Space above not to be filled in by the student

AE1103 Statics

25 January 2010 09.00h - 12.00h

Answer sheets

Last name and initials: ...Answermodel.....

Student no.:

Only hand in the answer sheets!
Other sheets will not be accepted

Write your name and study number on every page
Sheets without name or study number will not be accepted.

Write relevant calculations on the answer sheet
Use the blank sides of the answer sheets if necessary.
Answers without calculations or motivation will not be taken into account.

Use possible checks to avoid calculation errors
The order of answering the questions is free
NOTE: **this exam consists of 5 problems.**

The **neatness of the presentation** of the answers will be considered in the marking.

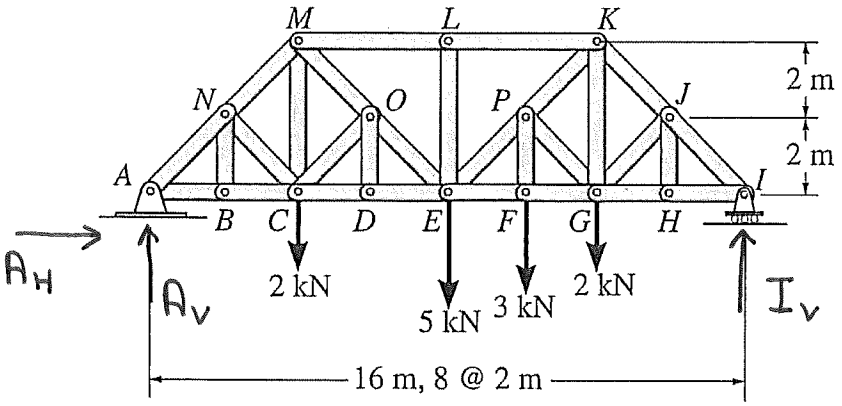
All answers must be given mentioning the correct SI units.

Answer sheets | Student no:

25 January 2010
Exam AE1103 Statics | Name: Answermodel

Problem 1 (Weight 2.0 - approx. 35 minutes)

The truss below is known as a Baltimore truss and is loaded as shown in the figure. All relevant dimensions can be found in the figure.
Het onderstaande vakwerk staat bekend als een "Baltimore" vakwerk en wordt belast zoals aangegeven in de figuur. Alle relevante afmetingen zijn aangegeven in de figuur.



Questions

a) Determine the reactions in A and in I and draw these in the figure in the direction in which they act on the structure in reality.
Bepaal de oplegreacties in A en in I en teken deze in de figuur zoals ze in werkelijkheid op de constructie werken.

3

$\Sigma F_H \overset{+}{\rightarrow} : 0 : \quad A_H = 0 \text{ kN}$

$\Sigma M_A \overset{+}{\circlearrowleft} : 0 = I_V \cdot 16 - 2 \cdot 12 - 3 \cdot 10 - 5 \cdot 8 - 2 \cdot 4$

$I_V = 6\frac{3}{8} \text{ kN} \quad (\approx 6.375 \text{ kN})$

$\Sigma F_V \overset{+}{\uparrow} : 0 = A_V + I_V - 2 - 5 - 3 - 2$

$A_V = 5\frac{5}{8} \text{ kN} \quad (\approx 5.625 \text{ kN})$

Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

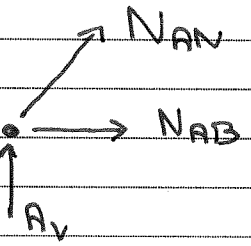
(Problem 1 continued)

b) Identify the zero-force members in the structure.
Identificeer de nulstaven in deze constructie.

7 BN, DO, HJ, CN, GJ, OC, EL

c) Calculate the normal forces in members CD, CM, EF, EP, and LK using a method of your choice with the correct sign for tension (+) or compression (-) and include these in the table on the next page. All results must be supported by calculations.
Bereken met een methode naar keuze de krachten in de staven CD, CM, EF, EP en LK met het juiste teken voor trek (+) en druk (-) en vermeld ze in de tabel op de volgende pagina. Alle resultaten moeten met berekeningen worden onderbouwd.

