

Exam Structure Mechanics2

Bachelor Civil Engineering 1st year

Module code/name: 202000060-2B M4 B-CE Designing Construction
Course code/name: 202400790 Structure Mechanics 2
Date: 22 May 2026
Time: 8.45-10.45 (+25% for students who may use extra time)
Instructors: Vanessa Magnanimo

Type of test: Exercises

INSTRUCTIONS & PRACTICALITIES

- All Rules of Order for Testing as established by the examination board apply to this test. In case of inconsistencies with other rules set by the examiner, the Rules of Order for Testing prevail.
- Please read each question carefully before answering the question.
- All paperwork must be handed in at the end of the test, including scrap paper.
- For answering questions, use the working sheets handed to you. If one sheet is not enough, use the sheet with the text "Continuation of ..." in the top right corner.
- The elaboration of the question must be clear. Show what you do, so use a lot of drawings, sketches, or schemas. Make sure to write/draw your answers in a readable form.

ALLOWED RESOURCES

Allowed material to be used during the exam:

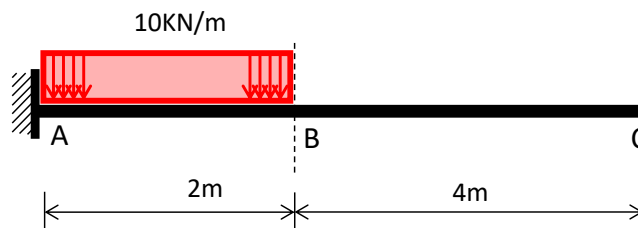
- Scientific calculator (not a communication device)
- Formula sheet
- English-Dutch dictionary
- Pen or/and pencil, coloured pens
- Ruler

Attachments: Formula sheet, Forget-me-Not

Exercise 1 (30 pt)

The cantilever beam in the figure is supported by a fixed support in A. A distributed load is applied from A to B. Dimensions are reported in the figure. EI is constant.

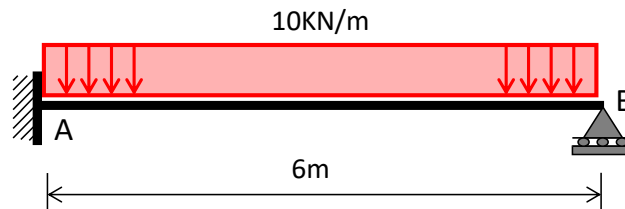
- Derive the equation of shear force, bending moment, curvature, vertical displacement. In your calculation state explicitly the boundary conditions to apply.
- Sketch the diagrams of shear force, bending moment and displacement.
- Calculate the values of curvature and vertical displacement in B and C, in terms of EI .



Exercise 2 (30 pt)

The statically indeterminate beam in the figure is supported by a fixed support in A and a roller in B. Support B settles 5mm vertically downward. Take $E=200\text{GPa}$ and $I=300\times 10^6\text{ mm}^4$.

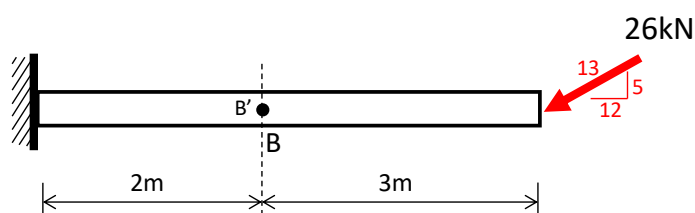
- Determine the reactions of A and B using the method of forces.
- Sketch the diagrams of shear force and bending moment.



Exercise 3 (40 pt)

The wooden beam is subjected to the 26kN force that is applied at the centre of its width. The cross section of the beam is solid square of side 150mm.

- Sketch the distribution of normal and tangential stress in the cross-section B.
- Determine the principal stresses and principal stress directions in the middle of the cross-section (point B').
- Check your results using Mohr's circle graphical procedure.



Formula Sheet Mechanics

Axial load

$$\sigma = \frac{P}{A} \quad \varepsilon = \frac{\Delta l}{l} \quad \sigma = E\varepsilon \Rightarrow \Delta l = \frac{Pl}{EA}$$

Area moment of Inertia

$$I_x = \int_A y^2 dA \quad I_y = \int_A x^2 dA$$

$$I_x = I_{x_{zw.p.}} + Ad_y^2 \quad I_y = I_{y_{zw.p.}} + Ad_x^2$$

Rectangular sections:

$$I_{x_{zw.p.}} = \frac{1}{12}bh^3 \quad I_{x_{basis}} = \frac{1}{3}bh^3$$

Bending

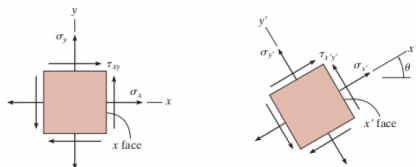
$$\sigma = -\frac{My}{I} \quad \sigma_{max} = \pm \frac{Mh/2}{I}$$

