Delft Applied Mechanics:
Statics

AE1-914-I

January 27, 2006, 9:00–12:00

ANSWER FORM

Student number: | | | | | | | |

Name: REMARKS

Section below is not to be filled in by the student

Marks:

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Problem 1 (Weight 1.0, approx. 20 min.)

Question a

What is the essential difference between a kinematically determinate and a kinematically indeterminate structure?

A structure is kinematically determinate when it is supported in such a way that all free movements are prohibited

In all other cases, the structure is called kinematically indeterminate (or a mechanism).

Question b

What is the essential difference between a statically determinate and a statically indeterminate structure?

When the number of constraints is just sufficient to guarantee kinematic determinacy, the structure is called statically determinate.

When constraints can be removed without cancelling out the static equilibrium, the structure is called statically indeterminate

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For 2-dimensional trusses a fast method can be used to determine the degree of determinacy of a structure:

$$s = 2k - 3$$

Question c

Explain what this formula means and also explain how it can be used to determine the degree of kinematical and statical (in)determinacy for trusses in general.

A 2-dimensional structure is kinematically determinate when it consists of rigid triangles. In that case, the number of bars (s) is equal (or greater) than the number of equilibrium equations (= 2 times the number of nodes k) minus the number of unknown constraints. (3). Note that this is a necessary, but not a sufficient requirement. (Bars can be placed in such a way that the condition $s \geq 2k-3$ is met, but the structure is still kinematically indeterminate

When $s > 2k-3$, the structure is statically indeterminate, when $s = 2k-3$, the structure is statically determinate

When $s < 2k-3$, the structure is kinematically indeterminate

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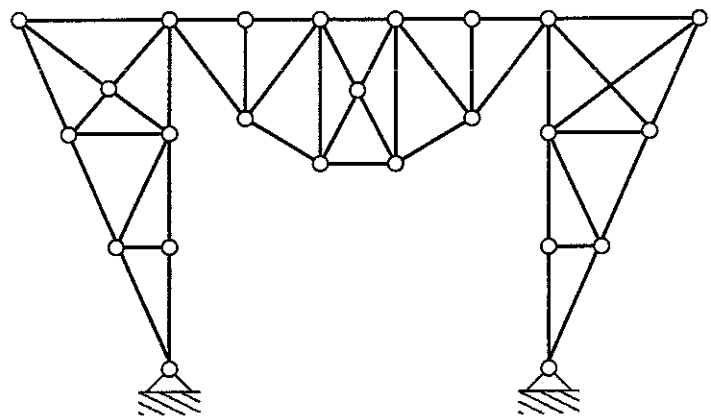
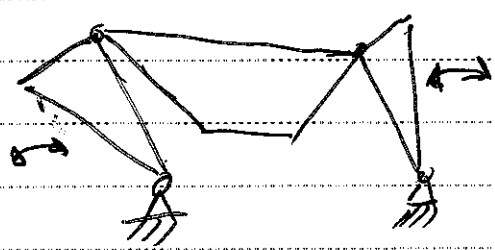
Question d

Evaluate the degree of kinematical and statical (in)determinacy of the truss below.



For this truss, $s > 2k-3$. But, remember that this is a necessary, but not a sufficient condition. In this case, the bars are placed in the wrong position.

Actually, the truss consists of three parts, each of them statically indeterminate. The complete structure however is a mechanism. (kinematically indeterminate)