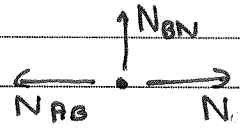
joint A:



$\Sigma F_V \uparrow_+ : 0 = A_V + \frac{1}{2}\sqrt{2}\, N_{AN} \rightarrow N_{AN} = -5\frac{5}{8}\sqrt{2}$ kN

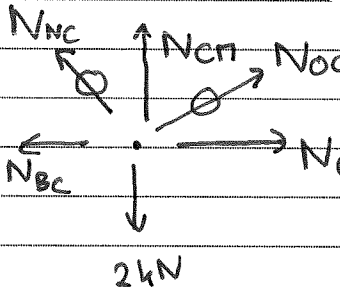
$\Sigma F_H \rightarrow : 0 = \frac{1}{2}\sqrt{2}\, N_{AN} + N_{AB} \rightarrow N_{AB} = 5\frac{5}{8}$kN (tension)

joint B



$\Sigma F_H : \rightarrow N_{AB} = N_{BC}$

joint C



$\Sigma F_H : \rightarrow N_{CD} = N_{BC} = N_{AB}$

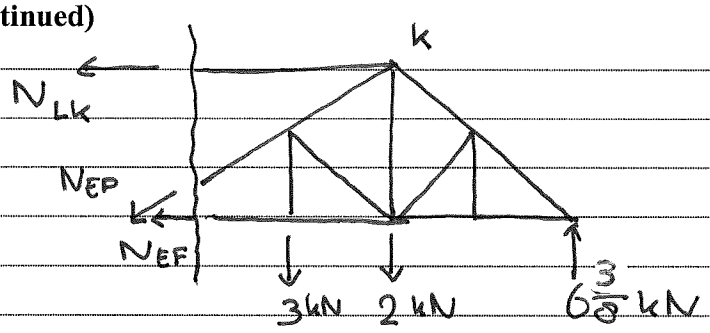
$N_{CD} = 5\frac{5}{8}$kN (tension)

$\Sigma F_V : \rightarrow N_{CM} = 2$kN (tension)

Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

(Problem 1 continued)



$\Sigma F_V \uparrow + : 0 = -\frac{1}{2}\sqrt{2}\, N_{EP} - 3 - 2 + 6\frac{3}{8}$

$\rightarrow N_{EP} = \frac{11}{8}\sqrt{2}$ kN (tension)

$\Sigma M_k \overset{+}{\circlearrowleft} : 0 = -N_{EF} \cdot 4 + 3 \cdot 2 + 6\frac{3}{8} \cdot 4$

$\rightarrow N_{EF} = 7\frac{7}{8}$ kN (tension)

$\Sigma F_H \overset{+}{\rightarrow} : 0 = -N_{LK} - N_{EF} - \frac{1}{2}\sqrt{2}\, N_{EP} = 0$

$\rightarrow N_{LK} = -9\frac{1}{4}$ kN (compression)

N_{CD}	N_{CM}	N_{EF}	N_{EP}	N_{LK}
$5\frac{5}{8}$ [kN] (tension)	2 [kN] (tension)	$7\frac{7}{8}$ [kN] (tension)	$\frac{11}{8}\sqrt{2}$ [kN] (tension)	$-9\frac{1}{4}$ [kN] (compression)
≈ 5.625 kN		≈ 7.875 kN	≈ 1.94 kN	≈ 9.25 kN

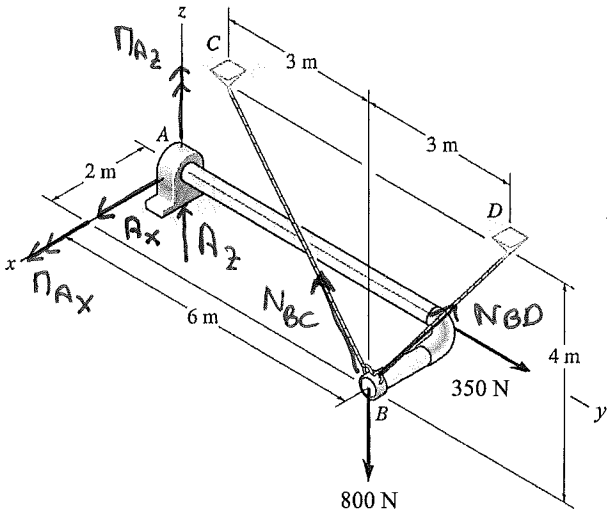
10

Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

Problem 2 (Weight 2.0 - approx. 35 minutes)

The structure in the figure below is supported by a journal bearing in A and suspended from two cables in B. All relevant information can be found in the figure.
De constructie in de onderstaande figuur wordt door een lager ondersteund in A en hangt aan twee kabels in B. Alle relevante gegevens kunnen in de figuur worden gevonden.



Questions

a) Calculate the reactions at A and the cable forces in BC and BD and include these in the table on the next page. All results must be supported by calculations.
Bereken de reacties in A en de kabelkrachten in BC en BD en vermeld ze in de tabel op de volgende pagina. Alle resultaten moeten van berekeningen worden voorzien.

