Aerospace Structure Design
Aerospace and Geodesy
Technical University of Munich

Ecorrection
Place student sticker here

Note:

- During the attendance check a sticker containing a unique code will be put on this exam.
- This code contains a unique number that associates this exam with your registration number.
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Mock Exam for Engineering Mechanics 1 and 2

Exam: xxxxxxx / Mock Exam **Date:** xxxxxxxxxxxxxxx xxxxxxx0th , 0

Examiner: xxxx **Time:** xxxx00:00 – xxxx00:00

	P 1	P 2	P 3	P 4	P 5	P 6
I						

Working instructions

- This exam consists of **14 pages** with a total of **6 problems**.
  Please make sure now that you received a complete copy of the exam.
- The total amount of achievable credits in this exam is 60 credits.
- Detaching pages from the exam is prohibited.
- Allowed resources:
  - one **non-programmable pocket calculator**
  - one **analog dictionary** English ↔ native language
- Subproblems marked by * can be solved without results of previous subproblems.
- **Answers are only accepted if the solution approach is documented.** Give a reason for each answer unless explicitly stated otherwise in the respective subproblem.
- Do not write with red or green colors nor use pencils.
- Physically turn off all electronic devices, put them into your bag and close the bag.

Left room from ________ to ________ / Early submission at ________

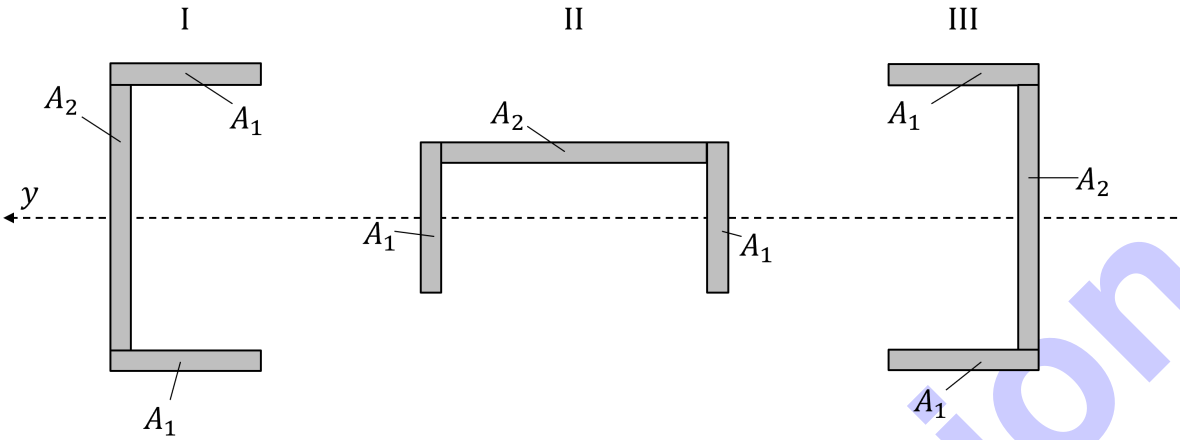
For multiple choice problems mark the correct answers as follows:

Mark correct answers with a cross	☒
To undo a cross, completely fill out the answer option	■
To re-mark an option, use a human-readable marking	×■

Correct answers result in positive credit, wrong answers will result in negative credit, empty boxes are not counted. It is not possible to get a total score that is negative.

Problem 1 **(6 credits)**

a)*



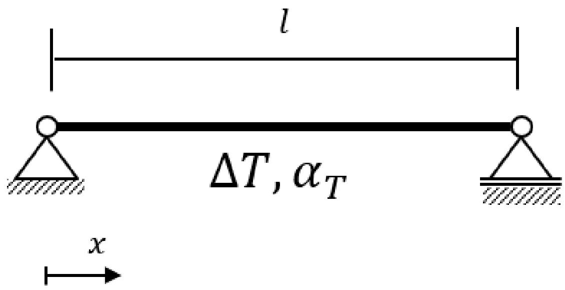
For the shown cross sections and the given coordinate, which statement is true for the second moment of area I_{yy}?

- [x] $I = III > II$
- [ ] $II > I > III$
- [ ] $I = III < II$
- [ ] $I > III > II$

b)*
Which statement regarding the second moments of area is true?

