BK80A4020 Engineering Mechanics III

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Exam 7.5.2026

Allowed: Calculator (no model restrictions), writing tools, formulae sheet of the course. No other written material besides the formulae sheet. No own markings or modifications are allowed in the formulae sheet.

Exam has two sections:

- **Section A, which contains 10 short & easy questions each worth 1p**
- **Section B, which contains broader questions worth 40p in total (point values for each question in parentheses)**

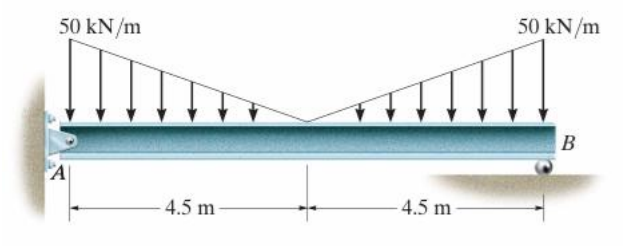
Student must get at least 6 points from section A, or section B won't be graded.

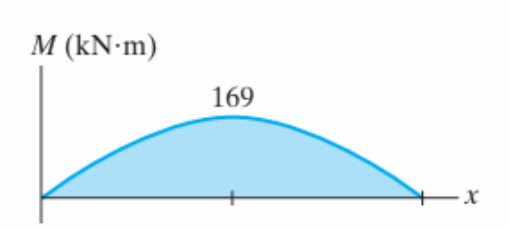
General advice:

- **Write your answers to all questions in the answer paper – not question paper!**
- **Answer section A on the front page of your answer paper**
    - **There is no NEED to provide explanations in section A - plain answers are sufficient (unless you think the question is a bit controversial; in this case please elaborate)**
    - **That said, calculations are naturally welcome**
    - **Please use CAPITAL LETTERS for the sake of clarity**
- **Tasks don't need to be solved in order, but please mark clearly the task numbers**

SECTION A

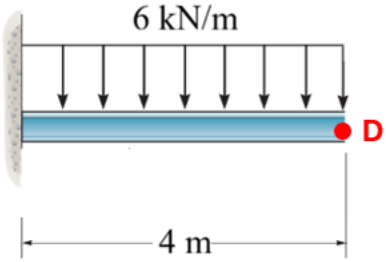
1. Beam AB is loaded as shown below on the left. The resulting moment diagram of the beam is shown on the right. If the beam is made of S420 steel and we want to use a safety factor of 1.5, what is the smallest IPE profile that can withstand the loading? (In terms of bending stress; shear capacity not taken into account here.)





A) IPE 240 B) IPE 270 C) IPE 330 D) IPE 400

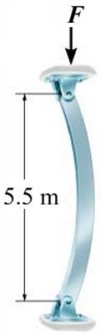
2. A cantilever steel beam (HEA 220, E = 210 GPa) is loaded as shown on the right. What is the deflection of the free end D? (One-decimal accuracy; positive direction downwards, neglect own weight of the beam.)



A) 1.7 mm B) 14.1 mm

C) 16.9 mm D) 46.9 mm

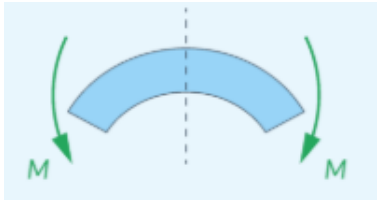
3. A S355 (E = 210 GPa) HEA 180 column has a height of 5.5 m and it is pinned on both ends. It has been calculated that the safety factor of it is 1.40 (which is a bit on the low side). Therefore, the material of the column is changed to S420. What is the safety factor now?

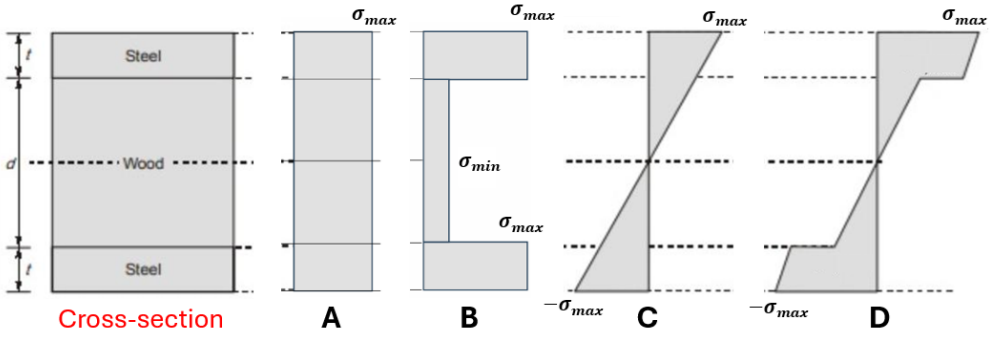


A) 1.40 B) 1.66 C) 1.96 D) 2.32

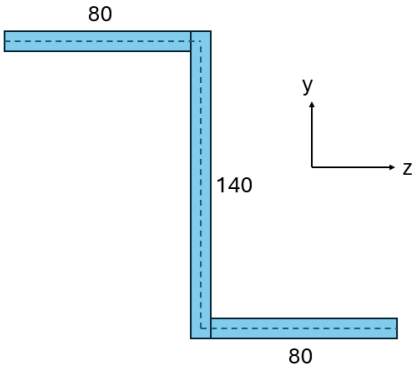
4. A composite beam that consists of a wooden section placed between two steel sheets is subjected to **bending moment M**. $E_{steel} = 210\ GPa, E_{wood} = 15\ GPa$. Which of the options below depicts the **stress distribution** in the beam cross-section?