$\Sigma F_x \rightarrow + : 0 = A_x \rightarrow A_x = 0\,N$ (1)

$\Sigma F_y \uparrow + : 0 = \frac{3}{5} N_{BD} - \frac{3}{5} N_{BC} + 350$ (2)

$\Sigma F_z \uparrow + : 0 = \frac{4}{5} N_{BD} + \frac{4}{5} N_{BC} - 800 + A_z$ (3)

Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

(problem 2 continued)

$\Sigma M_{Ax\text{-as}} \overset{+}{\circlearrowleft} : 0 = 800 \cdot 6 - \frac{4}{5} N_{BC} \cdot 6 - \frac{4}{5} N_{BD} \cdot 6 + M_{Ax} = 0$ (4)

$\Sigma M_{Ay\text{-as}} \overset{+}{\circlearrowright} : 0 = 800 \cdot 2 - \frac{4}{5} N_{BC} \cdot 2 - \frac{4}{5} N_{BD} \cdot 2 = 0$ (5)

From (3) and (5) it follows that $A_z = 0$ N

From (2) it yields that $N_{BC} = N_{BD} + 583\frac{1}{3}$ (6)

substituting (6) into (5) yields:

$800 - (N_{BD} + 583\frac{1}{3}) \cdot \frac{4}{5} - N_{BD} \cdot \frac{4}{5} \rightarrow N_{BD} = 208\frac{1}{3}$ N

From (6) it now yields that $N_{BC} = 791\frac{2}{3}$ N

From (4) it yields that $M_{Ax} = 0$ N after substituting N_{BD} & N_{BC}

$\Sigma M_{Az} \overset{+}{\circlearrowleft} : 0 = \frac{3}{5} N_{BD} \cdot 2 - \frac{3}{5} N_{BC} \cdot 2 + M_{Az} = 0$

$\rightarrow M_{Az} = 700$ Nm

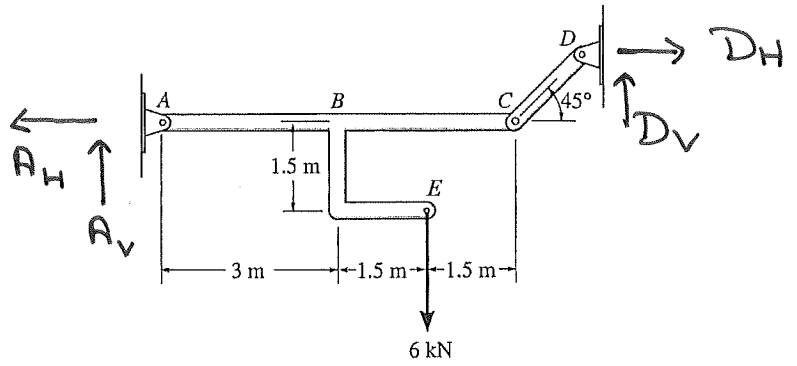
A_x	A_z	M_{Ax}	M_{Az}	N_{BC}	N_{BD}
0 N	0 N	0 N	700 Nm	$791\frac{2}{3}$ N	$208\frac{1}{3}$ N

20

Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

Problem 3 (Weight 2.0 - approx. 35 minutes)
The frame structure in the figure below is attached to the wall by hinges in A and D and also has a hinge in C. In E the structure is loaded by a vertical force F = 6 kN. Beam CD has length $\sqrt{2}$ m. All other relevant dimensions can be found in the figure.
De raamwerkconstructie in de onderstaande figuur is scharnierend verbonden aan de muren in A en D en heeft ook nog een scharnier in C. De constructie wordt in punt E belast door een verticale kracht F = 6 kN. Balk CD heeft lengte $\sqrt{2}$ m. Alle andere relevante afmetingen staan in de figuur aangegeven.



Questions:
a) Calculate the reactions in A and D and draw these in the figure in the direction in which they act on the structure in reality.
Bepaal de oplegreacties in A en in B en teken deze in de figuur zoals ze in werkelijkheid op de constructie werken.

$\Sigma F_H \rightarrow : 0 = -A_H + D_H \rightarrow A_H = D_H$

CD is a two-force member so $D_H = D_V$

$\Sigma M_A \circlearrowleft : 0 = -6 \cdot 4.5 + D_V \cdot 7 - D_H \cdot 1 \rightarrow D_H = 4.5\ kN$

$\rightarrow D_V = 4.5\ kN$.

