EINDHOVEN UNIVERSITY OF TECHNOLOGY **DEPARTMENT OF THE BUILT ENVIRONMENT**
UNIT STRUCTURAL DESIGN

Final test: Dimensioning of Structures (7PPX1)
Date: April 18, 2017 SURNAME:
INITIALS:
Time: 18.00 – 21.00 h ID.NR.:

Part Applied Mechanics

Assignments and answer sheets

First read the following terms and conditions regarding writing and submitting the replies of the test!

- First write your surname including initials and identity number of your study card clearly on the top of this front page.
- For open questions, only place the answers in the input fields and / or tables and / or figures, which should be done neatly and clearly readable; other notes on the answer sheets will not be graded
- graphs and sketches drawing to scale in the pre-printed characters
- only a single set of answer sheets per student is handed out, so think carefully first before writing down the answers
- **formulas see page 11 and 12**
- return the handed out assignment sheets with the answer sheets and the AMMC sheet
- course book, notes, laptop, mobile phone, and similar are not permitted
- a non-graphical pocket calculator is permitted

- **For multiple-choice questions, use the additionally given Applied Mechanics Multiple Choice (AMMC) sheet, fill in your ID NUMBER on the sheet following the example there below, and fill the bubbles with the correct answers completely and black. Hint: use a pencil (Dutch: potlood), not a pen, so you can correct your answers if required.**
- **Multiple Choice (MC) questions require a single correct answer. A multiple Response (MR) question may require a single or multiple correct answers: Each correct answer yields *t/c* points, with *t* the total number of points for the question, and *c* the number of correct answers. Marking an incorrect answer as positive deduces your results with (1/2)*t/c, but a negative result for the question is not possible (minimum = 0 points).**
- **Note that the AMMC sheets will be processed automatically: A missing or incorrect ID.NR., corrections and notes, or creased or folded paper will all results in 0 points. Hint: work with pencil so you can firmly erase a possible incorrect answer.**

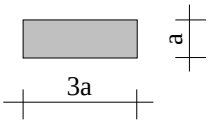
Do not remove the staples
It is permitted to separate the formulas (page 11 and 12)

Assessment of the assignments of this applied mechanics part *(50 points for mechanics in total):*
assignment 1: 5 points
assignment 2: 15 points
assignment 3: 15 points
assignment 4: 15 points

Assessment of the total final test: total number of points (applied mechanics part and material part together) divided by ten. The total final test contributes for 70% to the final mark.

Assignment 1

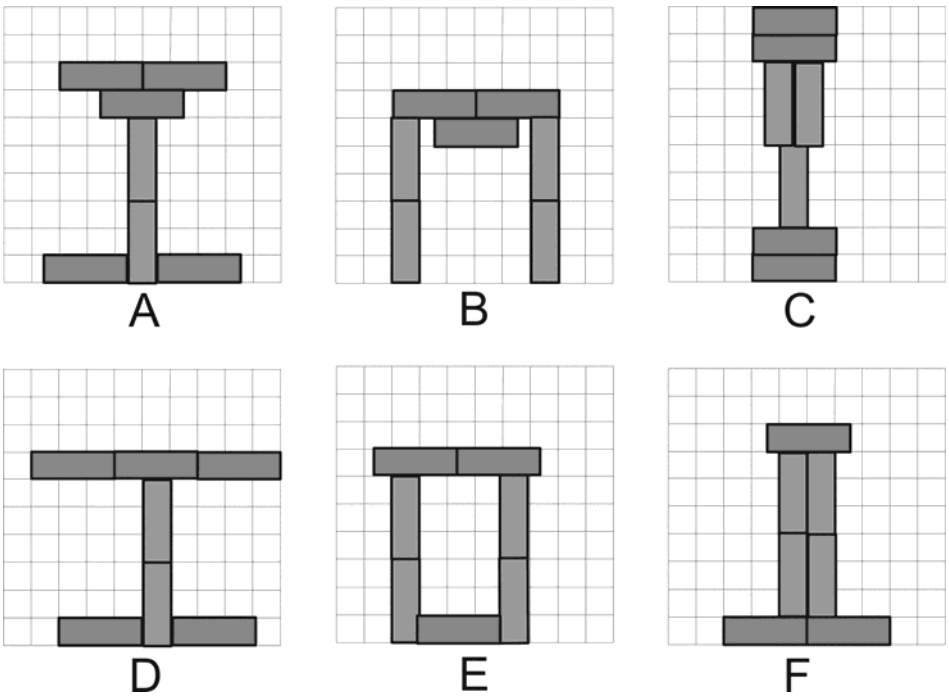
A beam cross-section has to be designed by gluing together 7 equal parts having each a cross-section equal to $a \times 3a$, see the small figure below.