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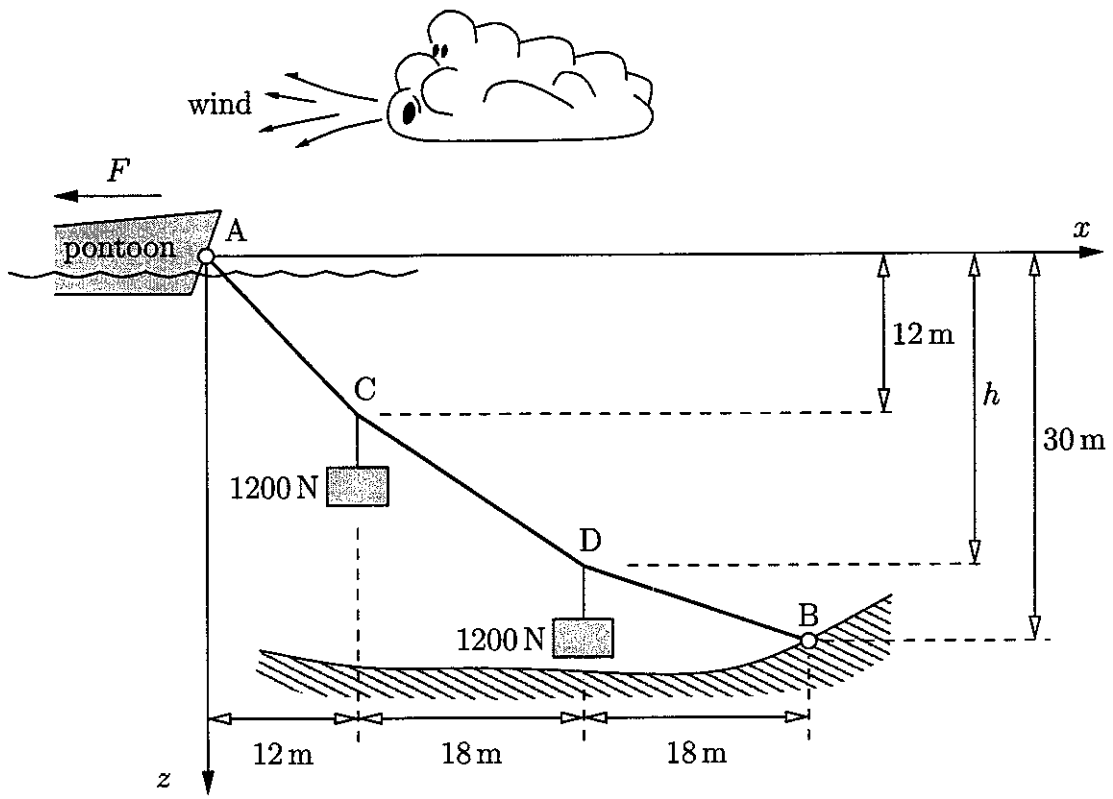
Problem 2 (Weight 2.0, approx. 35 min.)

A pontoon is anchored by a cable in a fjord which is 30 m deep. The cable is being weighted down by two concrete blocks of 1200 N each. It is assumed that the cable will not stretch under the given loads. In the situation below a horizontal force F due to the wind load is acting on the pontoon.

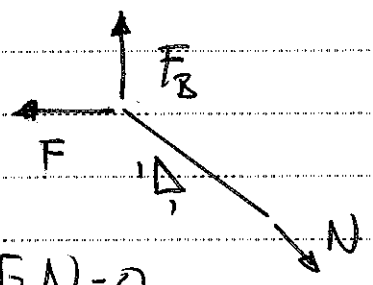
NOTE: The vertical position h of point D is unknown!



Question a

Calculate the magnitude of the force F due to the wind load acting on the pontoon. Draw the force that the cable exercises on the pontoon in the correct direction.

Cut at AC

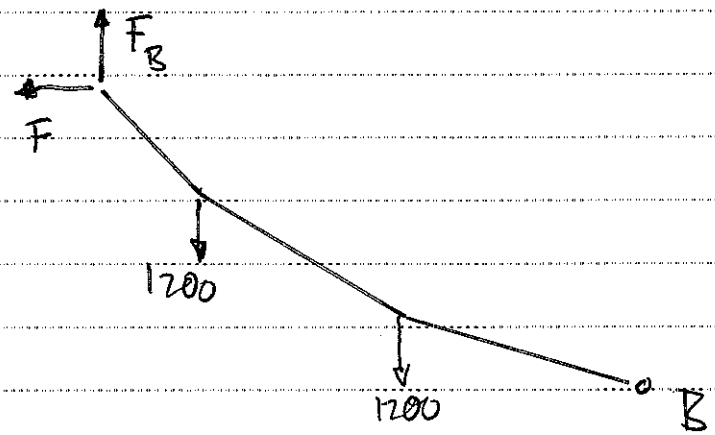


F_B = buoyant force.