Shear

$$\tau_{avg} = \frac{V}{A} \quad \tau = \frac{VQ}{It} \quad , Q = \int_A ydA$$

$$\text{Rectangular sections} \quad \tau_{max} = 1.5 \frac{V}{A}$$

Stress transformations



$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2(\theta + 90) + \tau_{xy} \sin 2(\theta + 90)$$

$$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2} \sin 2\theta + \tau_{xy} \cos 2\theta$$

$$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2} \quad R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_{1,2} = \sigma_{avg} \pm R \quad \tan 2\theta_p = \frac{\tau_{xy}}{(\sigma_x - \sigma_y)/2}$$

$$\tau_{max} = \pm R \quad \tan 2\theta_s = -\frac{(\sigma_x - \sigma_y)/2}{\tau_{xy}}$$

Relations between q, V, M

$$V(x) = \int q(x) dx, \quad M(x) = \int V(x) dx$$

Elastic curve

$$\theta(x) = \frac{1}{EI} \int M(x) dx$$

$$v(x) = \int \theta(x) dx = \frac{1}{EI} \iint M(x) dx$$

Cross method

Stiffness factors:

$$\text{Pin-end } K = 3EI/l$$

$$\text{Fixed-end } K = 4EI/l$$

$$\text{Free-end } K = 0$$

$$\mu_i = \frac{K_i}{\sum K}, M_i = \frac{K_i}{\sum K} M$$

Carry-over factors:

$$\text{Pin-end } M_{end} = 0$$

$$\text{Fixed-end } M_{end} = 1/2 M_i$$

$$\text{Free-end } M_{end} = 0$$

Concrete Design

$$\text{Variable: } \gamma_Q = 1,5$$

Safety factor loads (CC2):

$$\text{Permanent: } \gamma_G = 1,35$$

$$\text{Serviceability: } \gamma_G = \gamma_Q = 1$$

Safety factor strength:

$$\text{Concrete: } \gamma_c = 1,5$$

$$\text{Steel: } \gamma_s = 1,15$$

Bending:

$$\text{Moment of resistance: } M_{Rd} = 0.167 f_{ck} b d^2$$

single reinforcement (or tables):

$$\text{Steel: } A_{s1} = \frac{M_{Ed}}{0.87 f_{yk} z}$$

$$\text{with } z = d \left[0.5 + \sqrt{0.25 - 3K_0/3.4} \right] \text{ and } K_0 = M_{Ed}/f_{ck} b d^2$$

double reinforcement [condition $d_2/x \leq 0.38$]

$$\text{Steel: } A_{s2} = \frac{M_{Ed} - M_{Rd}}{0.87 f_{yk} (d - d_2)}, \quad A_{s1} = \frac{M_{Rd}}{0.87 f_{yk} z} + A_{s2}$$

$$\text{with } z = d \left[0.5 + \sqrt{0.25 - 3K'_0/3.4} \right], \quad K'_0 = 0.167, \quad x = (d - z)/0.4$$

Spacing > max(ϕ , dgrain+5, 20)

Shear:

Shear resistance:

$$v_{Rd,c} = 0.035 k^{3/2} \sqrt{f_{ck}}, \text{ with } k = 1 + \sqrt{200/d}$$

$$v_{Rd,max} = \frac{z}{d} v_1 f_{cd} / (\cot \theta + \tan \theta), \text{ with } v_1 = 0.6 \left[1 - \frac{f_{ck}}{250} \right]$$

$$\text{Steel: } v_{Rd,s} = 0.9 A_{sw} f_{yd} / b s \tan \theta \text{ (or tables)}$$

Anchoring:

$$l_{bd} = \alpha_1 l_{b,rqd} > l_{b,min}, \quad l_{b,rqd} = \frac{\phi \sigma_{sd}}{4 f_{bd}}$$

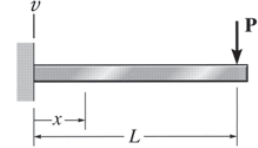
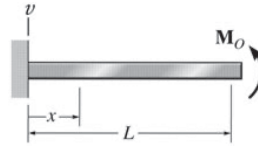
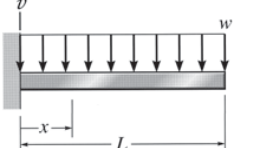
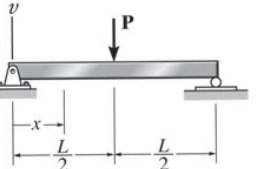
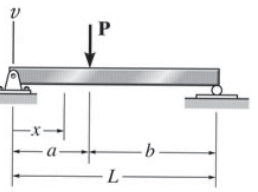
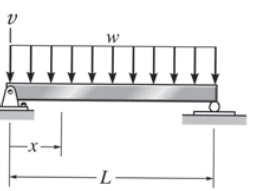
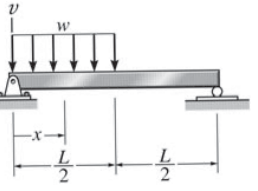
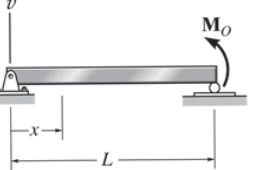
$$\text{(or tables)} \quad l_{b,min} = \max(0.3 l_{b,rqd}; 10\phi; 100)$$

$$\text{Cover: } c = c_{min} + \Delta c_{dev}$$

Bending:

$$\text{Ultimate: } v_{max} < l/250 \quad \text{Serviceability: } v_{max} < l/500$$