The beam cross-section should fit a grid $10a \times 10a$ (each grid cell equals $a \times a$) and should follow the following four properties:

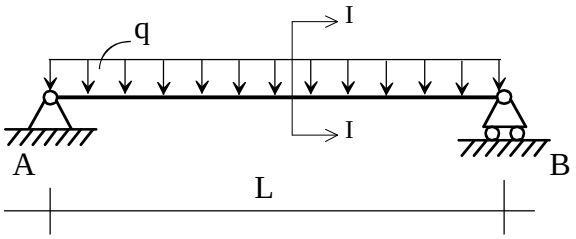
- it should have a vertical line of symmetry
- the maximum height equals $8a$
- the maximum width equals $7a$
- of the options below: it should have the highest or second highest possible second moment of area

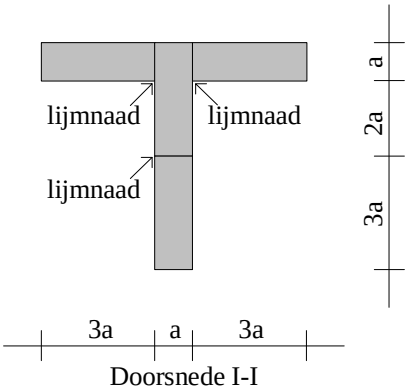
MR1. On the Applied Mechanics Multiple Choice (AMMC) answer sheet (provided separately), mark for MR1 the two correct solutions shown below (5p). Note: neglect small inaccuracies in the drawings.



Assignment 2

Beam AB below consists out of four equal timber parts, each having a cross-section $a \times 3a$ such that a T shaped cross-section results.





Derive in the box below that the line of gravity is positioned $\frac{7}{4}$a from the top of the cross-section (2p).

Derive in the box below that the second moment of area about the line of gravity equals $37\frac{1}{4}a^4$ (3p)

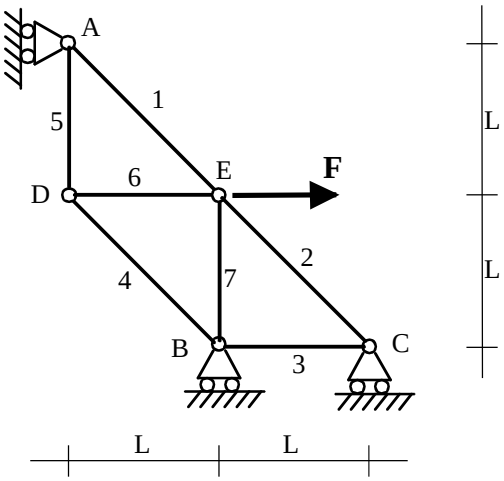
Calculate the extreme stresses due to bending, and indicate their type (compression or tension). In the box below please provide the value of each term in stress equation and the final answer itself (3p).

Calculate the maximum stress in the horizontal glued connection due to the shear force. In the box below please provide the value of each term in stress equation and the final answer itself (3p).

Calculate the maximum stress in the timber due to the shear force. In the box below please provide the value of each term in stress equation and the final answer itself (4p).

Exercise 3

In the structure below, all rods are hinge connected. The cross-sectional area of horizontal and vertical rods equals A and the cross-sectional area of the diagonal rods equals $A\sqrt{2}$. Young's modulus equals E for every bar.



MC2. Use equilibrium to calculate the horizontal reaction force at A. Mark the correct answer below on the Applied Mechanics Multiple Choice (AMMC) answer sheet (1p).

A) $R_{AH} = 2F$, working to the right
B) $R_{AH} = F$, working to the left
C) $R_{AH} = 1.5F$, working to the left
D) $R_{AH} = 2.5F$, working to the right
E) $R_{AH} = (3/2)F$, working to the right
F) $R_{AH} = (3/2)F$, working to the left

MC3. Use equilibrium to calculate the vertical reaction force at B. Mark the correct answer below on the Applied Mechanics Multiple Choice (AMMC) answer sheet (1p).

A) $R_{BV} = (1/2)F$, working upwards
B) $R_{BV} =(1/2)F$, working downwards
C) $R_{BV} = 2F$, working upwards
D) $R_{BV} = F$, working downwards
E) $R_{BV} = F$, working upwards
F) $R_{BV} = F/L$, working downwards

MC4. Use equilibrium to calculate the vertical reaction force at C. Mark the correct answer below on the Applied Mechanics Multiple Choice (AMMC) answer sheet (1p).

A) $R_{CV} = (1/2)F$, working upwards
B) $R_{CV} =(1/2)F$, working downwards
C) $R_{CV} = 2F$, working upwards
D) $R_{CV} = F$, working downwards
E) $R_{CV} = F$, working upwards
F) $R_{CV} = F/L$, working downwards

Use the table below to calculate the change of length for each bar. Then answer questions MC5 and MC6.