$\rightarrow A_H = 4.5\ kN$

$\Sigma F_V \uparrow + : 0 = A_V + D_V - 6$

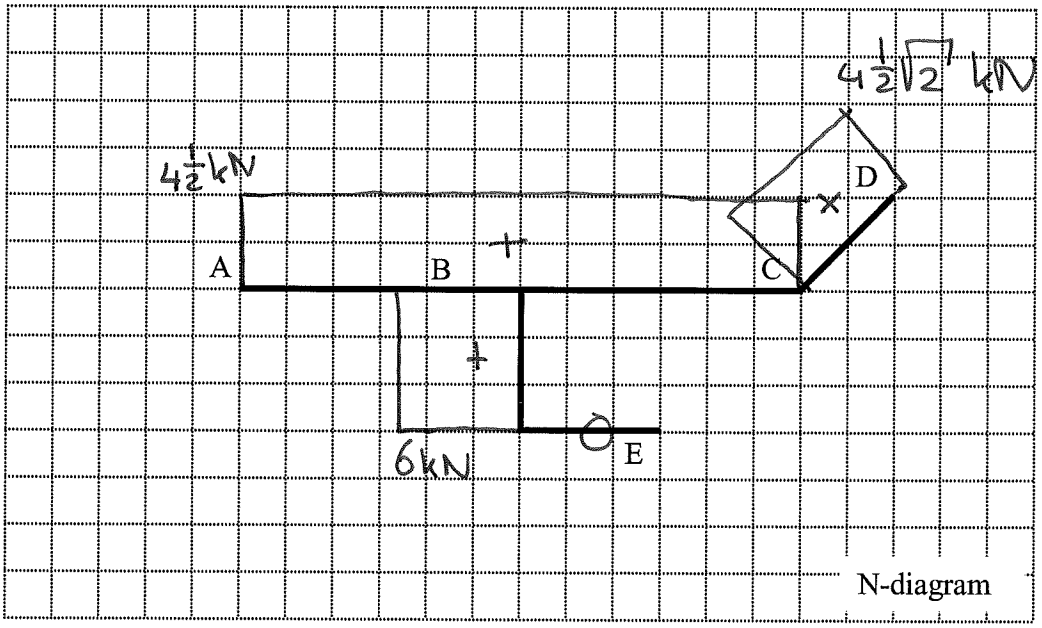
$\rightarrow A_V = 1.5\ kN$

4

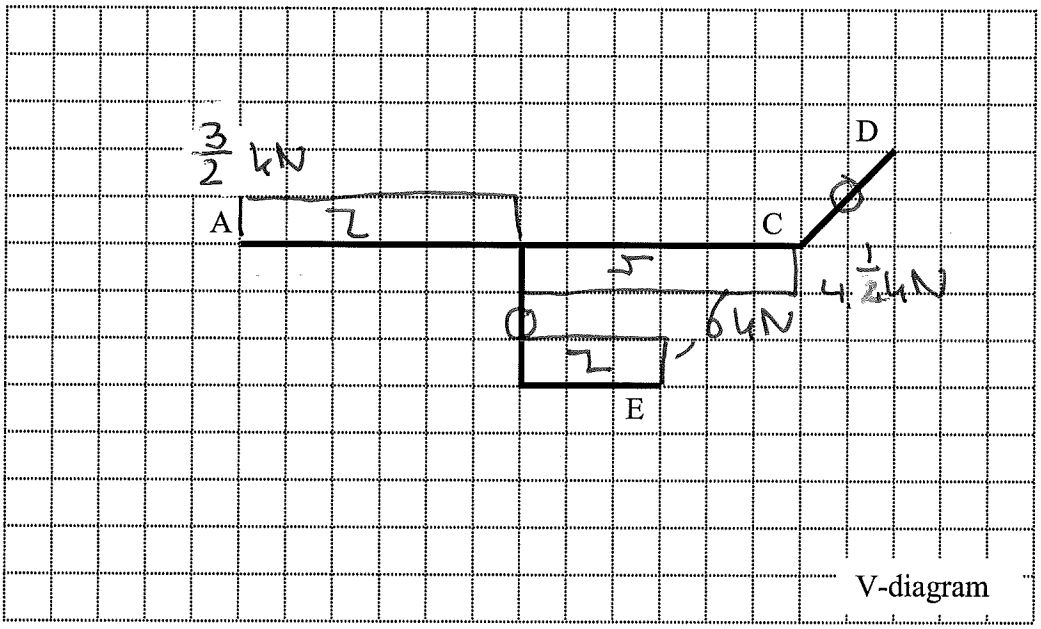
(Problem 3 continued)

b) Draw the normal force, shear force and moment diagrams (N, V and M-diagram) of the frame and use the correct deformation signs. Mention all relevant values including all extremes.
Teken de normaalkrachten-, dwarskrachten- en momentenlijn (N, V en M-lijnen) van het raamwerk en vermeld daarbij de juiste vervormingstekens. Vermeld alle relevante waardes inclusief de extremen.