ΣF_x: $-F + \frac{1}{2}\sqrt{2}N = 0$

ΣF_y: $F_B - \frac{1}{2}\sqrt{2}N = 0$ $\longrightarrow$ $F_B = F$

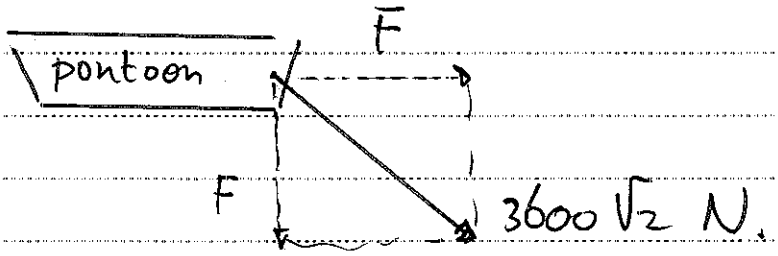
Whole structure



ΣM_B (+): $18 \cdot 1200 + 36 \cdot 1200 - 48 F_B + 30F = 0$

$18 \cdot 1200 + 36 \cdot 1200 - 18F = 0$

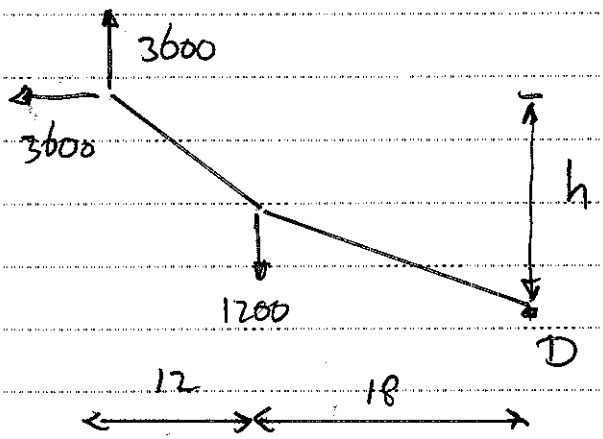
$F = 3600$ N.



Question b

Determine the vertical position h of point D.

Sum of moments about D



$\circlearrowleft^{+}$

ΣM_D : $18 \cdot 1200 - 30 \cdot 3600 + h \cdot 3600 = 0$

$h = 24$ m.

Question c

Determine the maximum force in the cable and indicate where this occurs.

Force is maximum where the slope is maximum, i.e. point A:

$N = 3600\sqrt{2}$ N.

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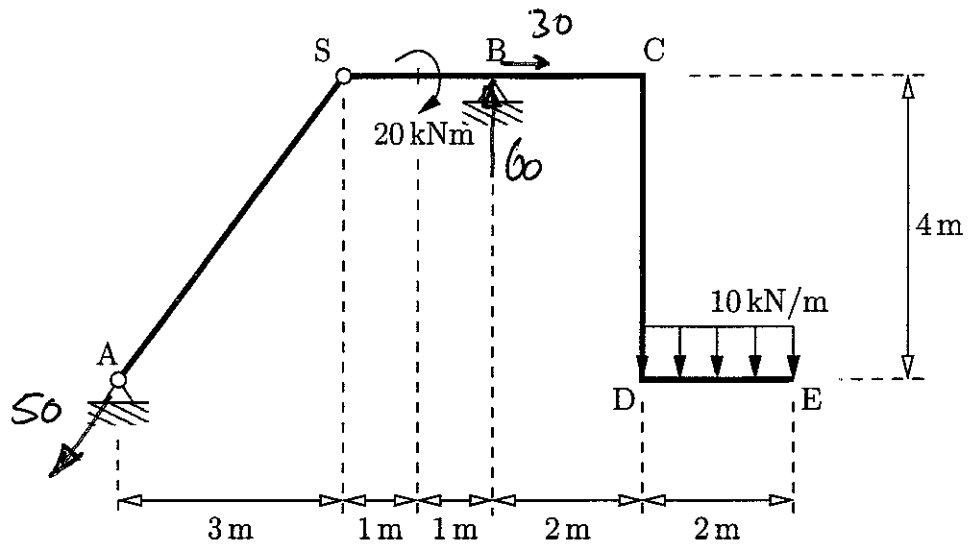
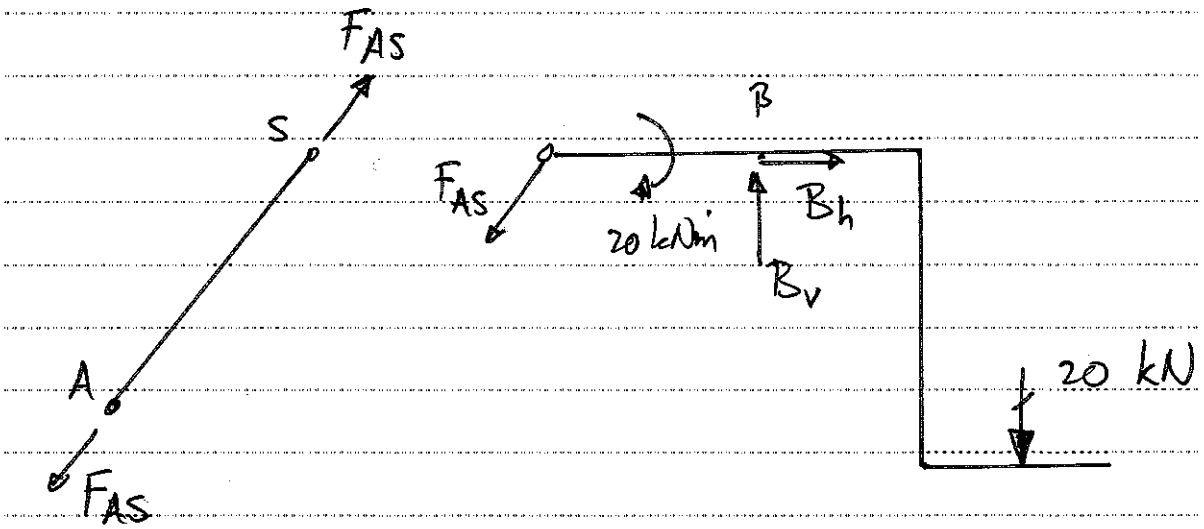
Problem 3 (Weight 2.5, approx. 45 min.)

