

Test: Structural Mechanics in Module 1
Unit of Study code: 2020-000-43

Date: 6-10-2023

Start of the exam: 08:45

End of the exam: 10:30

End of the exam for students with additional time: 10:55

Examiner: ing. G.H.Snellink

GRADING

- ✓ Weight of this test is 50% of the grade for Structural Mechanics.
- ✓ Within this test:
 - Assignment 1: 30%
 - Assignment 2: 40%
 - Assignment 3: 30%

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 and must contain name and student number.
- ✓ For answering questions, use the attached working sheets. If one sheet is not enough, use the sheet with the text "Continuation of ..." in the top right corner. Enter the number of the question where this sheet is the follow-up. Do not make different tasks on the same working sheet.
- ✓ The elaboration of the question must be clear to all (i.e. the teacher). Show what you do, so use a lot of drawings, sketches, or schemas.

RESOURCES ALLOWED TO BE USED DURING THE EXAM:

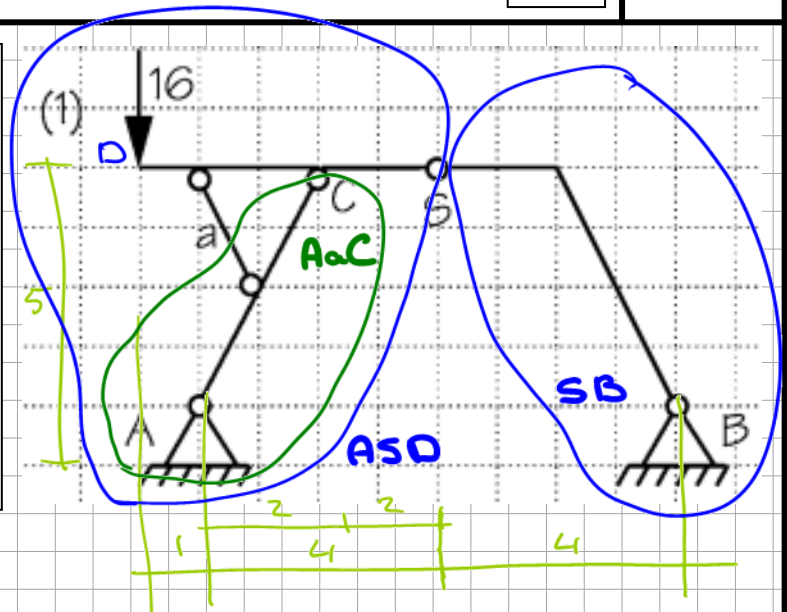
You are allowed to use the following resources during the exam (i.e. any other resource not list here is not allowed to be used during the exam):

- ✓ (graphical) calculator (not a communication device),
- ✓ pen or/and pencil,
- ✓ eraser,
- ✓ ruler.

Scratch paper:

Assignment 1. (30 %) Shored structures**Given:**The forces in kN; length scale: 1 square $\equiv$ 1m.All members have a cross section of 1000mm² (see Figure 1). The used material is steel $E=200\,000\text{N/mm}^2$ **Question:**

Determine the force in shoring bar a, with the correct sign.

**Key activities**

- undetermined structure
: divide structure to find support reactions (cloud ASD/SB)
using $\sum M=0$, $\sum V=0$, $\sum H=0$
- bar a: pendulumbar $\Rightarrow$ use cloud AaC using Eq. rules to find N_a .

Solution:**models**

$$\sum V=0 \quad -A_V + S_V + F = 0$$

$$\sum V=0 \quad -S_V + B_V = 0$$

$$\sum H=0 \quad -A_H + S_H = 0$$

$$\sum H=0 \quad -S_H + B_H = 0$$

$$\sum M_A=0 \quad +F \cdot 1 - S_V \cdot 4 - S_H \cdot 4 = 0$$

$$\sum M_B=0 \quad -S_V \cdot 4 + S_H \cdot 4 = 0 \Rightarrow S_H = S_V$$

$$+16 \cdot 1 - S_V \cdot 4 - S_V \cdot 4 = 0$$

$$16 - 8 S_V = 0$$

$$S_V = \frac{16}{8} = 2 \text{ kN} \Rightarrow S_H = 2 \text{ kN}$$

$$-A_H + 2 = 0 \Rightarrow A_H = 2 \text{ kN}$$

$$-A_V + 2 + 16 = 0 \Rightarrow A_V = 18 \text{ kN}$$

nice to know

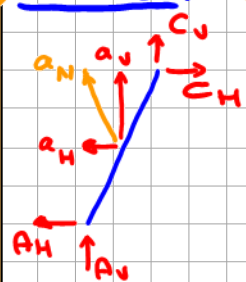
$$-2 + B_H = 0 \Rightarrow B_H = 2 \text{ kN}$$

$$-2 + B_V = 0 \Rightarrow B_V = 2 \text{ kN}$$

Overall equilibrium.