Rod	Tension (+) or Compression (-)	Internal force magnitude
1	+	F√2
2	+	F√2
3	-	F
4	-	F√2
5	-	F
6	+	F
7	0	0

MC5. The change of length for rod 1,2 and 4 equals respectively (1p):

A) $\frac{FL}{EA}\sqrt{2} \quad \frac{FL}{EA}\sqrt{2} \quad \frac{FL}{EA}\sqrt{2}$

B) $\frac{FL}{EA}2 \quad \frac{FL}{EA}2 \quad \frac{FL}{EA}2$

C) $\frac{FL}{EA}\sqrt{2} \quad \frac{FL}{EA}\sqrt{2} \quad \frac{FL}{EA}\frac{1}{2}\sqrt{2}$

D) $\frac{FL}{EA}2 \quad \frac{FL}{EA}2 \quad \frac{FL}{EA}$

E) $\frac{FL}{EA}\frac{1}{\sqrt{2}} \quad \frac{FL}{EA}\frac{1}{\sqrt{2}} \quad \frac{FL}{EA}\frac{1}{\sqrt{2}}$

F) $\frac{FL}{EA} \quad \frac{FL}{EA} \quad \frac{FL}{EA}$

MC6. The change of length for rod 3,5 and 6 equals respectively (1p):

A) $\frac{FL}{EA} \quad \frac{FL}{EA} \quad \frac{FL}{EA}$

B) $\frac{FL}{EA} \quad \frac{FL}{EA} \quad \frac{FL}{EA}2$

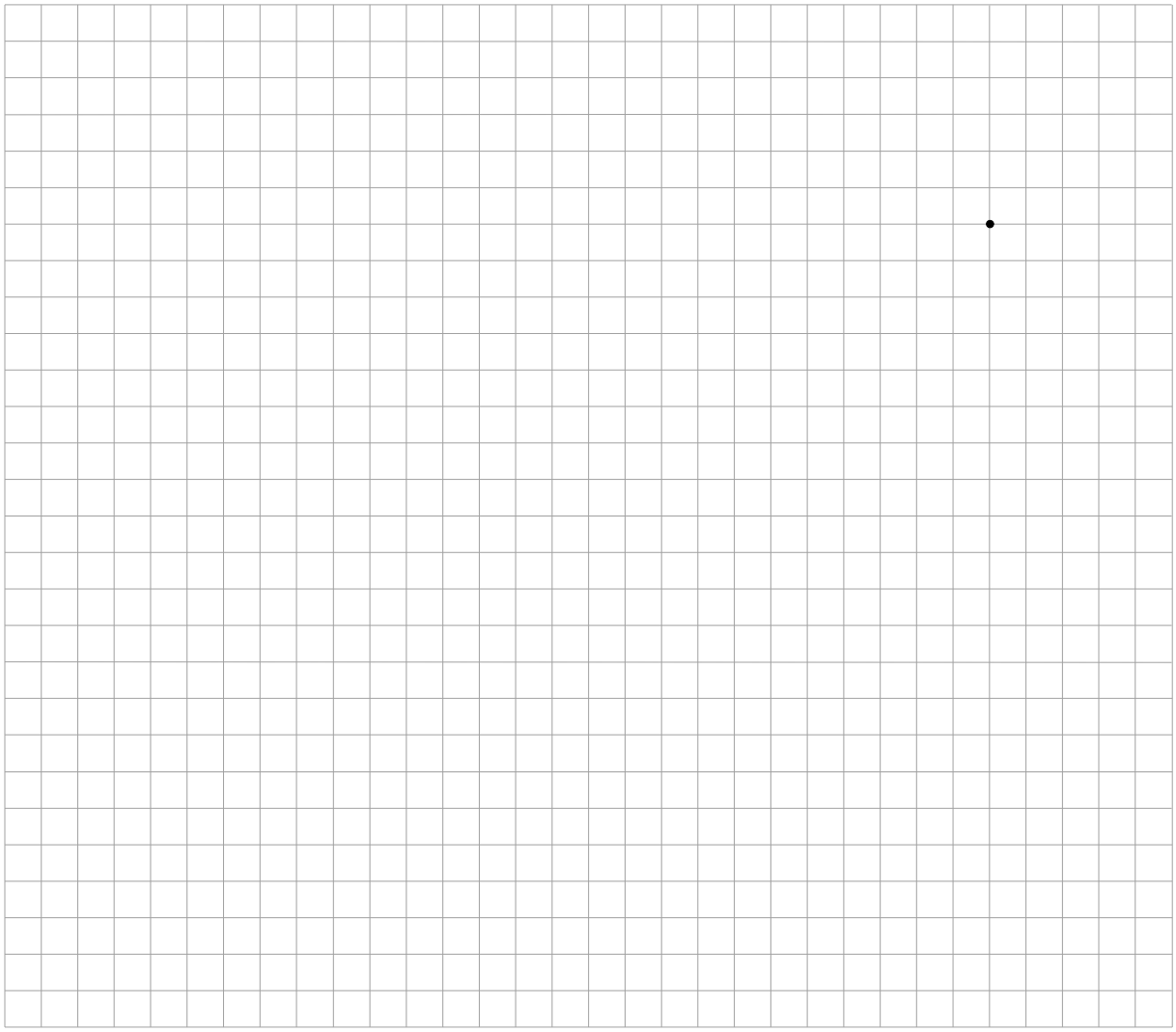
C) $\frac{FL}{EA}\sqrt{2} \quad \frac{FL}{EA}\sqrt{2} \quad \frac{FL}{EA}2\sqrt{2}$