The structure below consists of parts AS and SBCDE which are connected by a hinge in S. The structure is loaded by a couple of 20 kNm halfway between S and B and a uniform distributed load of 10 kN/m on part DE. The structure is simply supported in A and in B.



Question a

Calculate the reactions and draw them in the figure as they act on the structure in reality.



$\sum M_B \overset{+}{\circlearrowleft} \quad 2 \cdot \frac{4}{5} F_{AS} - 20 - 3 \cdot 20 = 0$

$F_{AS} = \frac{5}{8}(20 + 3 \cdot 20) = 50 \text{ kN}.$

$A = 50 \text{ kN}.$

$\overset{+}{\rightarrow}$

$\Sigma F_x: \quad -\frac{3}{5} F_{AS} + B_h = 0$

$B_h = 30 \text{ kN}.$

$\overset{+}{\uparrow}$

$\Sigma F_y: \quad -\frac{4}{5} F_{AS} + B_v - 20 = 0$

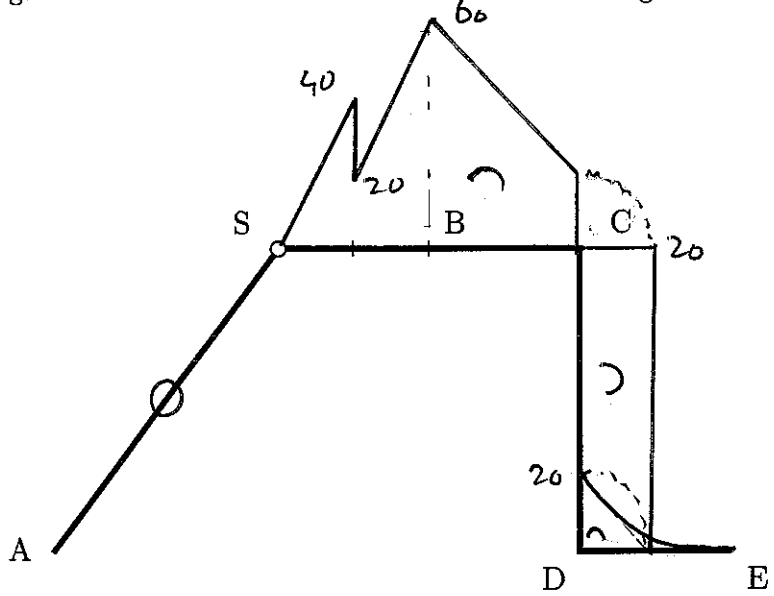
$B_v = 20 + \frac{4}{5} F_{AS} = 60 \text{ kN}.$

Check:

$\Sigma M_S \overset{+}{\circlearrowright}: \quad 20 - 2 \cdot 60 + 5 \cdot 20 = 0$ §.