$$\sum V=0 \quad F - A_V + B_V = 0 \quad 16 - 18 + 2 = 0 \quad \checkmark$$

$$\sum H=0 \quad -A_H + B_H = 0 \quad -2 + 2 = 0 \quad \checkmark$$

model:

$$a_v : a_H : a_N = 2 : 1 : \sqrt{1^2 + 2^2} \Rightarrow a_v = 2 a_H \quad a_N = \sqrt{5} \cdot a_H$$

$$\begin{aligned} \sum M_C = 0 \Rightarrow & -A_V \cdot 2 - A_H \cdot 4 - a_H \cdot 2 - a_v \cdot 1 = 0 \\ & -18 \cdot 2 - 2 \cdot 4 - 2a_H - (2a_H) = 0 \\ & -36 - 8 - 4a_H = 0 \Rightarrow a_H = \frac{-44}{4} = -11 \text{ kN} \end{aligned}$$

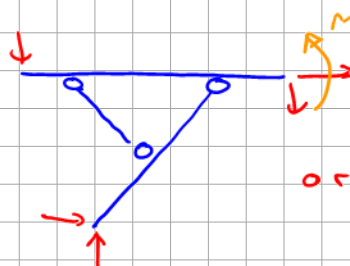
$$a_N = \sqrt{5} \cdot -11 = -24.6 \text{ kN}$$

Answer: $a_N = -24.6 \text{ kN}$.

$$= \frac{100}{5} = 20\%$$

Often seen mistakes:

- bar AC as pendulum bar:
- clouds thru member DS without adding internal force M.



- ratio $V_B \& H_B = 4:2$



It is not a real pendulum bar, but if the dotted line is considered, then a ratio of 4:4 can be used.

Assignment 2. (40 %) Axial extension.**Given:**

An entirely rigid and weightless beam ABCD is supported by a hinge at A and is suspended from the vertical bars (1) to (3) at B, C and D.

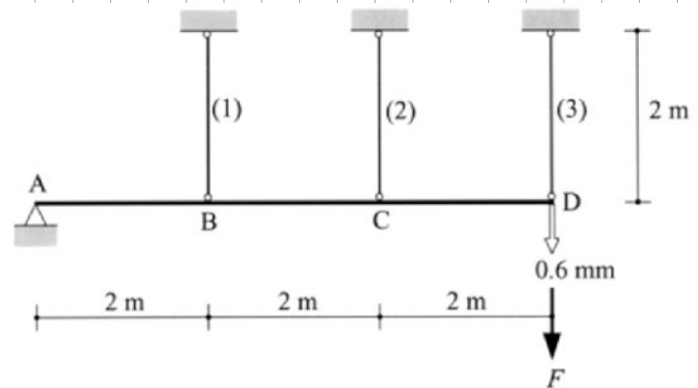
In unloaded condition, the beam is horizontal. As a result of force F at D, D drops by 0.6 mm.

$$A_{(1)} = 1000 \text{ mm}^2 \quad E_{(1)} = 200 \text{ GPa}$$

$$A_{(2)} = 1000 \text{ mm}^2 \quad E_{(2)} = 100 \text{ GPa}$$

$$A_{(3)} = 1000 \text{ mm}^2 \quad E_{(3)} = 300 \text{ GPa}$$

$$1 \text{ GPa} = 1000 \text{ N/mm}^2$$

**Questions:**

- Determine the magnitude of the load F
- Determine the Support reactions at A.

