Answer Sheet Introduction to FEM

Practical 1, Group: B

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Before you start, read the practical preparation manual carefully!
Only fill in the answers for nodes and elements that apply to your specific problem. This answer sheet may contain more elements/nodes than needed.

1. Determine the displacements and reaction forces in the nodes.

node	u_x [mm]	u_y [mm]
1	0	0
2	0.3571	-2.4387
3	0.7143	-3.5186
4	1.0714	-2.7959
5	1.4286	0
6	1.1905	-2.2006
7	0.7143	-3.5186

node	F_x [kN]	F_y [kN]
1	0	7.5
2	0	-5
3	0	-5
4	0	-5
5	0	7.5
6	0	0
7	0	0

2a. Check whether the sum of the forces equals zero (display the entire equation!).

sum	equation [kN]	[kN]
ΣF_x	0 + 0 + 0 + 0 + 0 + 0 + 0 + 0	0
ΣF_y	7.5 - 5 - 5 - 5 + 7.5 + 0 + 0	0

2b. Check whether the sum of the moments equals zero (display the entire equation!).

sum	equation (about node 1 in kNm)	[kNm]
ΣM_z	7.5*0 + (-5+0)*5 + (-5+0)*10 + (-5+0)*15 + 7.5*20	0

The truss forces can be calculated in two different ways to determine whether the results are correct.

3a. Determine the elongation Δl of the truss elements. Use the rotation matrices to rotate the element deformations into the local coordinate system.

elem.	**Δl [mm]**
1	0.3571
2	0.3571
3	0.3571
4	0.3571
5	-0.7143

elem.	**Δl [mm]**
6	-0.4762
7	-0.4762
8	-0.7143
9	0.2381

elem.	**Δl [mm]**
10	-4.41e-16
11	0.5952
12	0.5952
13	0.5952

3b. Redo the calculation of question 3a using the initial and final coordinates of the nodes and the Pythagoras rule.

elem.	**Δl [mm]**
1	0.3577
2	0.3573
3	0.3572
4	0.3579
5	-0.7139

elem.	**Δl [mm]**
6	-0.4760
7	-0.4760
8	-0.7139
9	0.2382

elem.	**Δl [mm]**
10	0
11	0.5953
12	0.5954
13	0.5954

3c. The answers of questions 3a and 3b are different. Using rotation matrices, the elongations are slightly off. Explain why:

The rotation matrix using only matrix multiplication and the values of cosine and sine. These values change with the change in angle as the structure deforms. We have assumed them to to be constant.Thus, the pythagoras method is more accurate.

3d. Calculate the strains $\varepsilon = \Delta l / l_0$ using the elongations from question 3a.

elem.	**ε [-]**
1	7.143e-5
2	7.143e-5
3	7.143e-5
4	7.143e-5
5	-1.0102e-4

elem.	**ε [-]**
6	-9.524e-5
7	-9.524e-5
8	-1.0102e-4
9	4.762e-5

elem.	**ε [-]**
10	-8.882e-20
11	-1.19e-4
12	8.418e-5
13	8.418e-5

3e. Determine the stresses $\sigma = E\varepsilon$ using the strains from question 3d.

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elem.	σ [MPa]
1	15
2	15
3	15
4	15
5	-21.2132

elem.	σ [MPa]
6	-20
7	-20
8	-21.2132
9	10

elem.	σ [MPa]
10	-1.86e-14
11	25
12	17.6778
13	17.6778

3f. Determine the truss forces $F = A\sigma$ using the stresses from question 3e.

elem.	F [kN]
1	7.5
2	7.5
3	7.5
4	7.5
5	-10.6066

elem.	F [kN]
6	-10
7	-10
8	-10.6066
9	5

elem.	F [kN]
10	-3.73e-15
11	5
12	3.5355
13	3.5355

4a. Determine the truss forces using the local stiffness matrix and the local displacement vectors $[K_{ei}]\{U\}$ using MATLAB.

elem.	F [kN]
1	7.5
2	7.5
3	7.5
4	7.5
5	-10.6066

elem.	F [kN]
6	-10
7	-10
8	-10.6066
9	5

elem.	F [kN]
10	-3.638e-15
11	5
12	3.5355
13	3.5355

4b. Do the answers of questions 3f and 4a agree? Why does that make sense?

Yes the answers of 3f and 4a agree.

It makes sense because, for both 3f and 4a, we use the stiffness matrix to find the force by multiplying it with the local displacement vectors. MATLAB is very good at matrix computations and hence the answers also agree.