A) Option A B) Option B C) Option C D) Option D





5. The Z-profile shown on the right has a constant thickness of t = 4 mm. Dimensions are given as midplane dimensions (=lengths of dashed lines) in millimeters. Using the given coordinate system, what is the product of inertia for this profile? (Two significant digits.)



A) $I_{yz} \approx -1.8 \cdot 10^6\ mm^4$

B) $I_{yz} \approx 0.90 \cdot 10^6\ mm^4$

C) $I_{yz} \approx 4.1 \cdot 10^6\ mm^4$

D) $I_{yz} \approx 5.8 \cdot 10^6\ mm^4$

6. A round bar (diameter 60 mm) is subjected to a bending load.
Material of the bar is steel with a yield strength of 450 MPa and an ultimate strength of 620 MPa. Surface roughness of the bar is $R_a = 1.6$. What is the reduced endurance limit? (Two significant digits.)

A) 150 MPa B) 210 MPa C) 260 MPa D) 310 MPa

7. We have solved the eigenvalues of our stress component matrix (units MPa) to be -130, 85 and 240. What is the corresponding Von Mises stress? (Rounded to nearest integer.)

A) 245 MPa B) 322 MPa C) 370 MPa D) 455 MPa

8. Materials that have different elastic modulus in loading directions perpendicular to each other are called

A) Isotropic B) Orthotropic C) Polytropic D) Anthropic

9. These two formulas on the right are very commonly used in torsion calculations of thin-walled hollow sections. What are these formulas called?

$$\tau = \frac{T}{2tA_m}$$

$$\theta = \frac{T}{4GA_m^2}\oint \frac{ds}{t}$$

A) Bredt's formulas B) Euler formulas

C) Lamé formulas D) Saint-Venant formulas

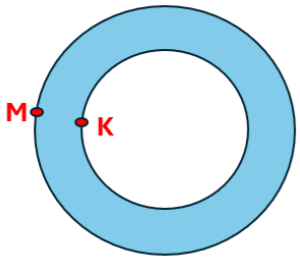
10. A process pipeline has an external diameter of 80 mm and wall thickness of 15 mm. The hydraulic liquid inside the pipeline is pressurized to 350 bar. What stress is the greatest and where?

A) Radial stress on the inside surface (K)

B) Radial stress on the outside surface (M)

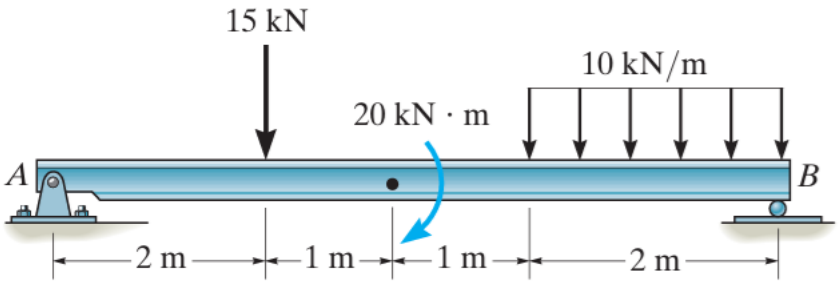
C) Tangential stress on the inside surface (K)

D) Tangential stress on the outside surface (M)

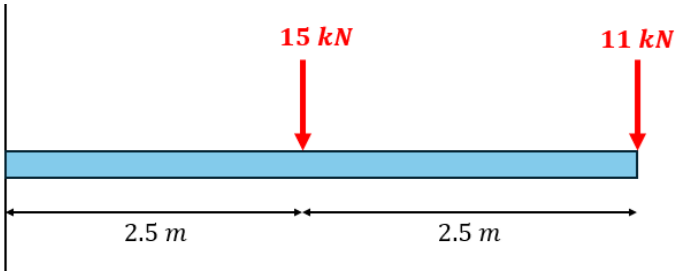


SECTION B

1. The beam AB shown on the right is loaded according to the picture. Choose the lightest possible IPE so that the beam will be able to endure the loading with a safety factor of 1.25. Material is S355, own weight of the beam can be neglected. (7p)



2. The cantilever beam shown on the right is a HEA 220 made of S275 steel (E = 210 GPa). It is loaded according to the picture.