Key activity:

- determine forces in cable using: $\Delta L = \frac{N \times L}{EA} \Rightarrow N = \frac{\Delta L}{L} \times EA$
- determine reaction forces using $\sum V = 0, \sum M = 0, \sum H = 0$

Model:**Solving:**

$$\Delta L_1 : \Delta L_2 : \Delta L_3 = 2 : 4 : 6 \Rightarrow \Delta L_1 = \frac{2}{6} \Delta L_3 = \frac{2}{6} \times 0.6 = 0.2 \text{ mm}$$

$$\Delta L_2 = \frac{4}{6} \Delta L_3 = \frac{4}{6} \times 0.6 = 0.4 \text{ mm}$$

$$V_1 = \frac{\Delta L_1}{L_1} \times EA_1 = \frac{0.2}{2000} \times 200 \times 10^3 \times 1000 = 20000 \text{ N (20 kN)}$$

$$V_2 = \frac{\Delta L_2}{L_2} \times EA_2 = \frac{0.4}{2000} \times 100 \times 10^3 \times 1000 = 20000 \text{ N (20 kN)}$$

$$V_3 = \frac{\Delta L_3}{L_3} \times EA_3 = \frac{0.6}{2000} \times 300 \times 10^3 \times 1000 = 90000 \text{ N (90 kN)}$$

$$\sum H = 0 \Rightarrow A_H = 0$$

$$\sum M_0 = 0 \Rightarrow -A_V \times 6 - V_1 \times 4 - V_2 \times 2 = 0$$

$$-A_V \times 6 - 20 \times 4 - 20 \times 2 = 0$$

$$A_V = -\frac{120}{6} = -20 \text{ kN}$$

$$-6A_V - 120 = 0$$

$$\sum V = 0 \Rightarrow -A_V - V_1 - V_2 - V_3 + F = 0$$

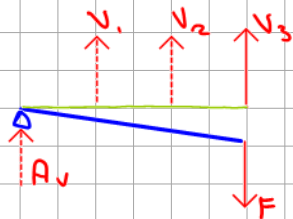
$$+20 - 20 - 20 - 90 + F = 0 \Rightarrow F = 110 \text{ kN}$$

Answers:

a: $F = 110 \text{ kN} (\downarrow)$

b: $A_v = 20 \text{ kN} (\downarrow)$
 $A_H = 0 \text{ kN}$

Often seen mistakes. :



- During determination of F only force V_3 is considered ($F = V_3$)
- Then for calculating A_v , V_1 & V_2 where included.....

$$- \Delta_1 = \Delta_2 = \Delta_3 = 0.6$$

$$- \Delta_1 : \Delta_2 : \Delta_3 = 1 : 2 : 4$$

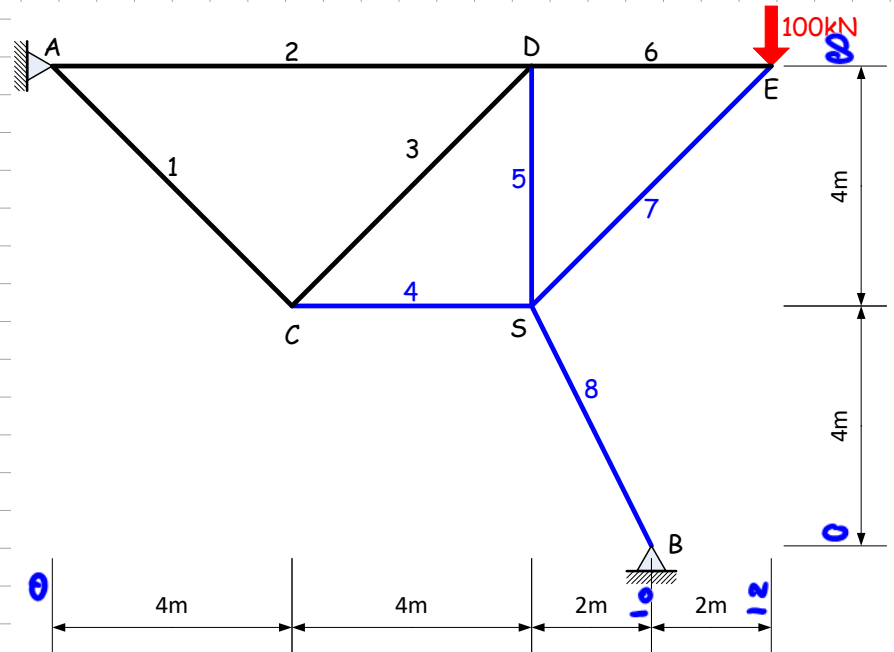
Assignment 3. (30 %) Truss.**Given:**

A truss supported at A and B is loaded by a load of 100 kN at E.