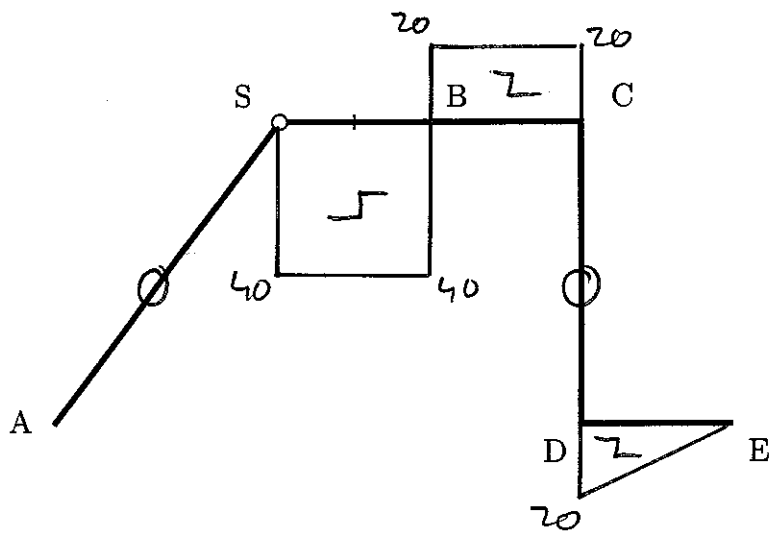
Question b

Draw the moment diagram (M-diagram) of the entire structure with the appropriate deformation signs. Mention all relevant values and draw the tangents when necessary.



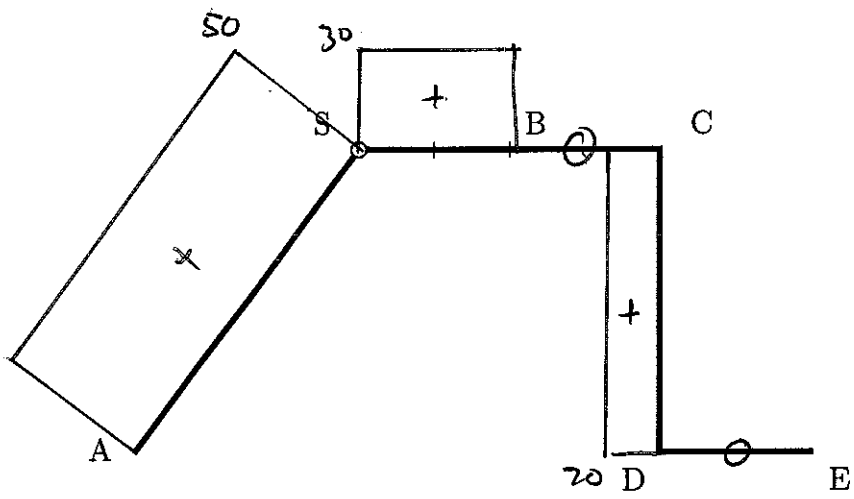
Question c

Draw the shear force diagram (V-diagram) of the entire structure with the appropriate deformation signs. Mention all relevant values.



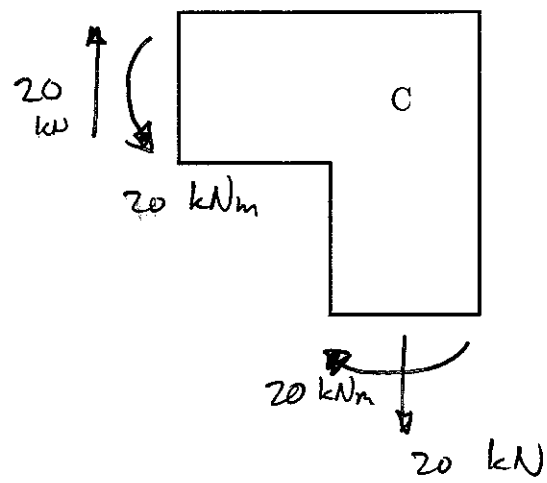
Question d

Draw the normal force diagram (N-diagram) of the entire structure with the appropriate signs for tension and compression. Mention all relevant values.



Question e

Isolate joint C and draw all forces (and moments) as they act on the joint.