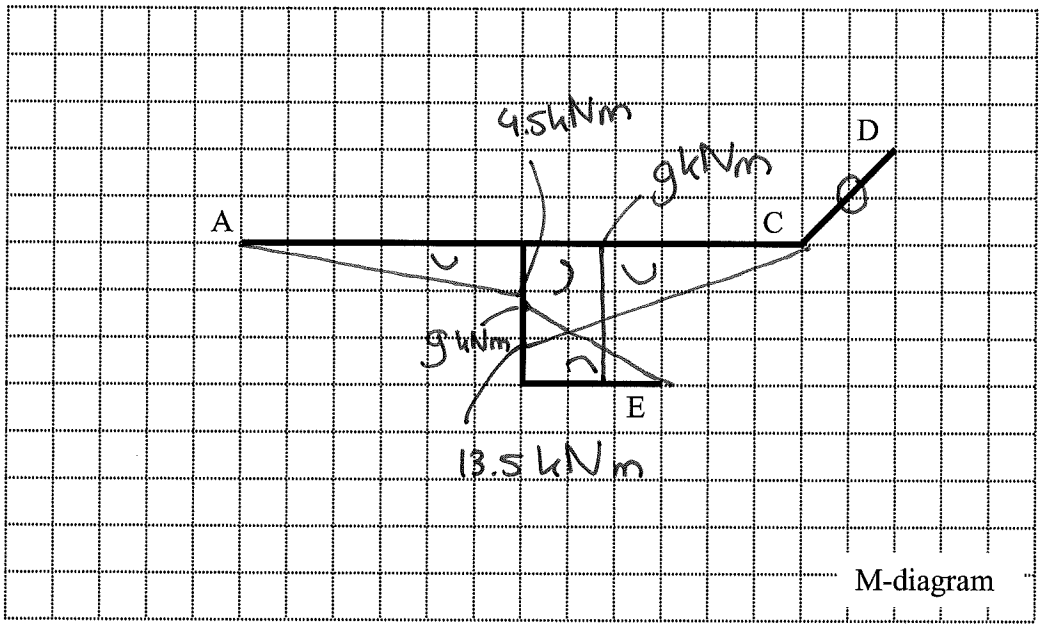
4



5

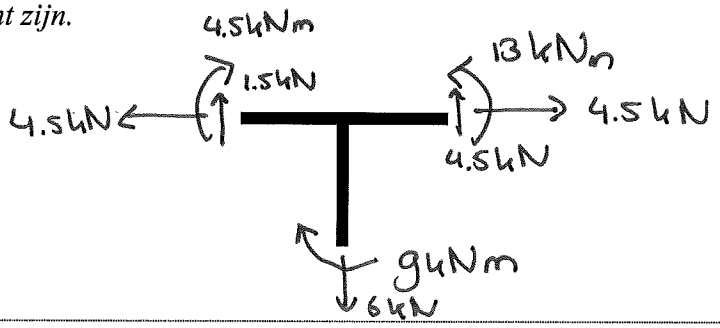


(Problem 3 continued)



5

c) Draw all the forces and moments acting on the connection in B and show that they are in equilibrium.
Teken alle krachten en momenten die op de verbinding in B werken en toon aan dat ze in evenwicht zijn.



2

$\Sigma M_B^{+5} = -4.5 - 9 + 13.5 = 0 \rightarrow 0 = 0$

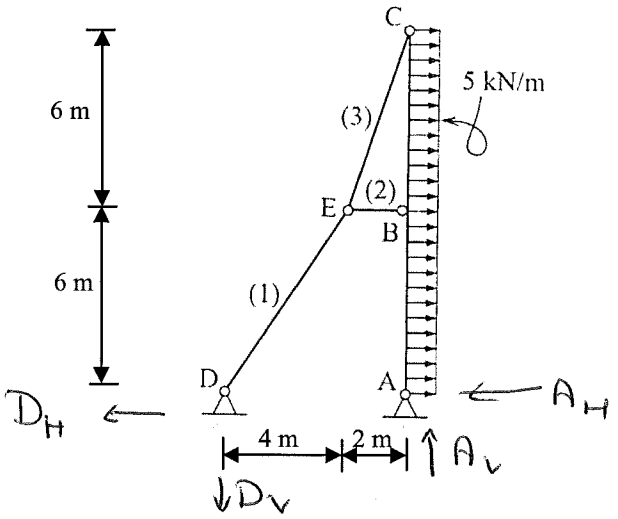
$\Sigma F_V \uparrow + : 0 = 1.5 + 4.5 - 6 = 0 \rightarrow 0 = 0$