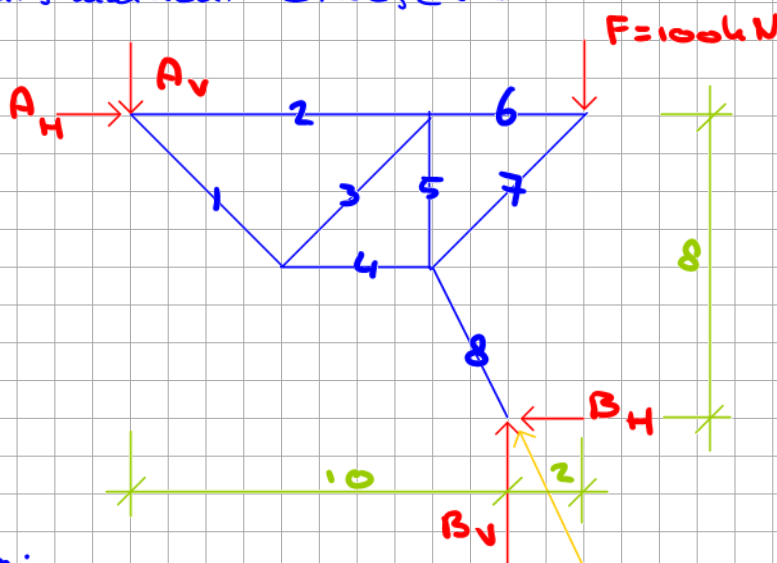
Members 2,4,6: $A=3000\text{mm}^2$ $E=200\text{ GPa}$
 Other Members $A=1000\text{mm}^2$ $E=200\text{ GPa}$

Question:

Determine the internal forces of members 4,5,7 and 8

**Key activities:**

- all members prismatic bars.
- determine reaction forces $\sum M=0, \sum V=0, \sum H=0$ (bar 8 = bar support)
- use joints method. $\sum H=0; \sum V=0$

Model**Solving:**

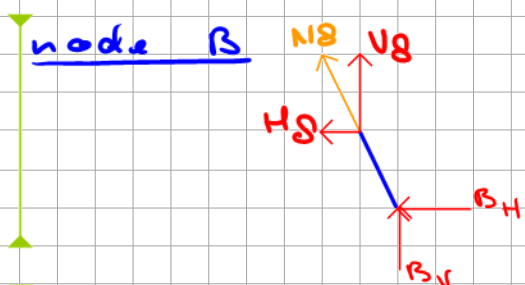
$$B_H : B_V = 2 : 4 \Rightarrow B_V = 2 B_H$$

$$\begin{aligned} \sum M_A = 0 & \quad + B_V \times 10 - B_H \times 8 - F \times 12 = 0 \\ & \quad + (2 B_H) \times 10 - 8 B_H - 100 \times 12 = 0 \\ & \quad + 20 B_H - 8 B_H = 1200 \\ & \quad 12 B_H = 1200 \\ & \quad B_H = 100 \text{ kN} \end{aligned}$$

$$B_V = 2 \times B_H = 2 \times 100 = 200 \text{ kN}$$

$$\begin{aligned} \sum H = 0 & \quad A_H - B_H = 0 \\ & \quad A_H - 100 = 0 \Rightarrow A_H = 100 \text{ kN} \end{aligned}$$

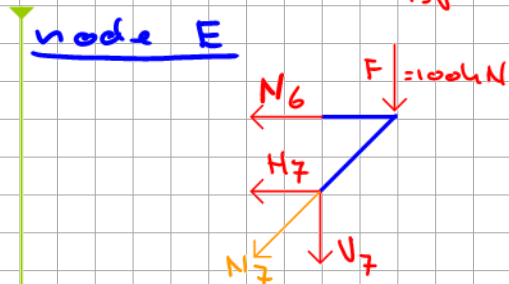
$$\begin{aligned} \sum V = 0 & \quad A_V - B_V + F = 0 \\ & \quad A_V - 200 + 100 = 0 \Rightarrow A_V = 100 \text{ kN} \end{aligned}$$



