en welke tekenafspraken zijn gebruikt.

Antwoord



$\delta A = 0 \qquad \delta\theta = \frac{4}{6}\delta u$

$\delta A = -15\,\delta\theta - 2\delta u \cdot D + \delta u\, 10\, 3 = 0$

$\Leftrightarrow -10\,\delta u - 2D\delta u + 30\cdot\delta u = 0$

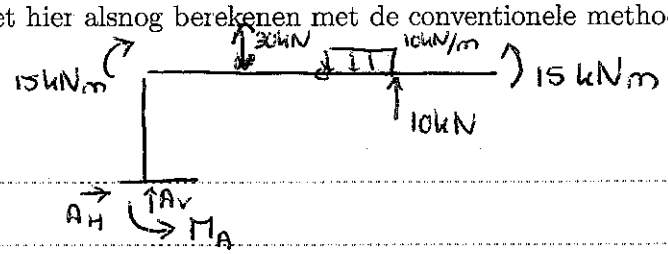
$\delta u \neq 0 \rightarrow \quad 2D = 20$

$D = 10\ kN\ \uparrow +$

Vraag b

Bepaal de overige reactiekrachten door gebruik te maken van conventionele methoden (de krachten- en momentenevenwichten) en teken ze in de figuur zoals ze in werklijkheid op de constructie werken. Indien je bij a) het antwoord niet op de gevraagde manier kon vinden, mag je het hier alsnog berekenen met de conventionele methode.

Antwoord



$\Sigma F_x \rightarrow : 0 \rightarrow A_H = 0\ kN$

$\Sigma F_y \uparrow + : 0 = A_V + 30 - 10\,3 + 10$

$A_V = -10\ kN\ \uparrow +$

$\Sigma T_A \circlearrowleft : 0 = 15 - 30\cdot 3 + 10\cdot 9 - 10\cdot 9 - 15 - M_A + 3\cdot 10\cdot\frac{15}{2}$

$M = 22.5\ kNm\ \circlearrowleft +$

Examen AE1-914-I

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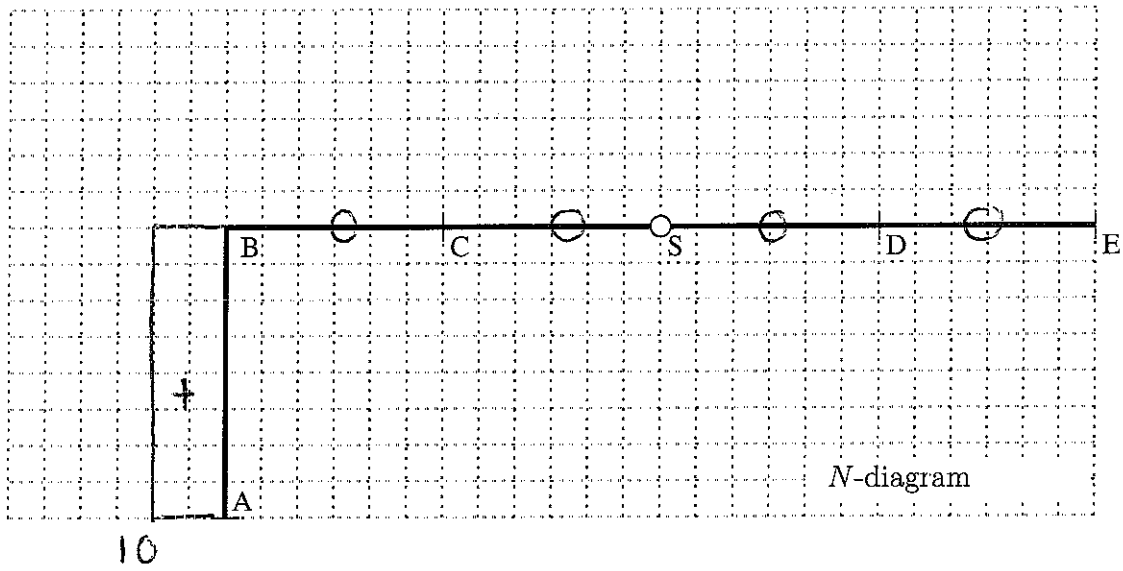
26 januari 2007

Naam: Antwoordmodel

Question c

Draw the normal force diagram (N-diagram) of the beam and use the correct deformation signs. Mention all relevant values.

