Exercise walk-through

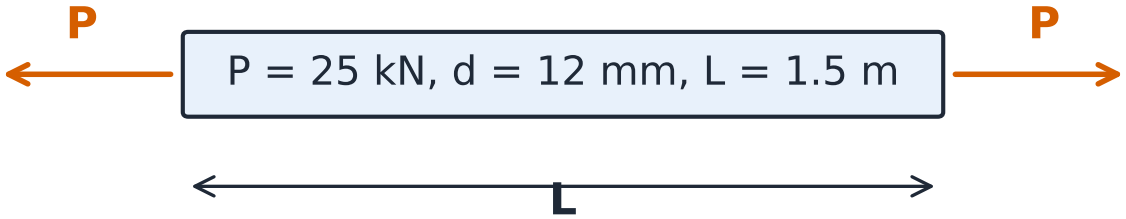
6.1 Axial loading

University Mechanical Engineering

Axial loading: stress, strain, held cold

the tie rod: one dimension, four traps

held cold by 40 K: σ_T = EαΔT = 96.0 MPa — no force needed

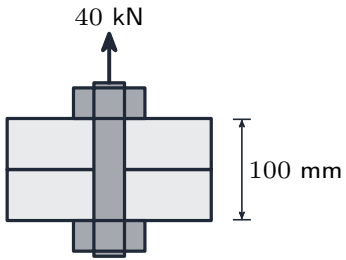


σ = P/A = 221.0 MPa · δ = PL/AE = 1.658 mm · ε = 0.001105

Tie rod $d = 12$ mm, $P = 25$ kN: $\sigma = P/A = \mathbf{221.0}$ MPa, $\delta = PL/AE = \mathbf{1.658}$ mm. Held cold by 40 K: $\sigma_T = E\alpha\Delta T = \mathbf{96.0}$ MPa with no force.

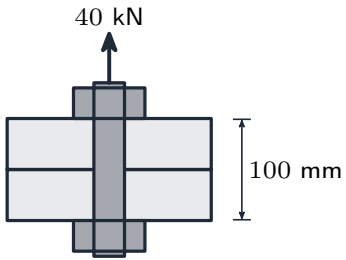
Exercise 2.1

2.1 A 20 mm bolt carries 40 kN of tension. Find the stress and the extension of its 100 mm grip length ($E = 200$ GPa). [2]



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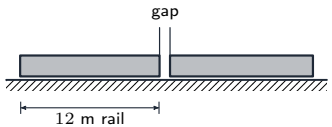


2.1

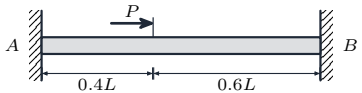
$$\sigma = \frac{40\,000}{314} = \mathbf{127\ MPa};\ \delta = \frac{127 \times 100}{200\,000} = \mathbf{0.064\ mm}$$

Exercises 2.2·2.3

2.2 12 m steel rails are laid at 10°C and reach 50°C in summer. Find the gap needed for free expansion. If the gap is only 3.0 mm, find the stress in the rail. [3]

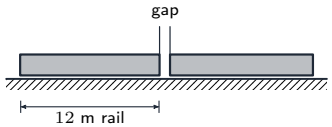


2.3 A bar is fixed to walls at both ends. An axial load $P = 30$ kN acts at $0.4L$ from the left wall. Find the two wall reactions. [3]



Exercises 2.2·2.3

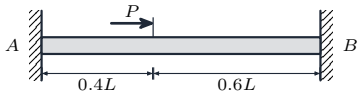
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2.2

free expansion $= 12 \times 10^{-6} \times 40 \times 12\,000 =$ **5.8 mm**; 2.76 mm is blocked; $\sigma = \dfrac{2.76}{12\,000} \times 200\,000 =$ **46 MPa** compression

2.3 A bar is fixed to walls at both ends. An axial load $P = 30$ kN acts at $0.4L$ from the left wall. Find the two wall reactions. [3]



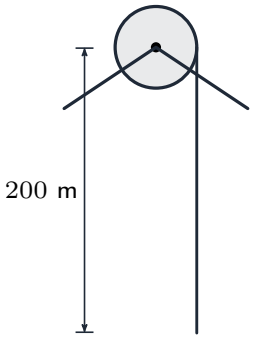
2.3

equilibrium: $R_A + R_B = 30$ kN; compatibility: the left part stretches as much as the right part shortens, $R_A(0.4L) = R_B(0.6L)$; $R_A =$ **18 kN**, $R_B =$ **12 kN**

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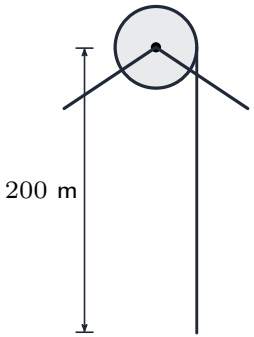
Exercise 2.4

2.4 A 200 m steel cable hangs down a mine shaft ($\rho = 7850$ kg/m^3). Find its extension under its own weight. [3]



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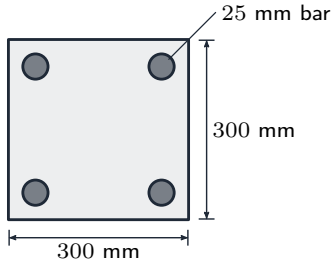
2.4

the force grows from 0 at the bottom to $\rho g A L$ at the top; $\delta = \dfrac{\rho g L^2}{2E} = \dfrac{7850 \times 9.81 \times 200^2}{2 \times 200 \times 10^9}$ $= \mathbf{7.7\ mm}$

Exercise 3.1

3.1 A 300×300 mm concrete column has four 25 mm steel bars. It carries 1200 kN. $E_s = 200$ GPa, $E_c = 25$ GPa.

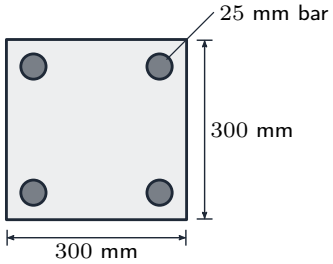
Find the stress in the concrete and in the steel. [5]



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3.1 A 300×300 mm concrete column has four 25 mm steel bars. It carries 1200 kN. $E_s = 200$ GPa, $E_c = 25$ GPa.