$$\Sigma H = 0 \quad -H_8 - B_H = 0 \Rightarrow H_8 = -B_H = -100 \text{ kN}$$

$$\Sigma V = 0 \quad -V_8 - B_V = 0 \Rightarrow V_8 = -B_V = -200 \text{ kN}$$

$$N_8 = -\sqrt{100^2 + 200^2} = -100\sqrt{5} = -223.6 \text{ kN}$$



$$\Sigma V = 0 \quad 100 + V_7 = 0 \Rightarrow V_7 = -100 \text{ kN}$$

$$V_7 : H_7 = 1 : 1 \Rightarrow V_7 = H_7 \Rightarrow H_7 = -100 \text{ kN}$$

$$\Sigma H = 0 \quad -N_6 - H_7 = 0 \Rightarrow N_6 = -H_7 = +100 \text{ kN}$$

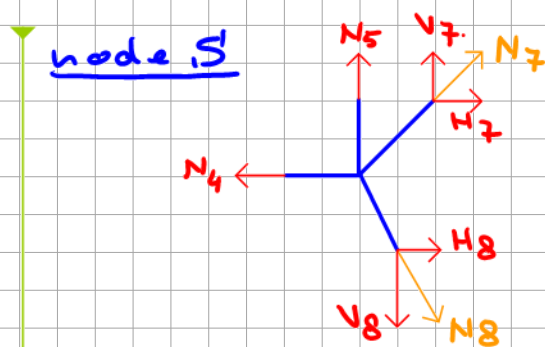
$$N_7 = -\sqrt{100^2 + 100^2} = -100\sqrt{2} = -141.4 \text{ kN}$$

$$\Sigma V = 0 \quad -N_5 - V_7 + V_8 = 0$$

$$N_5 = -V_7 + V_8 = -(-100) + (-200) = -100 \text{ kN}$$

$$\Sigma H = 0 \quad -N_4 + H_7 + H_8 = 0$$

$$N_4 = H_7 + H_8 = (-100) + (-100) = -200 \text{ kN}$$



Answers

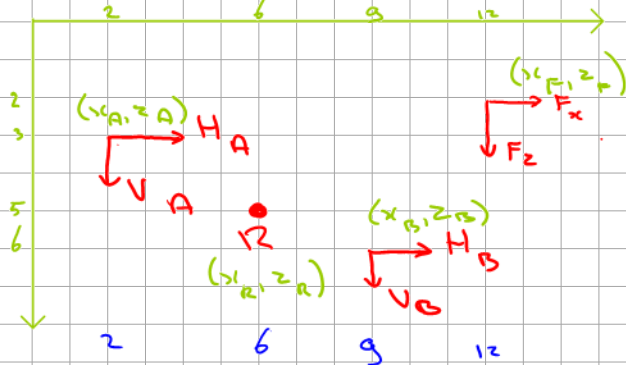
$$\begin{aligned} N_4 &= -200 \text{ kN} \\ N_5 &= -100 \text{ kN} \\ N_7 &= -141.4 \text{ kN} = 100\sqrt{2} \\ N_8 &= -223.6 \text{ kN} = 100\sqrt{5} \end{aligned}$$

20%

A common mistake in Assignment 3(aud1) was making use of the equilibrium rules:

$$\begin{aligned}\sum V &= 0 \\ \sum H &= 0 \\ \sum M_A &= 0 \\ \sum M_B &= 0\end{aligned}$$

Assume F_x & F_z are known; then $\sum M_R = 0$



$$V_A(x_R - x_A) - H_A(z_R - z_A) + V_B(x_R - x_B) - H_B(z_R - z_B) + F_z(x_R - x_F) - F_x(z_R - z_F) = 0$$

base equation

use $(x_R, z_R) = (6, 5)$

$$\begin{aligned}V_A(6-2) - H_A(5-3) + \\ V_B(6-9) - H_B(5-6) + \\ F_z(6-12) - F_x(5-2) &= 0\end{aligned}$$

$$4V_A - 2H_A - 3V_B + 1H_B - 6F_z - 3F_x = 0$$

use $(x_R, z_R) = (2, 3)$ $R = A$

$$\begin{aligned}V_A(2-2) - H_A(3-3) + \\ V_B(2-9) - H_B(3-6) + \\ F_z(2-12) - F_x(3-2) &= 0\end{aligned}$$

$$0V_A - 0H_A - 7V_B + 3H_B - 10F_z - 1F_x = 0$$

use $(x_R, z_R) = (9, 6)$ $R = B$

$$\begin{aligned}V_A(9-2) - H_A(6-3) + \\ V_B(9-9) - H_B(6-6) + \\ F_z(9-12) - F_x(6-2) &= 0\end{aligned}$$

$$7V_A - 3H_A + 0V_B + 0H_B - 3F_z - 4F_x = 0$$

As you can see $\sum M_A = 0$ & $\sum M_B = 0$ are the result of the same base equation.

$$\begin{aligned}\sum V &= 0 \\ \sum H &= 0 \\ \sum M_A &= 0 \\ \sum M_B &= 0\end{aligned}$$

So solving 4 unknowns using these 4 equilibrium rules will only result in an answer after (several) calculation errors!