D) $\frac{FL}{EA}2 \quad \frac{FL}{EA}2 \quad \frac{FL}{EA}$

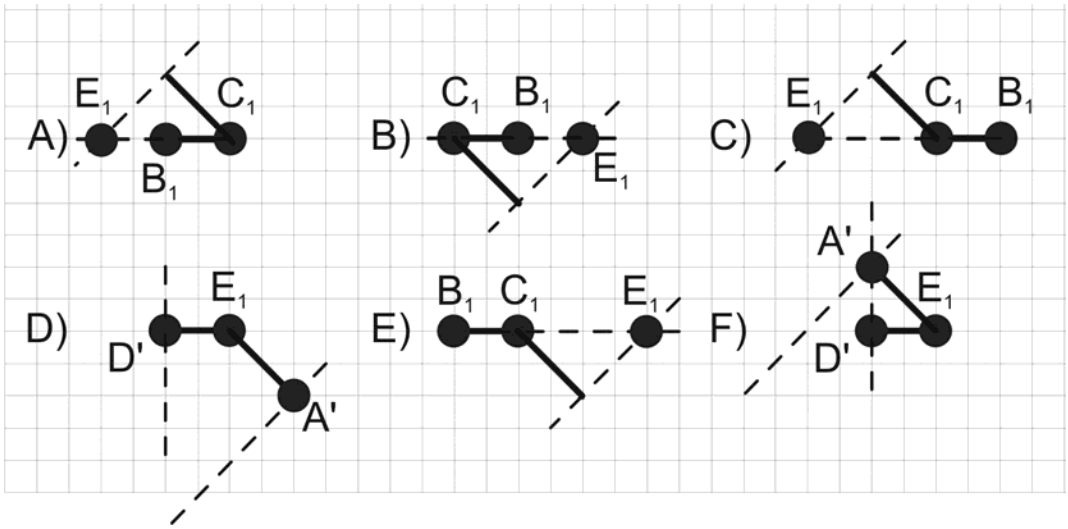
E) $\frac{FL}{EA}\frac{1}{\sqrt{2}} \quad \frac{FL}{EA}\frac{1}{\sqrt{2}} \quad \frac{FL}{EA}$

F) $\frac{FL}{EA} \quad \frac{FL}{EA} \quad \frac{FL}{EA}3$

Use the grid below to draw the displacement diagram (the Williot diagram) for all knots/hinges. Start with your drawing at the black dot. Use for the scale: *FL*/*EA* = 2 cells. Then answer MR7 and MC8. **Note that your drawing of the diagram is only to help you answering MR7 and MC8, it will not be graded separately.**



MR7. Which parts of the Williot diagram are correct, a single or multiple answers may be correct (4p):



MC8. The horizontal and vertical displacement of node D equal (2p):