- [x] I_{yz} can be positive, negative or zero
- [ ] For every cross section of a beam: $I_{zz} > I_{yy}$
- [ ] I_{yz} can be positive and negative, but never zero
- [ ] For every cross section of a beam: $I_{yy} > I_{zz}$

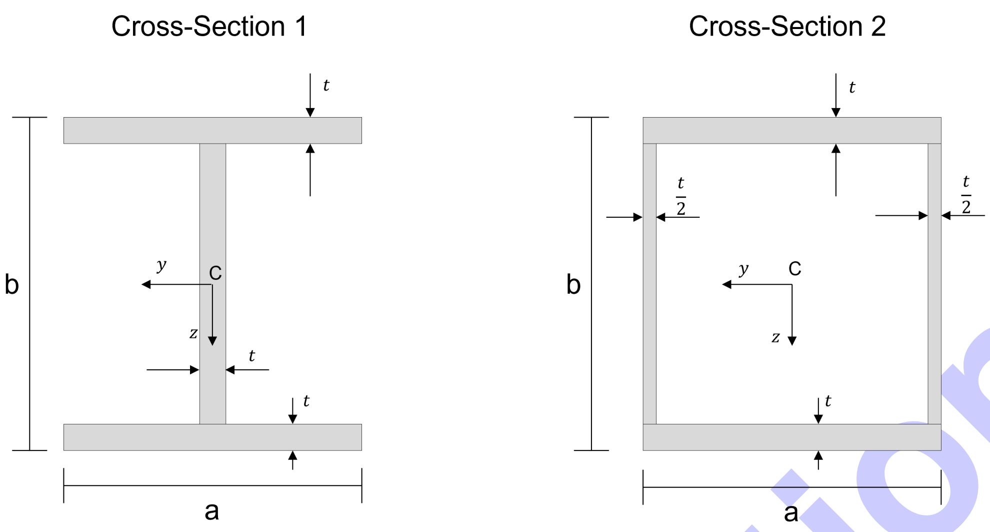
c)*



The shown bar is heated uniformly by ΔT. The thermal expansion coefficient is constant (α_T). No other loads are applied. The displacement function $u(x)$ will be:

- [ ] Constant
- [ ] Cubic
- [ ] Quadratic
- [x] Linear

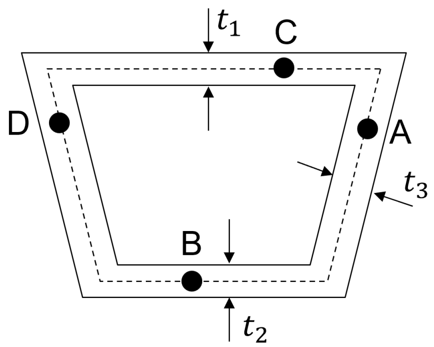
d)*



For the shown cross sections, which statement is true? (I_{yy} and I_{zz} are second moment of areas about the respective axis and I_T is the torsion constant of the cross-section)

- [ ] $I_{yy,1} > I_{yy,2}$; $I_{zz,1} < I_{zz,2}$; $I_{T,1} < I_{T,2}$
- [x] $I_{yy,1} = I_{yy,2}$; $I_{zz,1} < I_{zz,2}$; $I_{T,1} < I_{T,2}$
- [ ] $I_{yy,1} = I_{yy,2}$; $I_{zz,1} < I_{zz,2}$; $I_{T,1} > I_{T,2}$
- [ ] $I_{yy,1} < I_{yy,2}$; $I_{zz,1} > I_{zz,2}$; $I_{T,1} < I_{T,2}$
- [ ] $I_{yy,1} > I_{yy,2}$; $I_{zz,1} < I_{zz,2}$; $I_{T,1} = I_{T,2}$
- [ ] $I_{yy,1} > I_{yy,2}$; $I_{zz,1} = I_{zz,2}$; $I_{T,1} = I_{T,2}$

