Istanbul Technical University
Graduate School of Science Engineering and Technology

MKC525E
Finite Element Analysis in Engineering

Homework 4

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1 Question 1

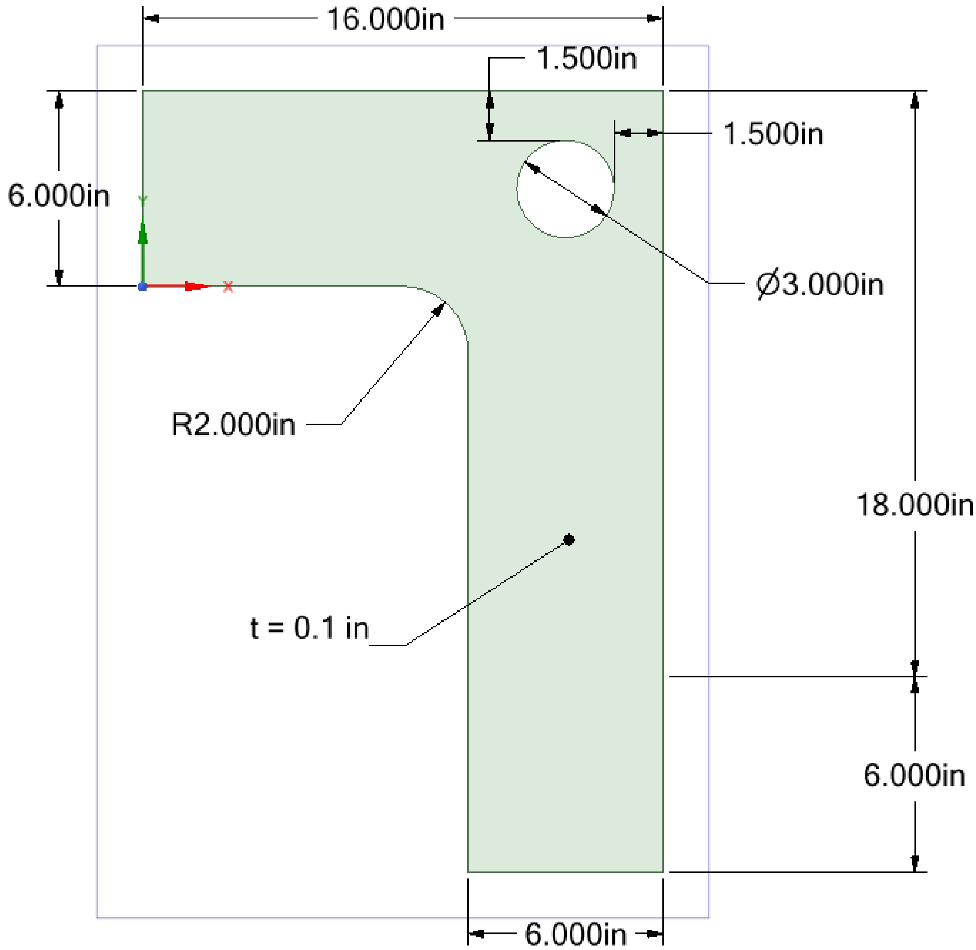


Figure 1: Geometry used in Question 1.