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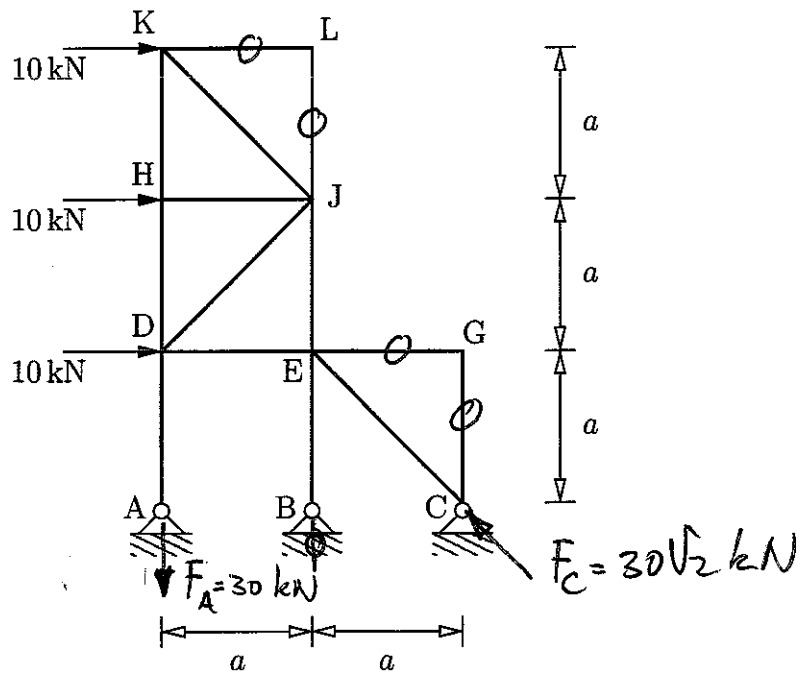
Problem 4 (Weight 2.5, approx. 45 min.)

As indicated in the figure, the truss is loaded by three forces of 10 kN each.



Question a

Identify the zero-force members and indicate them in the figure.

CG, EG, JL, KL

Question b

Calculate the reactions in A, B, and C and draw them in the figure as they act on the structure in reality.

$\sum M_E \overset{+}{\circlearrowleft}: \quad -a \cdot 10 - 2a \cdot 10 + a F_A = 0$

$F_A = 30 \text{ kN}.$

$\xrightarrow{+}$

ΣF_x: $3 \cdot 10 - \frac{1}{2}\sqrt{2} F_C = 0$

$F_C = 30\sqrt{2}$ kN.

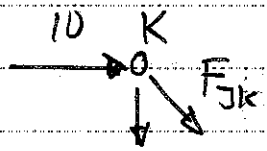
$\Sigma F_y \uparrow^+$: $-F_A + F_B + \frac{1}{2}\sqrt{2} F_C = 0$

$F_B = 0$ kN.

Question c

Calculate all the forces in the members with the correct sign for tension and compression. Write all answers in the table at the end of this question.

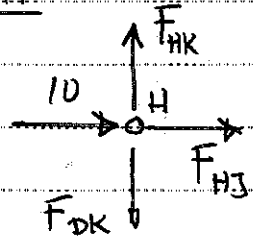
Node K



ΣF_x: $10 + \frac{1}{2}\sqrt{2} F_{JK} = 0$ $F_{JK} = -10\sqrt{2}$ kN

ΣF_y: $-F_{HK} - \frac{1}{2}\sqrt{2} F_{JK} = 0$ $F_{HK} = 10$ kN.

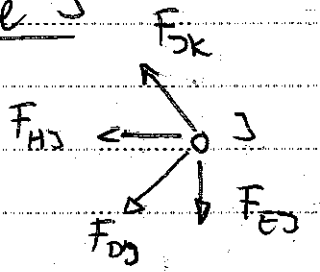
Node H



ΣF_x: $10 + F_{HJ} = 0$ $F_{HJ} = -10$ kN

ΣF_y: $F_{HK} - F_{DK} = 0$ $F_{DK} = 10$ kN.

Node J



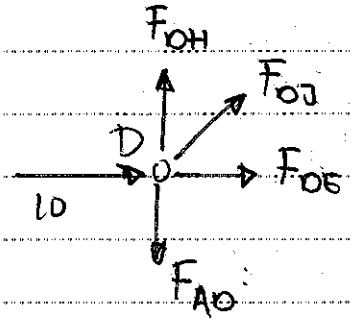
$\Sigma F_x: -F_{HJ} - \frac{1}{2}\sqrt{2}F_{JK} - \frac{1}{2}\sqrt{2}F_{DJ} = 0$

$F_{DJ} = 20\sqrt{2}$ kN.