e)*



$t_3 > t_2 > t_1$

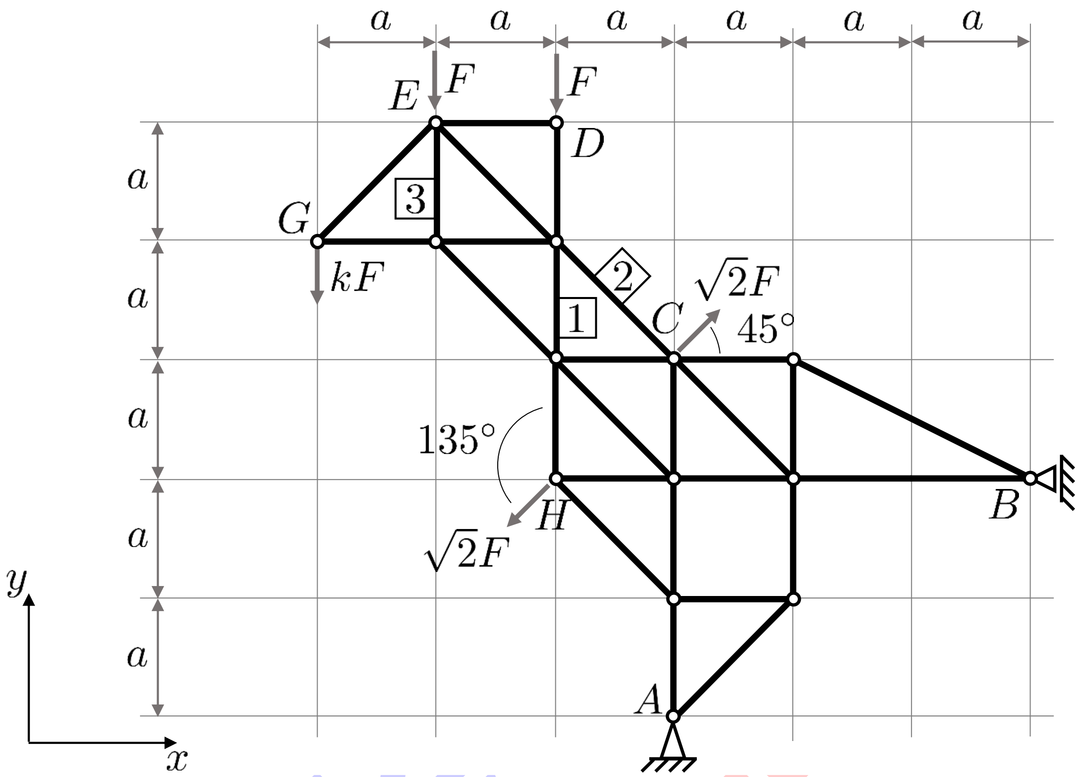
Shown is the thin-walled cross section of a bar. The bar is loaded by a torsional moment. At which point would one expect the greatest magnitude of the torsional shear stress $|\tau|$?

☐ D ☒ C ☐ B ☐ A

Problem 2 **Plane truss (19 credits)**

Given is the shown plane truss made of rigid bars. It is supported in the points A and B. The system is loaded by point loads at points C, D, E, G, and H. Bearing conditions, loads and dimensions are shown in the drawing.

Given quantities: a, F, coordinate system *xy* (right-hand system)



All subtasks can be solved independently of each other.

a)* Is the truss statically determined?

- ☐ No
- ☒ Yes

b)* How many degrees of freedom are constrained by the support in A?

- ☒ 2
- ☐ 0
- ☐ 1
- ☐ 3

c)* Calculate the support forces A_x. Consider the constant $k = 2$ in point G.

- ☒ $A_x = -4.5F$
- ☐ $A_x = 7.0F$
- ☐ $A_x = -9.0F$
- ☐ $A_x = 3.5F$

d)* Calculate the support forces A_y. Consider the constant $k = 2$ in point G.

- ☐ $A_y = -2.5F$
- ☐ $A_y = 8.0F$
- ☐ $A_y = -6.0F$
- ☒ $A_y = 4.0F$

e)* Calculate the support forces B_x. Consider the constant $k = 2$ in point G.

- [ ] $B_x = 0\text{F}$
- [x] $B_x = 4.5\text{F}$
- [ ] $B_x = 3.0\text{F}$
- [ ] $B_x = 6.5\text{F}$

f)* Calculate the bar force S_1 in bar $\boxed{1}$. Consider the constant $k = 4$ in point G.

Given: The support forces are given with the values being $A_x = -\frac{15}{2}F$, $A_y = 6F$ and $B_x = \frac{15}{2}F$.

Convention: The positive direction of the support forces is aligned with the positive direction of the coordinate system axes.

- [ ] $S_1 = -7.0\text{F}$
- [ ] $S_1 = -6.0\text{F}$
- [x] $S_1 = -5.0\text{F}$
- [ ] $S_1 = -4.0\text{F}$

g)* Calculate the bar force S_2 in bar $\boxed{2}$. Consider the constant $k = 4$ in point G.

Given: The support forces are given with the values being $A_x = -\frac{15}{2}F$, $A_y = 6F$ and $B_x = \frac{15}{2}F$.