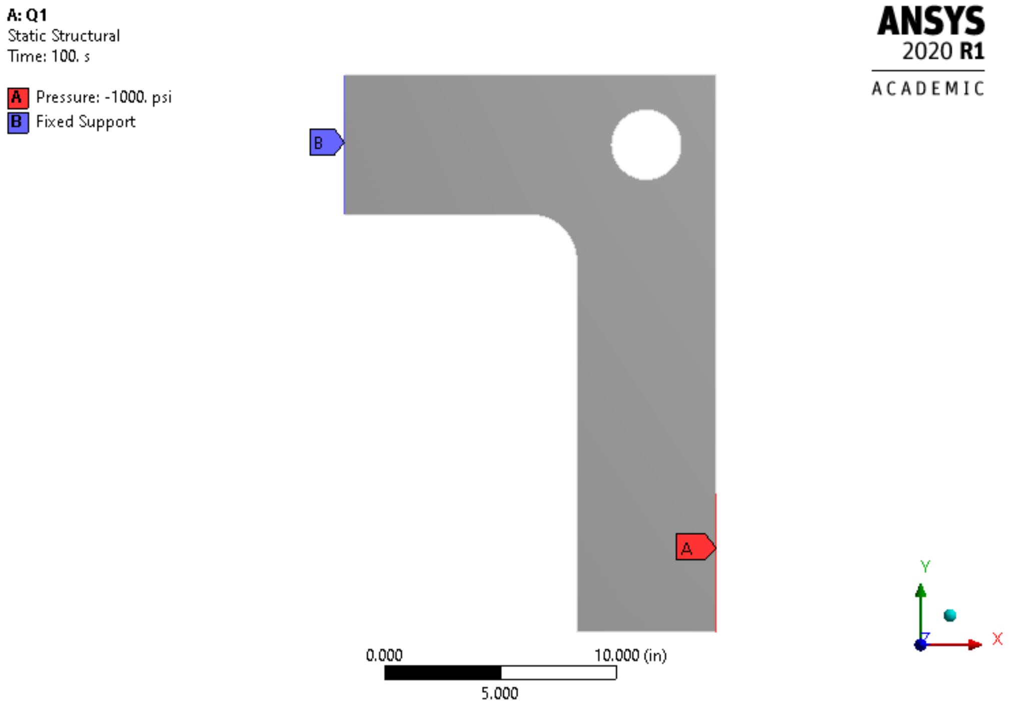
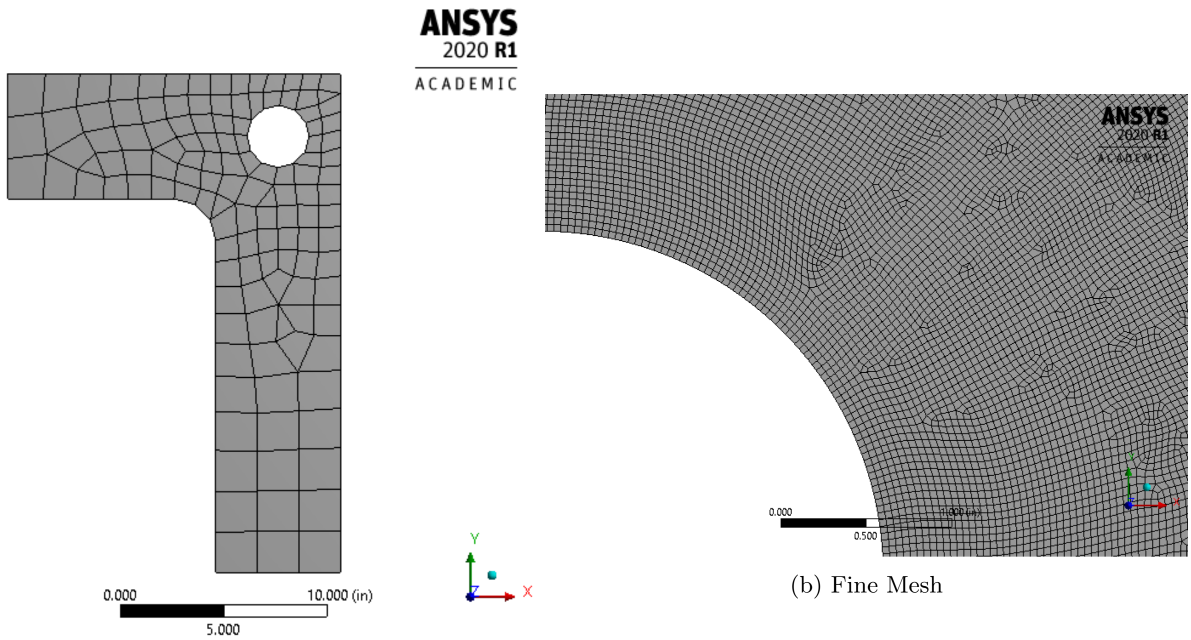