$\Sigma F_x \rightarrow : 0 = 4.5 - 4.5 = 0 \rightarrow 0 = 0$ Q.E.D

Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answer model

Problem 4 (Weight 2.5 - approx. 45 minutes)
Mast ABC is supported sideways by a number of two force members. The dimensions and loads are shown in the figure below.
Mast ABC wordt zijdelings ondersteund door een aantal pendelstaven. De afmetingen en belastingen zijn aangegeven in de onderstaande figuur.



Questions

a) Calculate the reactions in A and D and draw these in the figure in the direction in which they act on the structure in reality.
Bepaal de oplegreacties in A en in D en teken deze in de figuur zoals ze in werkelijkheid op de constructie werken.

4

DE is a two-force member $\rightarrow$ $D_H = \frac{2}{3} D_V$

$\Sigma M_A (+\circlearrowleft): 0 = D_V \cdot 6 - 5 \cdot 12 \cdot 6 \rightarrow D_V = 60\ kN$

$D_H = \frac{2}{3} D_V \rightarrow D_H = 40\ kN$

$\Sigma F_H (+\rightarrow): 0 = 5 \cdot 12 - A_H - D_H \rightarrow A_H = 20\ kN$

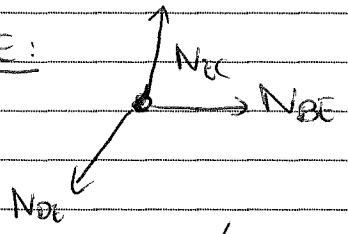
$\Sigma F_V (+\uparrow): 0 = A_V - D_V \rightarrow A_V = 60\ kN$

(Problem 4 continued)

b) Calculate the normal forces in members DE, BE, and EC with the correct sign for tension (+) or compression (-) and include these in the table below. All results must be supported by calculations.
Bereken de krachten in de staven DE, BE en EC met het juiste teken voor trek (+) en druk (-) en vermeld ze in de onderstaande tabel. Alle resultaten moeten met berekeningen worden onderbouwd.

$N_{DE} = \sqrt{D_H^2 + D_V^2} = 20\sqrt{13}$ kN

joint E:



$\Sigma F_V \uparrow + : 0 = \frac{6}{2\sqrt{10}} N_{EC} - \frac{6}{2\sqrt{13}} N_{DE} \rightarrow N_{EC} = 20\sqrt{10}$ kN

$\Sigma F_H \rightarrow + : 0 = -\frac{4}{2\sqrt{13}} N_{DE} + N_{BE} + \frac{2}{2\sqrt{10}} N_{EC}$