Convention: The positive direction of the support forces is aligned with the positive direction of the coordinate system axes.

- [ ] $S_2 \approx 3.58\text{F}$
- [x] $S_2 \approx -12.73\text{F}$
- [ ] $S_2 \approx -9.41\text{F}$
- [ ] $S_2 \approx 7.21\text{F}$

h)* Calculate the bar force S_3 in bar $\boxed{3}$. Consider the constant $k = 4$ in point G.

Given: The support forces are given with the values being $A_x = -\frac{15}{2}F$, $A_y = 6F$ and $B_x = \frac{15}{2}F$.

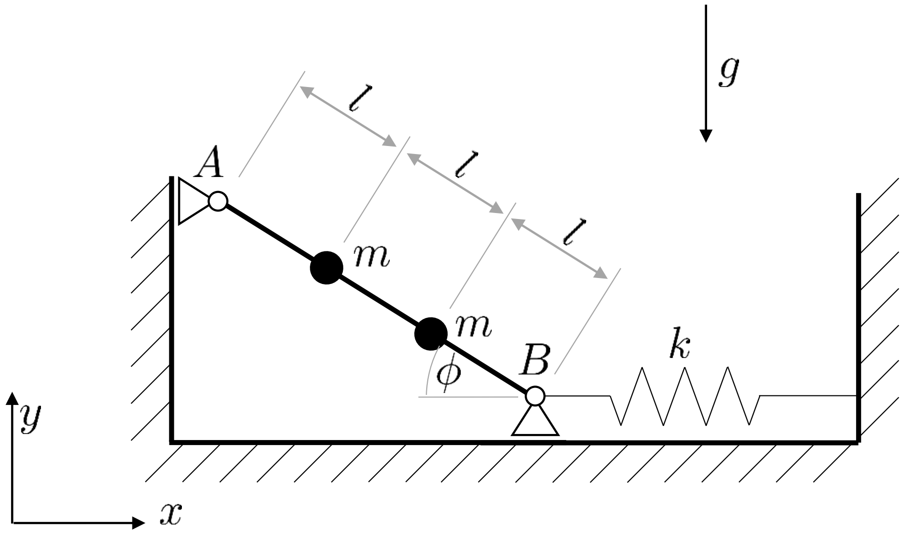
Convention: The positive direction of the support forces is aligned with the positive direction of the coordinate system axes.

- [ ] $S_3 = 3.0\text{F}$
- [ ] $S_3 = -5.0\text{F}$
- [x] $S_3 = -9.0\text{F}$
- [ ] $S_3 = 4.0\text{F}$

Problem 3 **(6 credits)**

Given is the shown planar system. The massless, rigid bar (length $3l$) is supported at points A and B and is support against the rigid environment at point B by a linear, mass-free spring (spring stiffness k). Two point masses m and m and are attached to the bar. The position of the bar is completely and unambiguously described by the angular coordinate ϕ. The linear spring is relaxed in the position $\phi = \frac{\pi}{2}$. The acceleration due to gravity g acts in the negative y-direction. Bearing conditions, loads as well as dimensions can be taken from the drawing.

Given quantities: l, k, m, g, coordinate systems xy (right-handed systems), Angular coordinate $\phi \in [0, \frac{pi}{2}]$

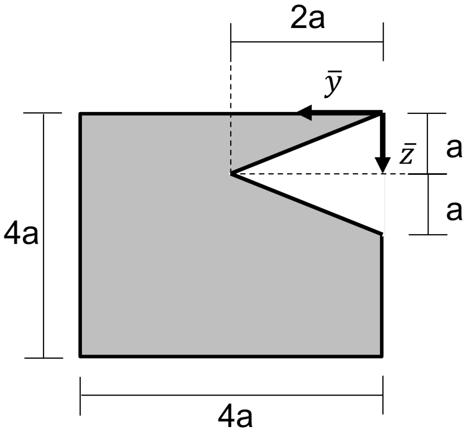


0
1
2
3
4
5
6

The system has two equilibrium positions. Cross the two correct equilibrium conditions.