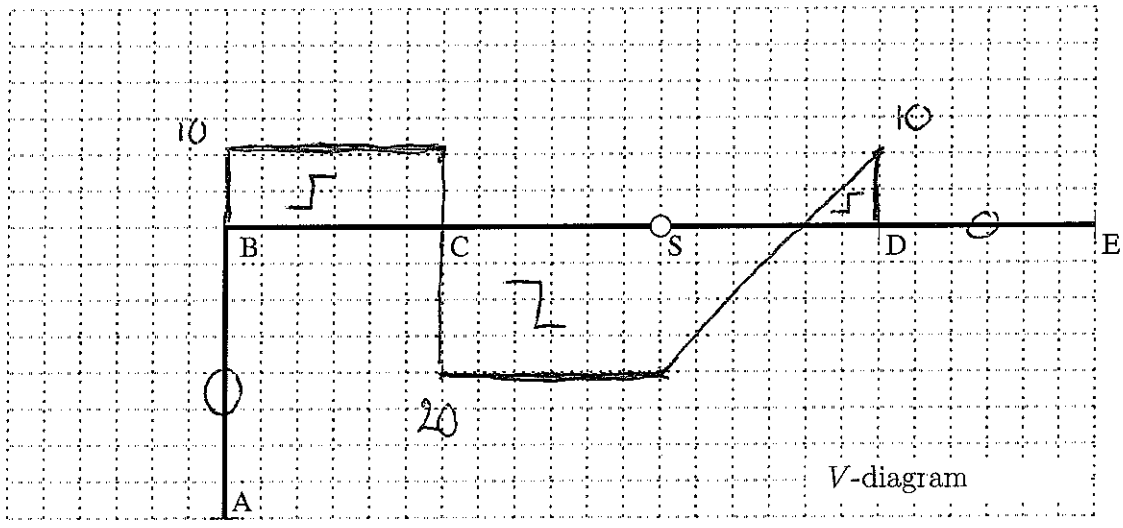
Answer



Question d

Draw the shear force diagram (V-diagram) of the beam and use the correct deformation signs. Mention all relevant values.

Answer



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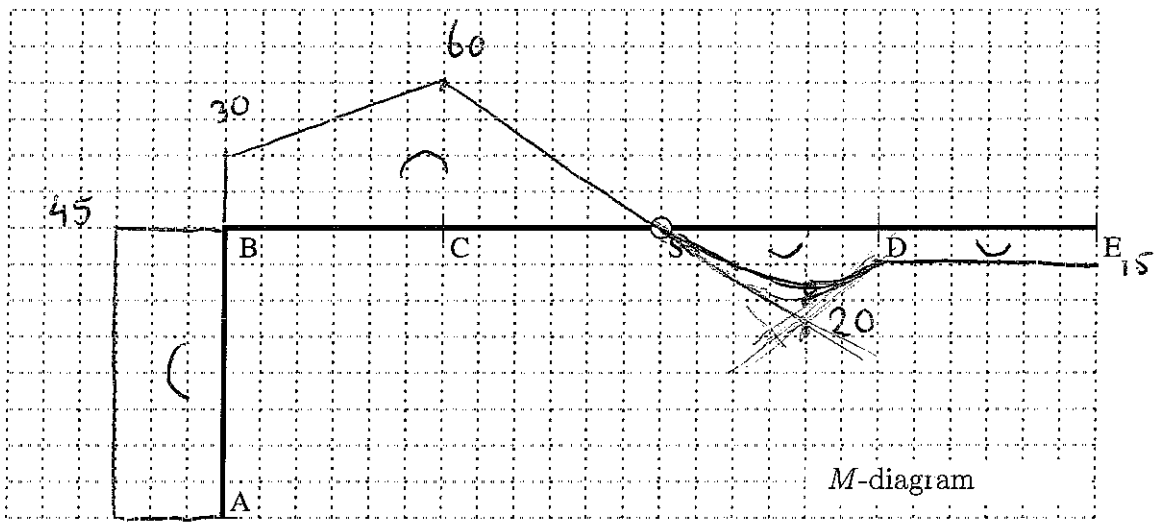
Question e

Draw the moment diagram (M-diagram) of the beam and use the correct deformation signs. Mention all relevant values and draw tangents where neccesary.