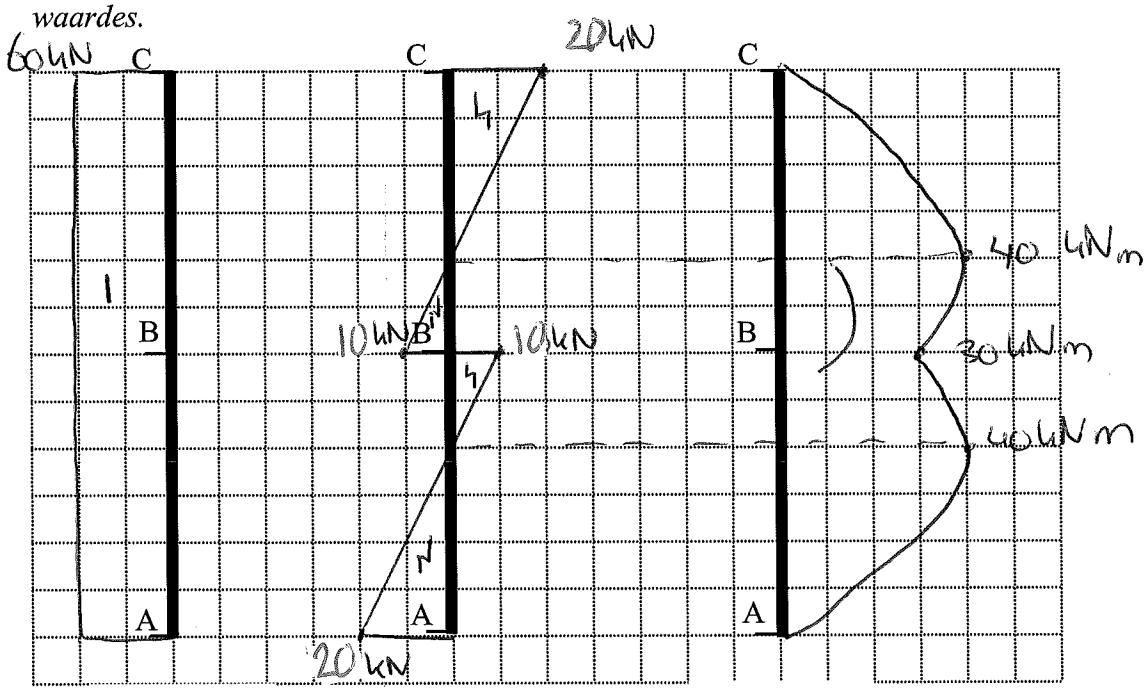
$\rightarrow N_{BE} = 20$ kN

N_{DE}	N_{BE}	N_{EC}
$20\sqrt{13}$ kN (tension)	20 kN (tension)	$20\sqrt{10}$ kN (tension)

6

(Problem 4 continued)

c) Draw the normal force, shear force and moment diagrams (N, V and M-diagram) of the frame and use the correct deformation signs. Mention all relevant values.
Teken de normaalkrachten-, dwarskrachten- en momentenlijn (N, V en M - lijnen) voor de ligger en vermeld daarbij de juiste vervormingstekens. Vermeld alle relevante waardes.



1 N-diagram 4 V-diagram 8 M-diagram

d) Calculate the location and value of the maximum moment in beam ABC.
Bereken de locatie en waarde van het maximale moment in balk ABC.

Mmax @ 4 m from A & C

(follows from V = 0)

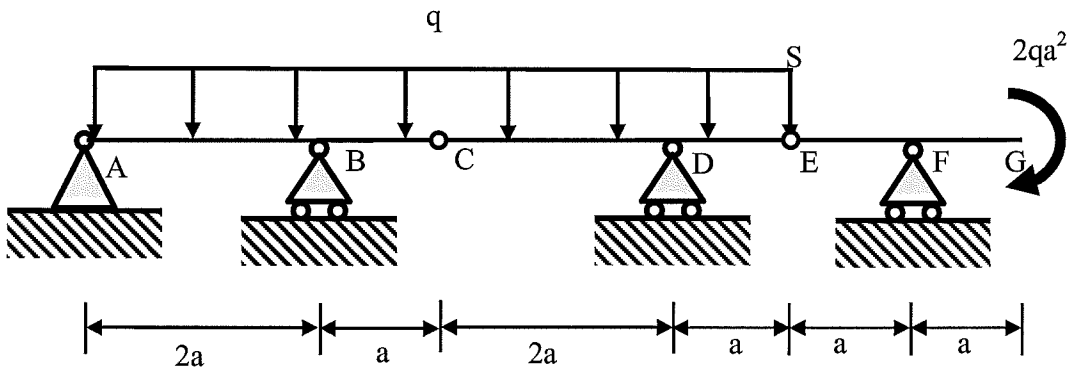
2

$M_{max} = 5 \cdot 4 \cdot 2 - 10 \cdot 4 = 40\ kNm$

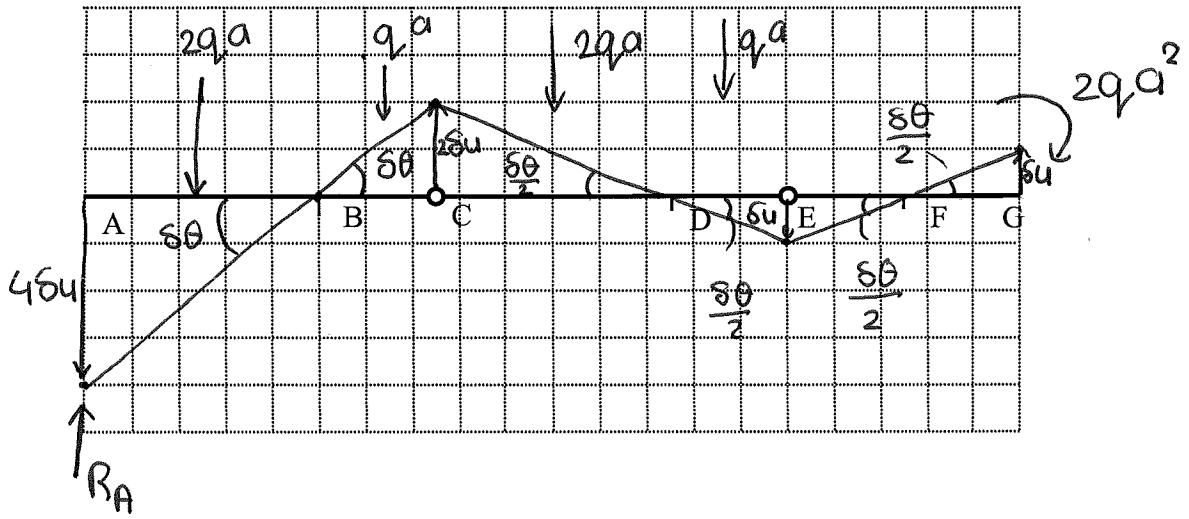
Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