A) $w_{DH} = \leftarrow 6\frac{FL}{EA}$ $w_{DV} = \downarrow 8\frac{FL}{EA}$

B) $w_{DH} = \rightarrow 9\frac{FL}{EA}$ $w_{DV} = \uparrow 7\frac{FL}{EA}$

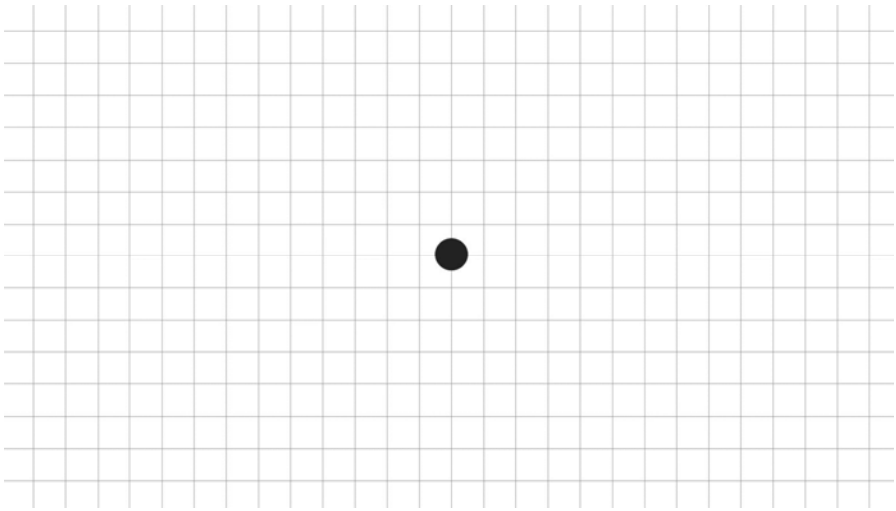
C) $w_{DH} = \rightarrow 16\frac{FL}{EA}$ $w_{DV} = \uparrow 12\frac{FL}{EA}$

D) $w_{DH} = \rightarrow 8\frac{FL}{EA}$ $w_{DV} = \downarrow 6\frac{FL}{EA}$

E) $w_{DH} = \rightarrow 8\frac{FL}{EA}$ $w_{DV} = \downarrow 2\frac{FL}{EA}$

F) $w_{DH} = \rightarrow 16\frac{FL}{EA}$ $w_{DV} = \downarrow 4\frac{FL}{EA}$

MC9. Now assume that node B and C are completely fixed in their position as shown in the drawing, i.e. both now have a hinge instead of a roller as boundary condition. Also assume that rod 7 elongates due to tension with FL/EA and rod 2 shortens due to compression with $2\sqrt{2}FL/EA$. (these need not to be the values you found correctly before). What are now the horizontal and vertical displacement of node E? You may want to use the grid below to draw a Williot diagram. Hint: use for the scale: *FL*/*EA* = 2 cells and start at the dot (4p)



A) $w_{EH} = \rightarrow \frac{FL}{EA}$ $w_{DV} = \uparrow 5\frac{FL}{EA}$

B) $w_{EH} = \leftarrow 3\frac{FL}{EA}$ $w_{DV} = \uparrow \frac{FL}{EA}$

C) $w_{EH} = \rightarrow 3\frac{FL}{EA}$ $w_{DV} = \downarrow \frac{FL}{EA}$

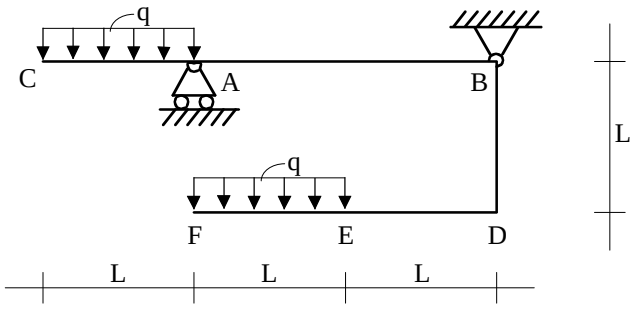
D) $w_{EH} = \leftarrow 5\frac{FL}{EA}$ $w_{DV} = \downarrow \frac{FL}{EA}$

E) $w_{EH} = \rightarrow 5\frac{FL}{EA}$ $w_{DV} = \uparrow \frac{FL}{EA}$

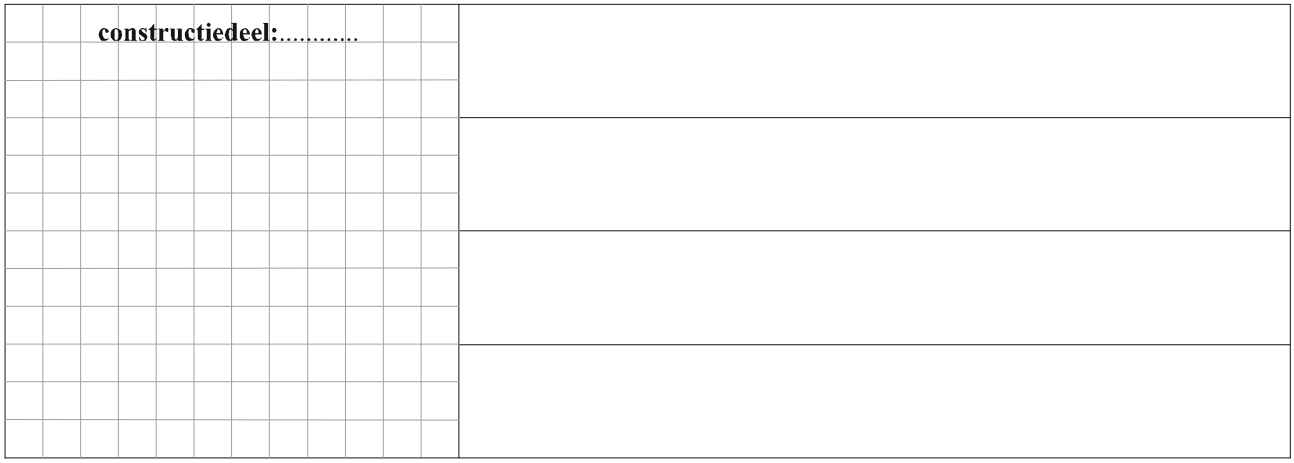
F) $w_{EH} = \rightarrow 5\frac{FL}{EA}$ $w_{DV} = \downarrow \frac{FL}{EA}$