Find the stress in the concrete and in the steel. [5]



3.1

$A_s = 4 \times 491 = 1963$ mm^2, $A_c = 90\,000 - 1963 = 88\,037$ mm^2

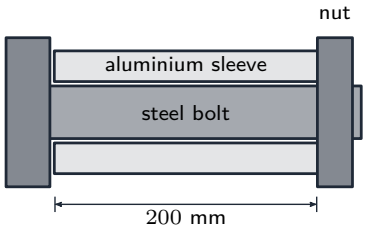
compatibility: same strain, so $\sigma_s = \dfrac{E_s}{E_c}\sigma_c = 8\sigma_c$

$\sigma_c(88\,037 + 8 \times 1963) = 1.2 \times 10^6$; $\sigma_c = \mathbf{11.6\ MPa}$, $\sigma_s = \mathbf{92.5\ MPa}$

Exercise 3.2

3.2 A steel bolt ($A = 150$ mm^2) passes through an aluminium sleeve ($A = 300$ mm^2). Both are 200 mm long. The nut (pitch 2.0 mm) is turned a quarter turn after it touches the sleeve.

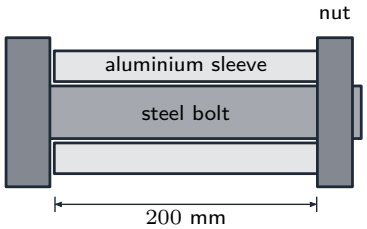
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3.2

the nut moves 0.50 mm; equilibrium: bolt tension = sleeve compression = F

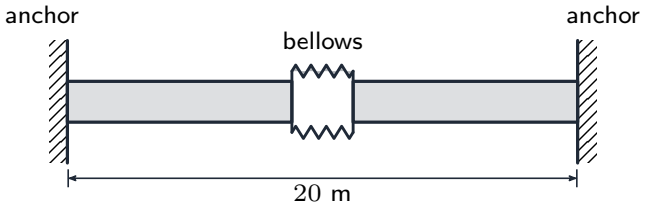
compatibility: $\delta_b + \delta_s = 0.50$ mm, $F \times 200 \left(\dfrac{1}{150 \times 200\,000} + \dfrac{1}{300 \times 70\,000} \right) = 0.50$

$F = \mathbf{30.9\ kN}$; $\sigma_b = \mathbf{206\ MPa}$ T, $\sigma_s = \mathbf{103\ MPa}$ C

Exercise 3.3 (a)

3.3 A 20 m steel steam pipe ($A = 3000$ mm^2, $\sigma_y = 250$ MPa) is fixed between two anchors. It is installed at 20°C and runs at 180°C.

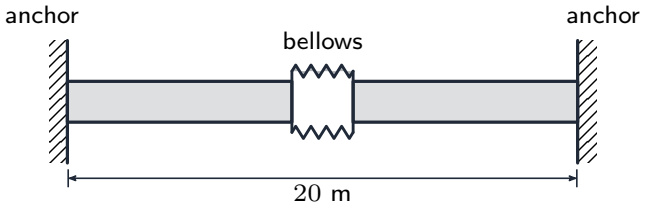
(a) Find the stress if the pipe is fully restrained, and the force on each anchor. Decide whether the pipe is safe. [3]



Exercise 3.3 (a)

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(a) Find the stress if the pipe is fully restrained, and the force on each anchor. Decide whether the pipe is safe. [3]



(a) $\sigma = 200\,000 \times 12 \times 10^{-6} \times 160 =$ **384 MPa** C; $F = 384 \times 3000 =$ **1150 kN**; $384 > 250$: the pipe **yields** or buckles

Exercise 3.3 (b)

3.3 A 20 m steel steam pipe ($A = 3000$ mm^2, $\sigma_y = 250$ MPa) is fixed between two anchors. It is installed at 20°C and runs at 180°C.

(b) Find the free thermal expansion. [2]

Exercise 3.3 (b)

3.3 A 20 m steel steam pipe ($A = 3000$ mm^2, $\sigma_y = 250$ MPa) is fixed between two anchors. It is installed at 20°C and runs at 180°C.

(b) Find the free thermal expansion. [2]

(b) $\delta = 12 \times 10^{-6} \times 160 \times 20\,000 = \mathbf{38.4\ mm}$

Exercise 3.3 (c)

3.3 A 20 m steel steam pipe ($A = 3000$ mm^2, $\sigma_y = 250$ MPa) is fixed between two anchors. It is installed at 20°C and runs at 180°C.

(c) A bellows joint that absorbs 30 mm is fitted. Find the new stress and the factor of safety on yield. [3]

Exercise 3.3 (c)

3.3 A 20 m steel steam pipe ($A = 3000$ mm^2, $\sigma_y = 250$ MPa) is fixed between two anchors. It is installed at 20°C and runs at 180°C.

(c) A bellows joint that absorbs 30 mm is fitted. Find the new stress and the factor of safety on yield. [3]

(c) 8.4 mm is still blocked; $\sigma = \dfrac{8.4}{20\,000} \times 200\,000 = \mathbf{84\ MPa}$; factor of safety $\dfrac{250}{84} = \mathbf{3.0}$: safe