$\Sigma F_y: \frac{1}{2}\sqrt{2}F_{JK} - \frac{1}{2}\sqrt{2}F_{DJ} - F_{EJ} = 0$

$F_{EJ} = -30$ kN.

Node D



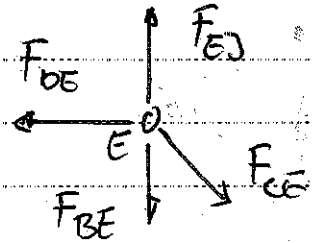
$\Sigma F_x: 10 + \frac{1}{2}\sqrt{2}F_{DJ} + F_{DE} = 0$

$F_{DE} = -30$ kN.

$\Sigma F_y: F_{DH} + \frac{1}{2}\sqrt{2}F_{DJ} - F_{AD} = 0$

$F_{AD} = 30$ kN.

Node E



$\Sigma F_x: -F_{DE} + F_{CE} = 0$

$F_{CE} = -30\sqrt{2}$ kN

$\Sigma F_y: F_{EJ} - F_{BE} - \frac{1}{2}\sqrt{2}F_{CE} = 0$

$F_{BE} = 0$ kN.

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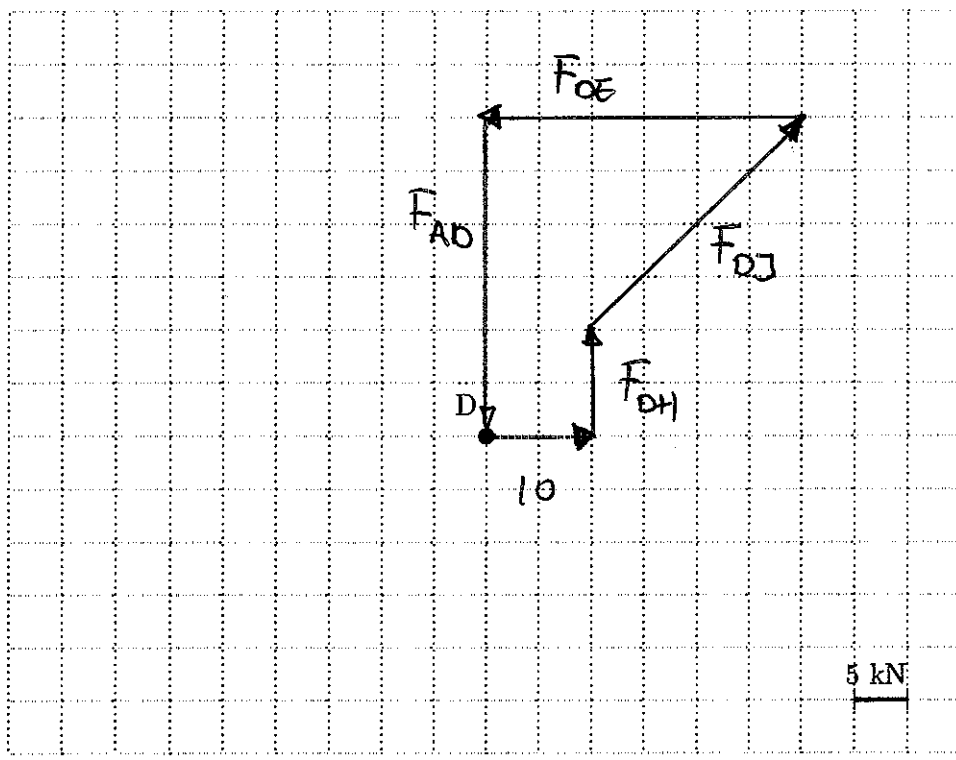
F_{AD}	F_{BE}	F_{CE}	F_{CG}	F_{DE}	F_{DJ}	F_{DH}
30	0	$-30\sqrt{2}$	0	-30	$20\sqrt{2}$	10
F_{EG}	F_{EJ}	F_{HJ}	F_{HK}	F_{JK}	F_{JL}	F_{KL}
0	-30	-10	10	$-10\sqrt{2}$	0	0

kN

Question d

Draw the force polygon for the equilibrium of point D.