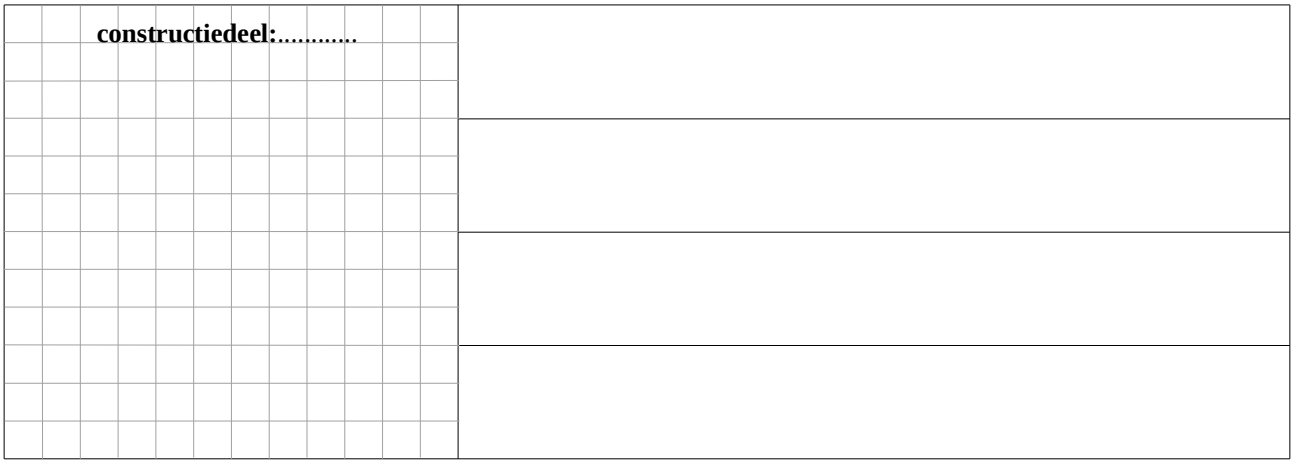
Assignment 4

For the structure below, each part has an equal bending stiffness *EI*. Deformations due to normal and shear force are to be neglected.



First determine the rotation of node B due to bending action (no normal and shear deformations can be neglected). Use for each part of the structure needed a separate box as shown below. Draw each part of the structure with its (fictitious) supports and use as scale L = 4 cells. The rows to the right of the drawing can be used for the expressions and the values of the displacements and rotations (5p).





See next page!

MR10. Secondly, assume that node B rotates counter clockwise with value φ_B. What are ALL the below correct statements about the rotation for node E? (a single or multiple answers may be possible, also including the correct value for φ_B derived above). Please answer on the AMMC-sheet (5p).

A) $\circlearrowright\varphi_E = \circlearrowright\varphi_B + \frac{qL\frac{3}{2}LL}{EI} + \frac{qL\frac{1}{2}LL}{EI} + \frac{qLL^2}{2EI}$

B) $\circlearrowright\varphi_E = \frac{10qL^3}{3EI}$

C) $\circlearrowright\varphi_E = \circlearrowright\varphi_B + \frac{qL\frac{3}{2}LL}{EI} + \frac{qLL^2}{2EI}$

D) $\circlearrowright\varphi_E = \circlearrowright\varphi_B + \frac{qL\frac{3}{2}LL}{EI} + \frac{qL\frac{1}{2}LL}{EI} + \frac{qLL^2}{2EI} + \frac{qL^3}{4EI}$

E) $\circlearrowright\varphi_E = \circlearrowright\varphi_B$

F) $\circlearrowright\varphi_E = \frac{8qL^3}{3EI}$

MR11. Finally, assume that node B rotates counter clockwise with value φ_B. What are ALL the below correct statements about the displacement for node E? (a single or multiple answers may be possible, also including the correct value for φ_B derived above). Please answer on the AMMC-sheet (5p).