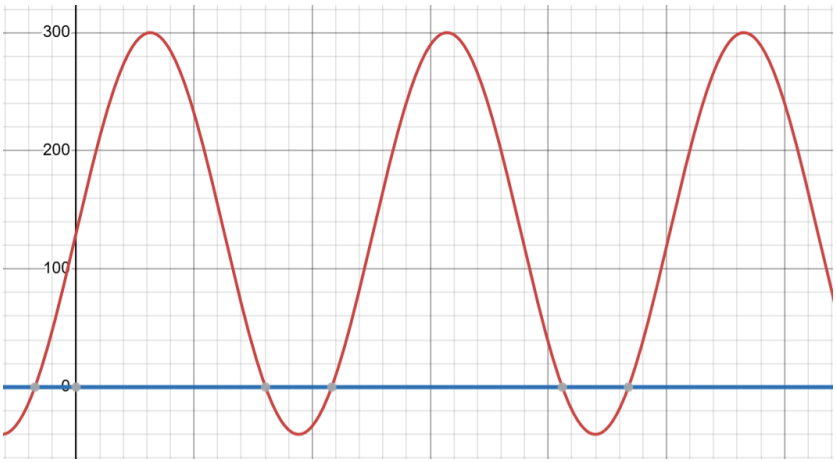


a) Calculate the maximum deflection of the beam. Neglect its own weight and the effect of shear force. (4p)

b) Are all assumptions of the beam deflection calculation theory valid in this case – can the result be trusted? (2p)

3. A HEA 260 column of length 7 m (S420, E = 210 GPa) experiences a compressive force of 1800 kN. The supports of the column can be considered pinned in x-x-direction and fixed-pinned in y-y-direction. Calculate the safety factor for the column. (6p)

4. The stress variation in our structure follows the graph on the right (units MPa). Material is S355, ultimate strength 500 MPa. Reduced endurance limit of our structure is 195 MPa.

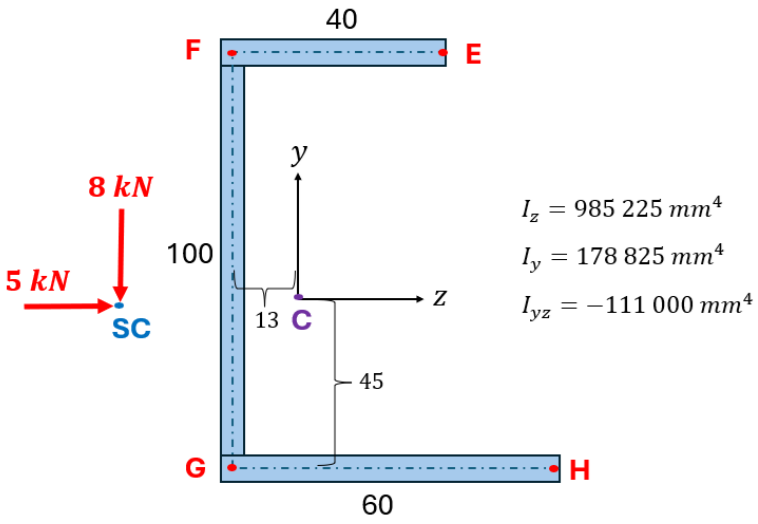


a) Define the mean stress and stress amplitude in our structure. Will the structure last indefinitely or will it fatigue at some point? (3p)

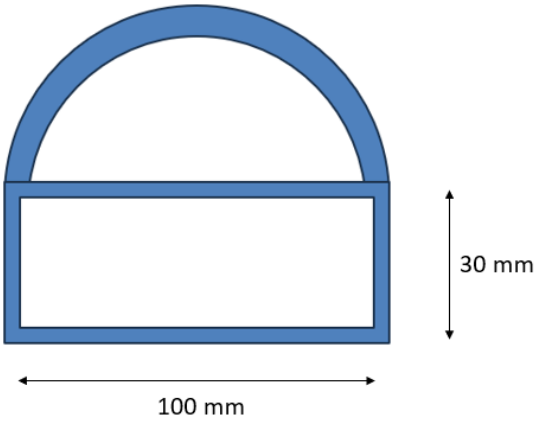
b) If the answer is indefinitely, calculate the safety factor using Haigh-Goodman diagram. Otherwise, fit the appropriate S-N-curve and calculate the resulting fatigue life in cycles. (4p)

5. Our C-profile (picture on the right; dimensions are midplane dimensions in millimeters) has a uniform thickness of 3 mm and it is loaded by two forces that act at the shear center (SC). Calculate the absolute magnitude of shear flow and shear stress at point G. The location of the centroid C and all inertias are given in the picture. (7p)

Note: Exact location of SC not given because it is irrelevant.



6. Cross-section of our shaft consists of a rectangular hollow section with wall thickness of 3 mm and a half of a circular hollow section with a wall thickness of 5 mm. Dimensions given in the picture on the right are midplane dimensions. Material is steel ($E = 210\ GPa$ & $G = 80\ GPa$).



The shaft is loaded by a torsional moment of 450 Nm.

a) Formulate the shear flow equations for both cells, solve them and calculate the torsion constant I_t for the profile. (5p)

b) Calculate the greatest shear stress in the cross-section. Stress concentrations can be ignored. (2p)