Beam Deflections and Slopes

Loading	$v + \uparrow$	$\theta + \curvearrowright$	Equation $+ \uparrow + \curvearrowright$
	$v_{\max} = -\frac{PL^3}{3EI}$ at $x = L$	$\theta_{\max} = -\frac{PL^2}{2EI}$ at $x = L$	$v = -\frac{P}{6EI}(x^3 - 3Lx^2)$
	$v_{\max} = \frac{M_O L^2}{2EI}$ at $x = L$	$\theta_{\max} = \frac{M_O L}{EI}$ at $x = L$	$v = \frac{M_O}{2EI}x^2$
	$v_{\max} = -\frac{wL^4}{8EI}$ at $x = L$	$\theta_{\max} = -\frac{wL^3}{6EI}$ at $x = L$	$v = -\frac{w}{24EI}(x^4 - 4Lx^3 + 6L^2x^2)$
	$v_{\max} = -\frac{PL^3}{48EI}$ at $x = L/2$	$\theta_{\max} = \pm \frac{PL^2}{16EI}$ at $x = 0$ or $x = L$	$v = \frac{P}{48EI}(4x^3 - 3L^2x),$ $0 \leq x \leq L/2$
		$\theta_L = -\frac{Pab(L+b)}{6LEI}$ $\theta = \frac{Pab(L+a)}{6LEI}$	$v = -\frac{Pbx}{6LEI}(L^2 - b^2 - x^2)$ $0 \leq x \leq a$
	$v_{\max} = -\frac{5wL^4}{384EI}$ at $x = \frac{L}{2}$	$\theta_{\max} = \pm \frac{wL^3}{24EI}$	$v = -\frac{wx}{24EI}(x^3 - 2Lx^2 + L^3)$
		$\theta_L = -\frac{3wL^3}{128EI}$ $\theta_R = \frac{7wL^3}{384EI}$	$v = -\frac{wx}{384EI}(16x^3 - 24Lx^2 + 9L^3)$ $0 \leq x \leq L/2$ $v = -\frac{wL}{384EI}(8x^3 - 24Lx^2 + 17L^2x - L^3)$ $L/2 \leq x \leq L$
	$v_{\max} = -\frac{M_O L^2}{9\sqrt{3}EI}$	$\theta_L = -\frac{M_O L}{6EI}$ $\theta_R = \frac{M_O L}{3EI}$	$v = -\frac{M_O x}{6EIL}(L^2 - x^2)$

Fixed End Moments

$(FEM)_{AB} = \frac{PL}{8}$ $(FEM)_{BA} = \frac{PL}{8}$	$(FEM)'_{AB} = \frac{3PL}{16}$
$(FEM)_{AB} = \frac{Pb^2a}{L^2}$ $(FEM)_{BA} = \frac{Pa^2b}{L^2}$	$(FEM)'_{AB} = \left(\frac{P}{L^2}\right)(b^2a + \frac{a^2b}{2})$
$(FEM)_{AB} = \frac{2PL}{9}$ $(FEM)_{BA} = \frac{2PL}{9}$	$(FEM)'_{AB} = \frac{PL}{3}$
$(FEM)_{AB} = \frac{5PL}{16}$ $(FEM)_{BA} = \frac{5PL}{16}$	$(FEM)'_{AB} = \frac{45PL}{96}$
$(FEM)_{AB} = \frac{wL^2}{12}$ $(FEM)_{BA} = \frac{wL^2}{12}$	$(FEM)'_{AB} = \frac{wL^2}{8}$
$(FEM)_{AB} = \frac{11wL^2}{192}$ $(FEM)_{BA} = \frac{5wL^2}{192}$	$(FEM)'_{AB} = \frac{9wL^2}{128}$
$(FEM)_{AB} = \frac{wL^2}{20}$ $(FEM)_{BA} = \frac{wL^2}{30}$	$(FEM)'_{AB} = \frac{wL^2}{15}$
$(FEM)_{AB} = \frac{5wL^2}{96}$ $(FEM)_{BA} = \frac{5wL^2}{96}$	$(FEM)'_{AB} = \frac{5wL^2}{64}$
$(FEM)_{AB} = \frac{6EI\Delta}{L^2}$ $(FEM)_{BA} = \frac{6EI\Delta}{L^2}$	$(FEM)'_{AB} = \frac{3EI\Delta}{L^2}$