- [ ] $\phi = \frac{2\pi}{3}$
- [x] $\phi = \frac{\pi}{2}$
- [ ] $\phi = \frac{\pi}{3}$
- [ ] $\phi = \arcsin\frac{3mg}{2kl}$
- [ ] $\phi = \frac{\pi}{4}$
- [ ] $\phi = \arcsin\frac{mg}{4kl}$
- [x] $\phi = \arcsin\frac{mg}{3kl}$
- [ ] $\phi = \arcsin\frac{2mg}{3kl}$

Problem 4 Cross-Section Properties (8 credits)



Shown is the cross section of a beam with measurement a.
Given: a, $(\bar{y},\bar{z})$-coordinate-system

a)* Determine the coordinate $\bar{y}_c$ of the cross-section's centroid with respect to the given $(\bar{y}_c,\bar{z}_c)$-coordinate-system.

- ☐ $\bar{y}_c = 2.41a$
- ☐ $\bar{y}_c = 2.52a$
- ☒ $\bar{y}_c = 2.19a$
- ☐ $\bar{y}_c = 2.14a$

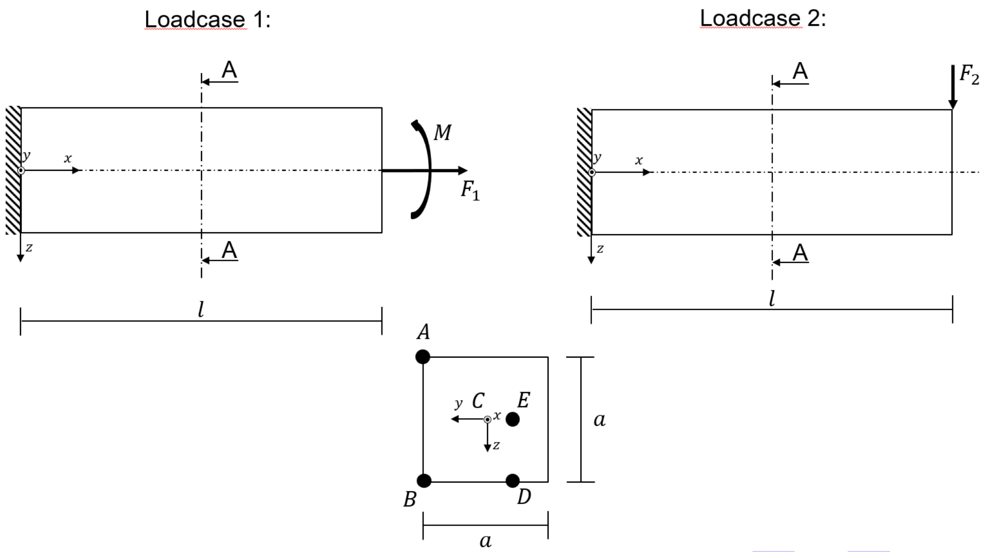
b)* Determine the coordinate $\bar{z}_c$ of the cross-section's centroid with respect to the given $(\bar{y}_c,\bar{z}_c)$-coordinate-system.

- ☐ $\bar{z}_c = 2.52a$
- ☒ $\bar{z}_c = 2.14a$
- ☐ $\bar{z}_c = 2.19a$
- ☐ $\bar{z}_c = 2.41a$

c)* For this subtask, use the rounded centroid coordinates $\bar{y}_c = 2.2a$ and $\bar{z}_c = 2.15a$. Compute the second moment of area I_{yy} with respect to the centroidal (y,z)-coordinate-system.

- ☐ $I_{yy} = 19.32a^4$
- ☐ $I_{yy} = 17.71a^4$
- ☒ $I_{yy} = 18.71a^4$
- ☐ $I_{yy} = 20.43a^4$

Problem 5 Beam Stresses (15 credits)



The shown clamped beam of length l is subjected to the moment M about the y-axis and the normal force F_1 at it's free end in loadcase 1 and to the force F_2 in loadcase 2. The cross-section and the modulus of elasticity are constant along the beam's x-axis. Each subtask is referring to only one of both loadcases. Use the given coordinate system with its origin in the cross sections centroid C.