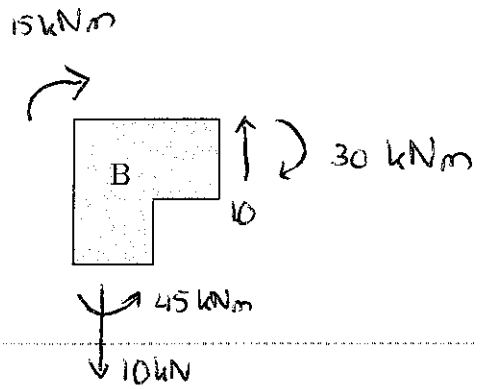
Answer



Question f

Draw all the forces and moments acting on the corner in B and show that they are in equilibrium

Answer



$\circlearrowleft +$ $\Sigma T_A = 0$ $\quad 45 - 15 - 30 = 0$

$\uparrow +$ $\Sigma F_y = 0$ $\quad -10 + 10 = 0$

$\rightarrow +$ $\Sigma F_x = 0$ $\quad 0 = 0$

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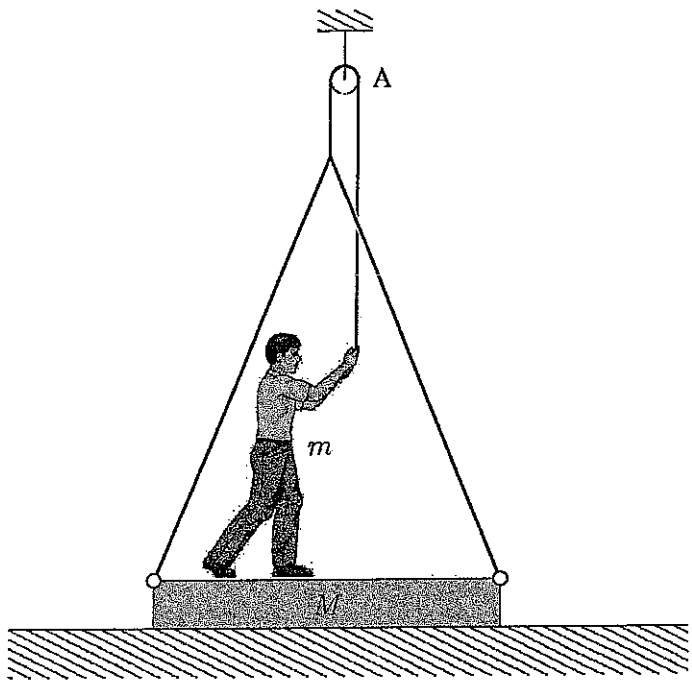
Problem 5 (Weight 1 5, approx. 30 min.)

The world's strongest man with mass m is standing on a platform with mass M. The platform currently lies on the floor. Using a cable and a pulley the man can hoist the platform. Neglect the mass of the cables and the pulleys.

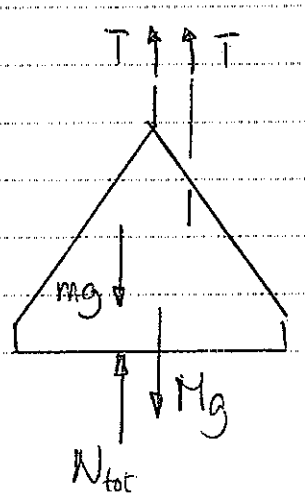


Question a

Derive the condition which must be met if the man is to hoist himself using the platform

Answer

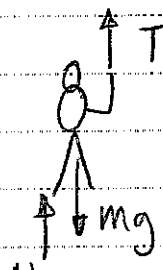
FBD of man and platform



The platform and the man are hoisted when $N_{tot} = 0$

$2T = mg + Mg$ (A)

FBD of man



The man hoists himself from the platform when $N_{man} = 0$

$T = mg$ (**)

Substituting (*) and (**):
The man hoists himself when:

$2mg = mg + Mg$ (***)

$m = M$

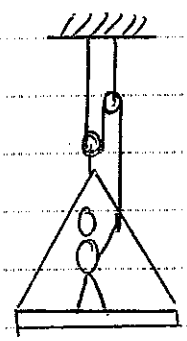
The mass of the man must be larger than the mass of the platform.

Question b

If the condition in question a) can't be met, what modification would allow the man to hoist himself? You are not required to completely redesign the structure in detail.

Answer

By adding a free pulley, e.g.



(eq. (*) and (***) in a) will change)

or, by strapping the man's feet to the platform. This solution is less convenient, but still correct