Problem 5 (Weight 1.5 - approx. 30 minutes)
Beam ABCDEFG has a hinged support in A and is supported by roller supports in B, D, and F. The beam is loaded by a uniform distributed load q acting on section AE and a couple $2qa^2$ in G. C and E are hinges. All other dimensions are indicated in the figure.
Balk ABCDEFG is scharnierend opgelegd in A en wordt door rollers ondersteund in B, D en F. De balk wordt belast door een uniform verdeelde belasting werkend op sectie AE en een koppel $2qa^2$ in G. C en E zijn scharnieren. Alle overige dimensies staan aangegeven in de figuur.



Questions:
a) Use the principal of virtual work to calculate the vertical reaction force in A. Clearly indicate which virtual displacement field and which sign convention has been used.
Gebruik het principe van virtuele arbeid om de verticale reactie kracht in A te berekenen. Geef duidelijk aan welk virtueel verplaatsingsveld en welke tekenafspraak is gebruikt.



Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

(problem 5 continued)

$\delta u = \frac{a}{2}\delta\theta \rightarrow \delta\theta = \frac{2\delta u}{a}$

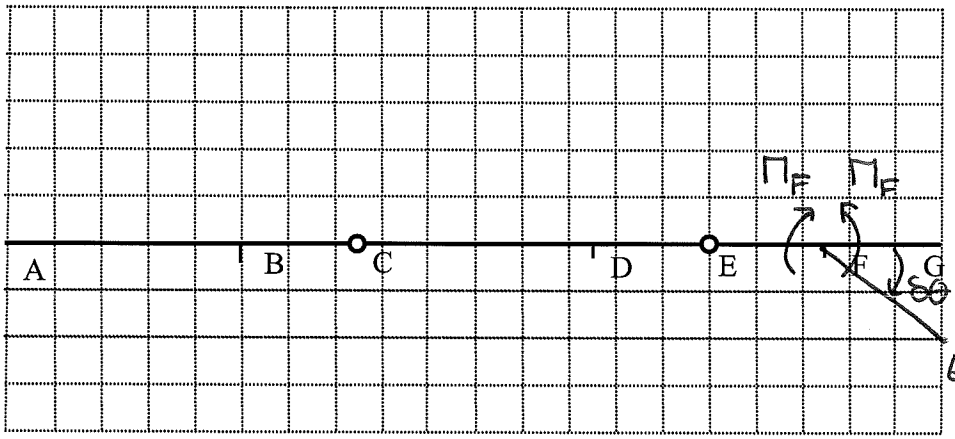
$\delta W = 0 = -R_A \cdot 4\delta u + 2qa \cdot 2\delta u - qa \cdot \delta u - 2qa \cdot \delta u + qa \cdot \frac{\delta u}{2} - \frac{\delta\theta}{2} \cdot 2qa^2$

$\Rightarrow 4R_A\delta u = \left(\frac{3}{2}qa - 2qa\right)\delta u$

$R_A = -\frac{1}{8}qa \quad (\downarrow)$

8

b) Use the principal of virtual work to calculate the internal bending moment in F. Clearly indicate which virtual displacement field and which sign convention has been used.
Gebruik het principe van virtuele arbeid om het interne buigende moment in F te berekenen. Geef duidelijk aan welk virtueel verplaatsingsveld en welke tekenafspraak is gebruikt.



Answer sheets Student no:

25 January 2010
Exam AE1103 Statics Name: Answermodel

(problem 5 continued)

$\delta W = 0 = 2qa^2 \delta\theta - M_F \delta\theta$

$\rightarrow M_F = 2qa^2$

7