A) $w_E \downarrow = \frac{6}{5}\frac{qL^3}{EI}L + \frac{qL\frac{3}{2}LL}{EI}L + \frac{qL\frac{1}{2}LL^2}{2EI} + \frac{qLL^3}{3EI}$

B) $w_E \downarrow = \frac{35qL^3}{24EI}$

C) $w_E \downarrow = \circlearrowright\varphi_B L + \frac{qL\frac{1}{2}LL^2}{2EI} + \frac{qLL^3}{3EI}$

D) $w_E \downarrow = \circlearrowright\varphi_B L + \frac{qL\frac{3}{2}LL}{EI}L + \frac{qL\frac{1}{2}LL^2}{2EI} + \frac{qLL^3}{3EI}$

E) $w_E \downarrow = \frac{35qL^4}{12EI}$

F) $w_E \downarrow = \circlearrowright\varphi_B L + \frac{35qL^3}{24EI}$

Formulas:

Stresses: $\sigma = \frac{N}{A}$ $\sigma = \frac{M z}{I}$ $\tau = \frac{V S}{b I}$ $\tau = \frac{M r}{I_p}$

I = second moment of area relative to the axis of gravity:

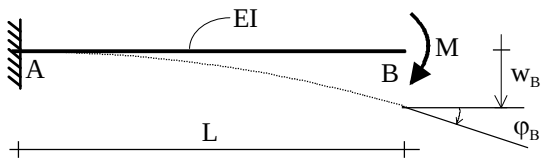
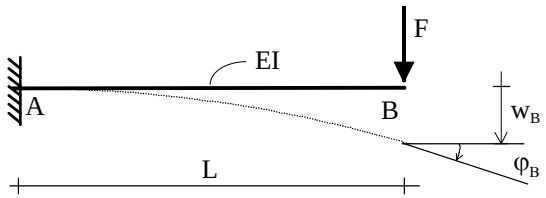
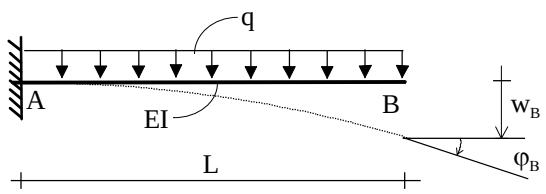
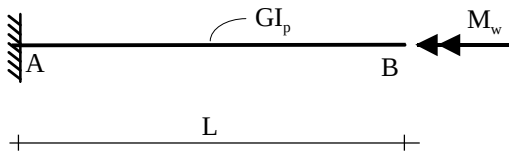
Rectangular cross-section: $I_y = \frac{1}{12} bh^3$ (only if the line about which I_y is defined is parallel to a side of the rectangle)

Triangular cross-section: $I_y = \frac{1}{36} bh^3$ (only if the line about which I_y is defined is parallel to a side of the triangle)

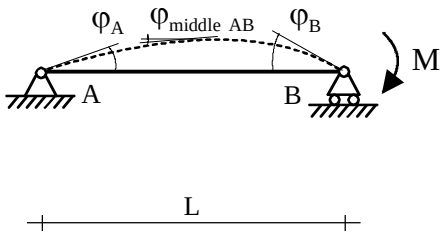
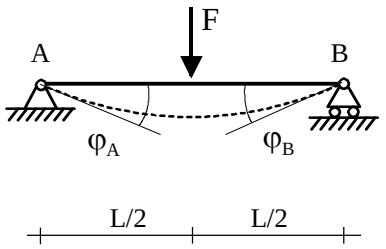
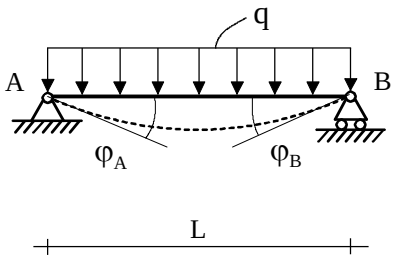
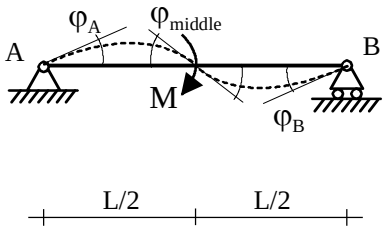
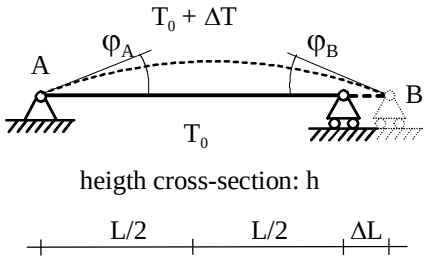
Circular cross-section: $I_y = I_z = \frac{I_p}{2} = \frac{1}{4} \pi \left(R_u^4 - R_i^4 \right)$