An other mistake:

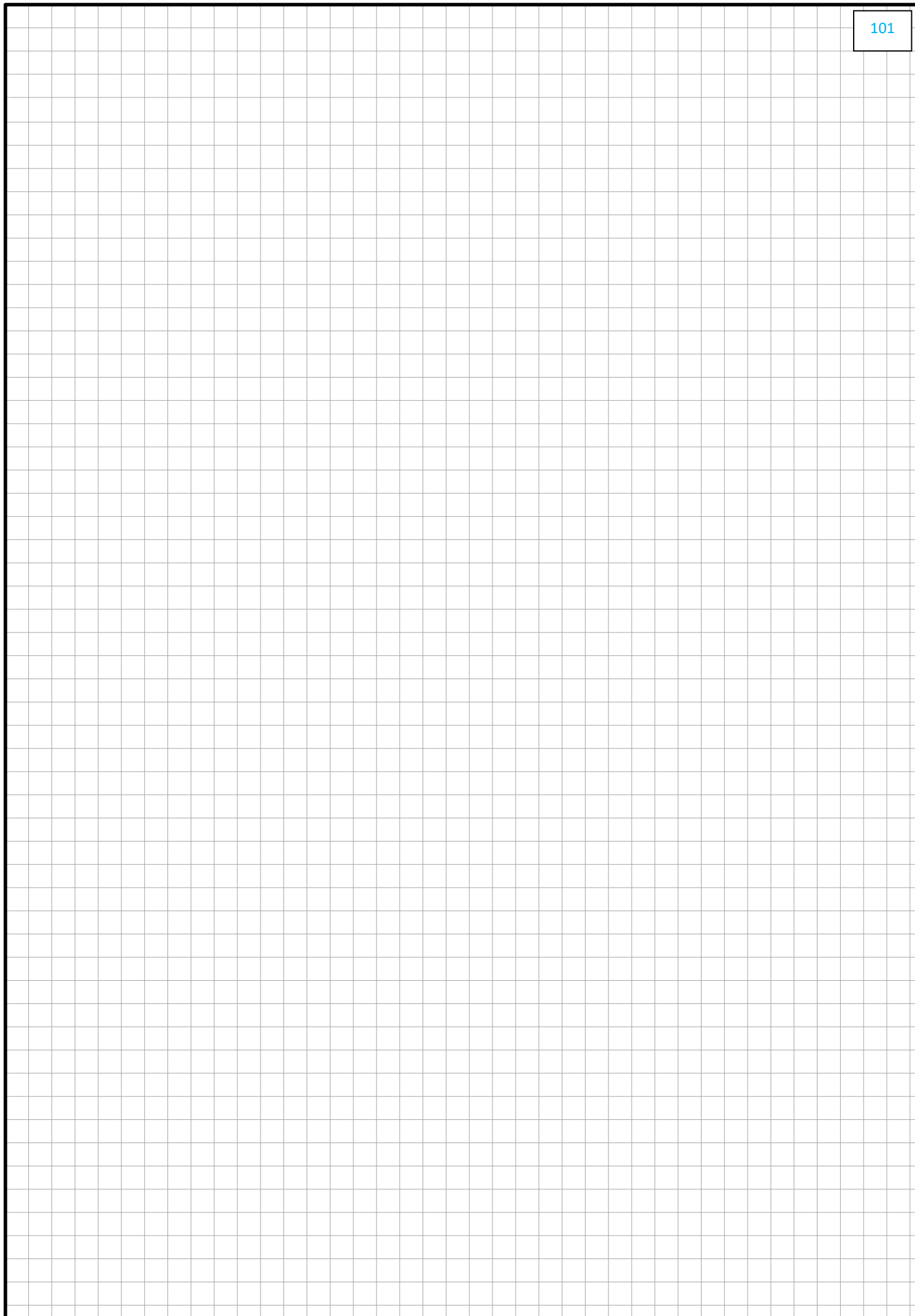
$$\begin{aligned}\sum H &= 0 & A_H + B_H &= 0 \\ & & A_H &= B_H\end{aligned}$$

since there is no horizontal force: $A_H = B_H = 0$

Simplification of the system to:



(force B_H is moved perpendicular to its line of action, without compensating with an extra moment at B)



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Test 1:

Continuation of

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Use this sheet for ONE assignment only!

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Test 1:

Continuation of

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