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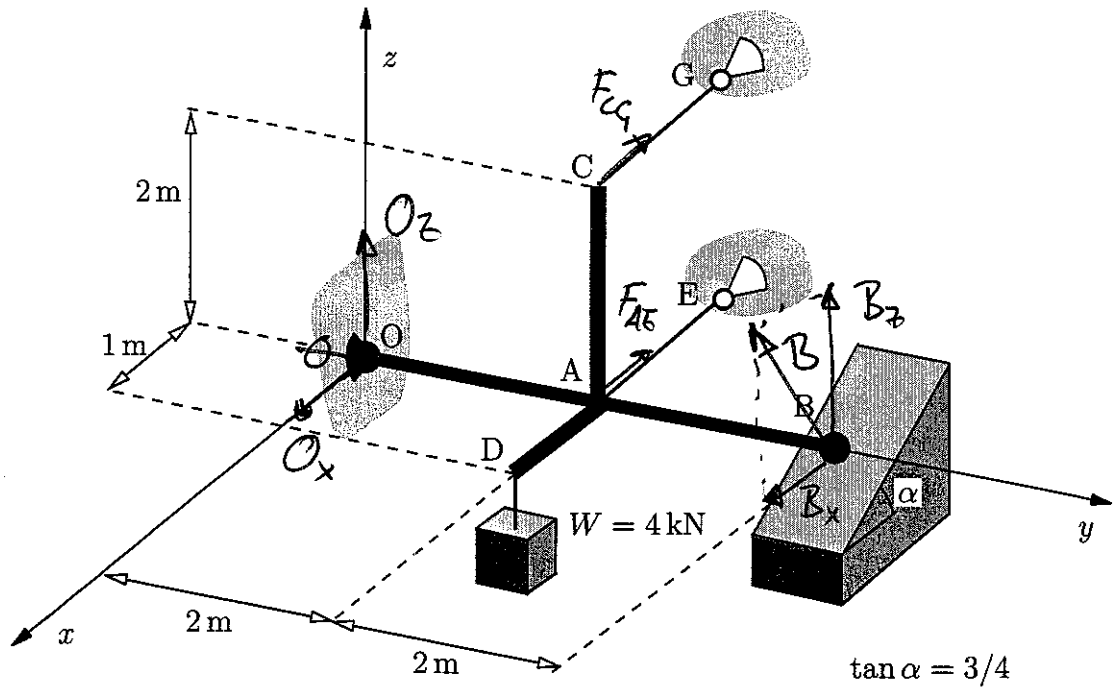
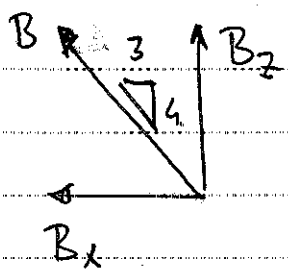
Problem 5 (Weight 2.0, approx. 35 min.)

The structure below consists of beam OAB with arms AC and AD attached perpendicularly. The weight of the structure may be neglected. Point O is a ball- and socket joint. The ball that is attached to point B slides over a frictionless slope. The angle α of the slope with respect to the x-axis is equal to $\tan\alpha = 3/4$. The structure is kept in equilibrium by means of the cables AE and CG which are parallel to the x-axis. A mass with a weight of $W = 4\,\text{kN}$ is attached to point D.



Question a

Calculate the reaction(s) in B. Draw them in the figure as they act on the structure in reality.



$B = \frac{4}{5} B_z$.

$\Sigma M_x|_O^{+} : \quad 4B_z - 2W = 0.$

$B_z = 2\,\text{kN}. \qquad B = 2{,}5\,\text{kN}.$

Question b

Calculate the forces in cables AE and CG.

$\Sigma M_y|_O \overset{+\downarrow}{} \quad -2F_{CG} + W = 0$

$F_{CG} = 2\ kN.$

$\Sigma M_z|_O \overset{+\uparrow}{} \quad 2F_{CG} + 2F_{AE} - 4B_x = 0$

$F_{AE} = 2B_x - F_{CG} = 1\ kN.$

Question c

Calculate the reaction(s) in the ball- and socket joint O. Draw them in the figure as they act on the structure in reality.

$\Sigma F_x: \quad O_x + B_x - F_{CG} - F_{AE} = 0$

$O_x = 1{,}5 \text{ kN}.$

$\Sigma F_y \quad O_y = 0 \text{ kN}.$

$\Sigma F_z \quad O_z + B_z - W = 0$

$O_z = 2 \text{ kN}.$