Length change as result of normal force: $\Delta L = \frac{N L}{E A}$

Standard beam equations:

	$\varphi_B \circlearrowleft = \frac{M L}{EI}$ $\downarrow w_B = \frac{M L^2}{2EI}$
	$\varphi_B \circlearrowleft = \frac{F L^2}{2EI}$ $\downarrow w_B = \frac{F L^3}{3EI}$
	$\varphi_B \circlearrowleft = \frac{q L^3}{6EI}$ $\downarrow w_B = \frac{q L^4}{8EI}$
	In point B only rotation about the axis of the beam $\varphi_B = \frac{M_w L}{GI_p}$ $w_B = 0$

Additional beam equations

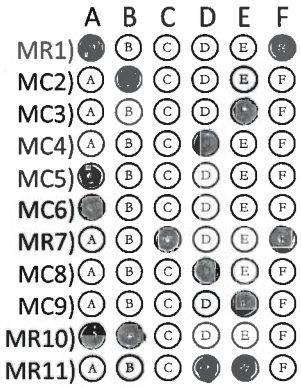
	$\varphi_A \circlearrowleft = \frac{ML}{6EI}$ $\varphi_B \circlearrowright = \frac{ML}{3EI}$ $\varphi_{middle\ AB} \circlearrowleft = \frac{ML}{24EI}$ $\uparrow w_{middle\ AB} = \frac{ML^2}{16EI}$
	$\varphi_A \circlearrowright = \frac{FL^2}{16EI}$ $\varphi_B \circlearrowleft = \frac{FL^2}{16EI}$ $\downarrow w_{middle\ AB} = \frac{FL^3}{48EI}$
	$\varphi_A \circlearrowright = \frac{qL^3}{24EI}$ $\varphi_B \circlearrowleft = \frac{qL^3}{24EI}$ $\downarrow w_{middle\ AB} = \frac{5}{384}\frac{qL^4}{EI}$
	$\varphi_A \circlearrowleft = \frac{ML}{24EI}$ $\varphi_B \circlearrowleft = \frac{ML}{24EI}$ $\varphi_{middle\ AB} \circlearrowright = \frac{ML}{12EI}$ $w_{middle\ AB} = 0$
	$\varphi_A \circlearrowleft = \frac{\alpha \Delta T L}{2h}$ $\varphi_B \circlearrowright = \frac{\alpha \Delta T L}{2h}$ $\uparrow w_{middle\ AB} = \frac{\alpha \Delta T L^2}{8h}$ $\Delta L = \alpha\ ½\Delta T\ L$

Applied Mechanics Multiple Choice (AMMC) sheet
Exam 7PPX1, April 18, 2017

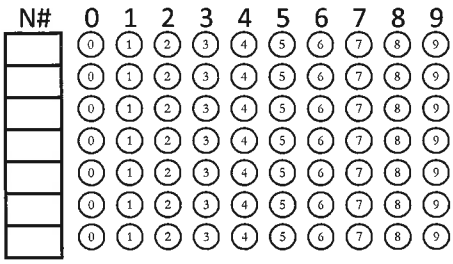
!! This sheet is processed automatically, a missing or incorrection ID.NR., or handwritten corrections or comments will all result in 0 points

!! Fill the correct answer bubbles <u>completely</u> and <u>black or dark blue</u>.
Hint: use a PENCIL (Dutch: potlood), so you can make corrections

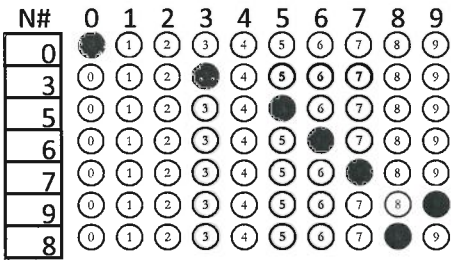
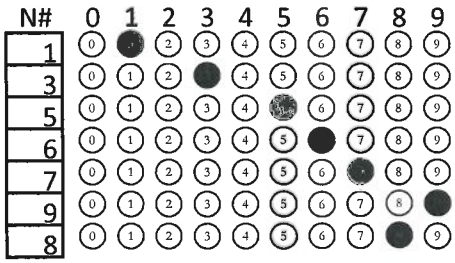
!! Corrections only possible by erasing your answer (be careful not to crease the paper), e.g. crossing incorrect answers won't help



ID. NR. via bubbles directly below, see example



EXAMPLE ID number 0356798
(use 7 digits, add zero in front of a 6 digit ID)



EXAMPLE ID number 1356798