Given: $I_{zz} = 8748\ mm^4$, (x, y, z)-coordinate-system, $a = 18\ mm$, $l = 1\ m$, $M = 40\ kNmm$, $F_1 = 10\ kN$, $F_2 = 20\ kN$

(y, z)-coordinates of points A, B, D and E: A: $(\frac{a}{2}, \frac{-a}{2})$; B: $(\frac{a}{2}, \frac{a}{2})$; D: $(\frac{-a}{4}, \frac{a}{2})$; E: $(\frac{-a}{4}, 0)$

a)* **Loadcase 1:** Calculate the normal stress σ_{xx} at point A at $x = \frac{1}{2}l$

- [ ] $\sigma_{xx,A} = 72.03 MPa$
- [ ] $\sigma_{xx,A} = -72.03 MPa$
- [ ] $\sigma_{xx,A} = 10.29 MPa$
- [x] $\sigma_{xx,A} = -10.29 MPa$

b)* **Loadcase 1:** Calculate the normal stress σ_{xx} at point B at $x = \frac{1}{2}l$

- [ ] $\sigma_{xx,B} = -10.29 MPa$
- [ ] $\sigma_{xx,B} = -72.03 MPa$
- [ ] $\sigma_{xx,B} = 10.29 MPa$
- [x] $\sigma_{xx,B} = 72.03 MPa$

c) **Loadcase 1:** Which statement is correct?

- [ ] Point A is stress free
- [x] Point A is in compression
- [ ] Point A is in tension

d) **Loadcase 1:** Which statement is correct?

- [x] Point B is in tension
- [ ] Point B is stress free
- [ ] Point B is in compression

e) **Loadcase 1:** Calculate F_1, such that the whole beam is in tension at $x = \frac{1}{2}l$.

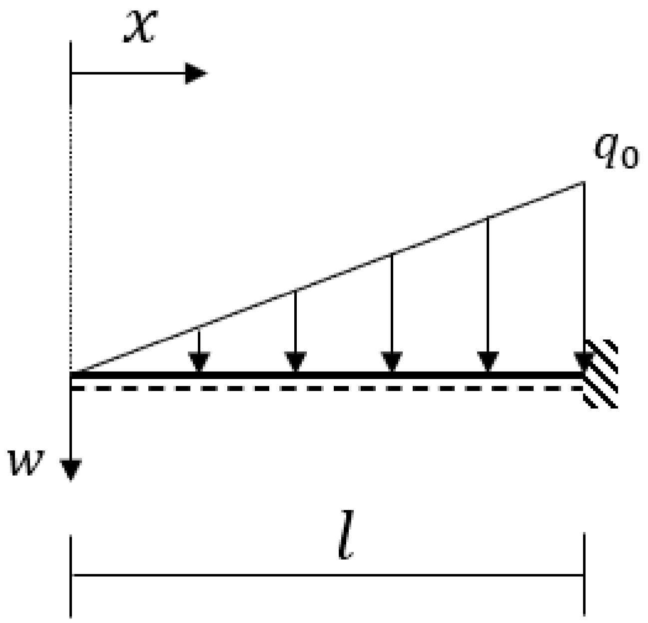
- [ ] $F_1 > 13.33 N$
- [ ] $F_1 < 13.33 N$
- [x] $F_1 > 13.33 kN$
- [ ] $F_1 < 13.33 kN$

f)*

g)* **Loadcase 2:** Calculate the shear stress τ_{xz} at point E at $x = \frac{1}{2}l$

- [ ] $\tau_{xz,E} = 0$
- [x] $\tau_{xz,E} = 92.59 MPa$
- [ ] $\tau_{xz,E} = 185.18 MPa$
- [ ] $\tau_{xz,E} = 30.86 MPa$

Problem 6 Energy Methods (6 credits)



Given: $l = 3m$; $q_0 = 150\frac{N}{m}$; $E = 210GPa = 210 * 10^9 \frac{N}{m^2}$; $I_{yy} = 6 * 10^{-8} m^4$; $GA_s = \infty$

a)* For the depicted system, the polynomial order of the bending moment $M(x)$ will be:

- [ ] Constant
- [x] Cubic
- [ ] Quadratic
- [ ] Linear

b)* Compute $M(x = l)$.

- [ ] $-112.5Nm$
- [ ] $112.5Nm$
- [x] $-225Nm$
- [ ] $225Nm$

c)* To calculate the deflection w of the beam at $x = 0$, one could use energy methods and apply a virtual force in the direction of the sought deflection. For the virtual "1"-System with the applied virtual force, the polynomial order of the bending moment $\bar{M}(x)$ would be:

- [ ] Quadratic
- [x] Linear
- [ ] Cubic
- [ ] Constant

d)* Compute $\bar{M}(x = l)$.

- [x] $-3Nm$
- [ ] $1.5Nm$
- [ ] $3Nm$
- [ ] $-1.5Nm$

e)* Compute the deflection w at $x = 0$.

- [ ] $w = 0.0214m$
- [ ] $w = 0.0401m$
- [ ] $w = 0.0442m$
- [x] $w = 0.0321m$