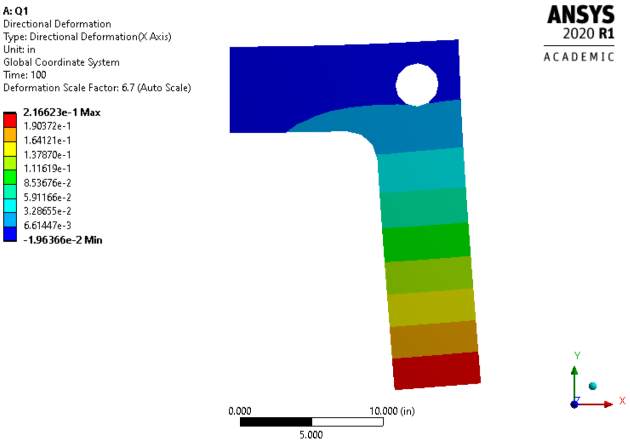
Figure 2: Boundary conditions in Question 1.



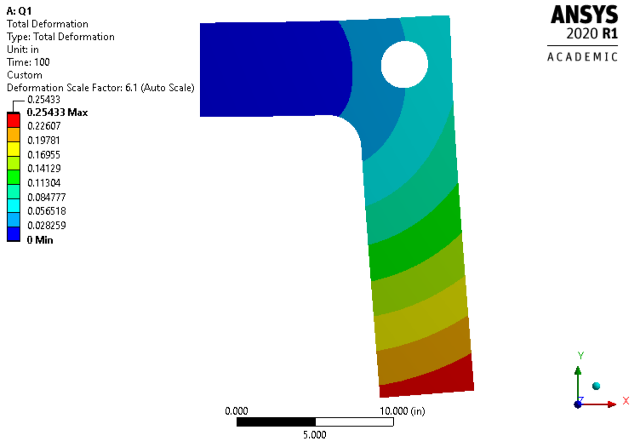
(b) Fine Mesh

(a) Coarse mesh

Figure 3: Example for the different mesh sizes used in Question 1. 2D, Plane stress, linear quadrilateral (PLANE182).

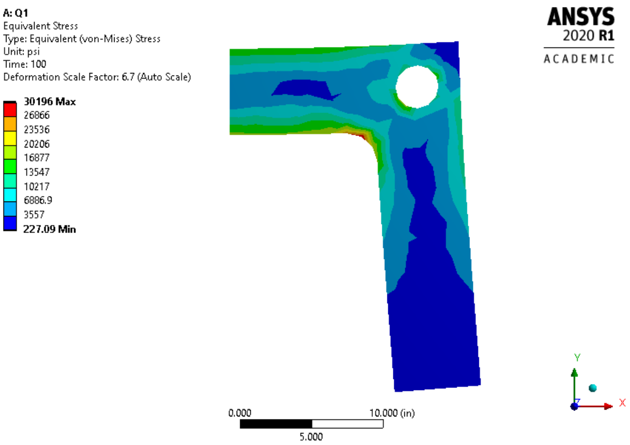


(a) Coarse mesh

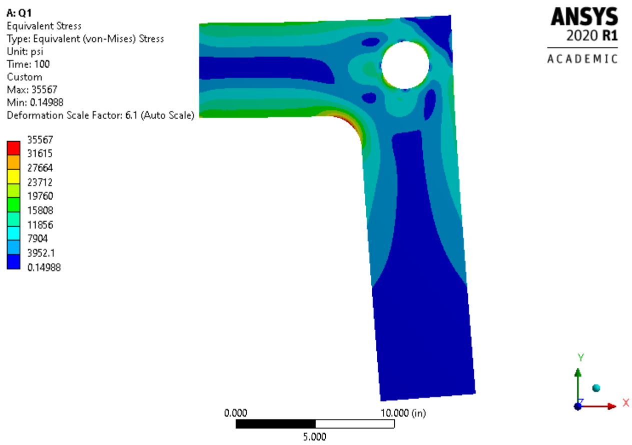


(b) Fine Mesh

Figure 4: Deformation for the mesh sizes given in figure above.



(a) Coarse mesh



(b) Fine Mesh

Figure 5: von-Mises stress for the mesh sizes given in figure above.

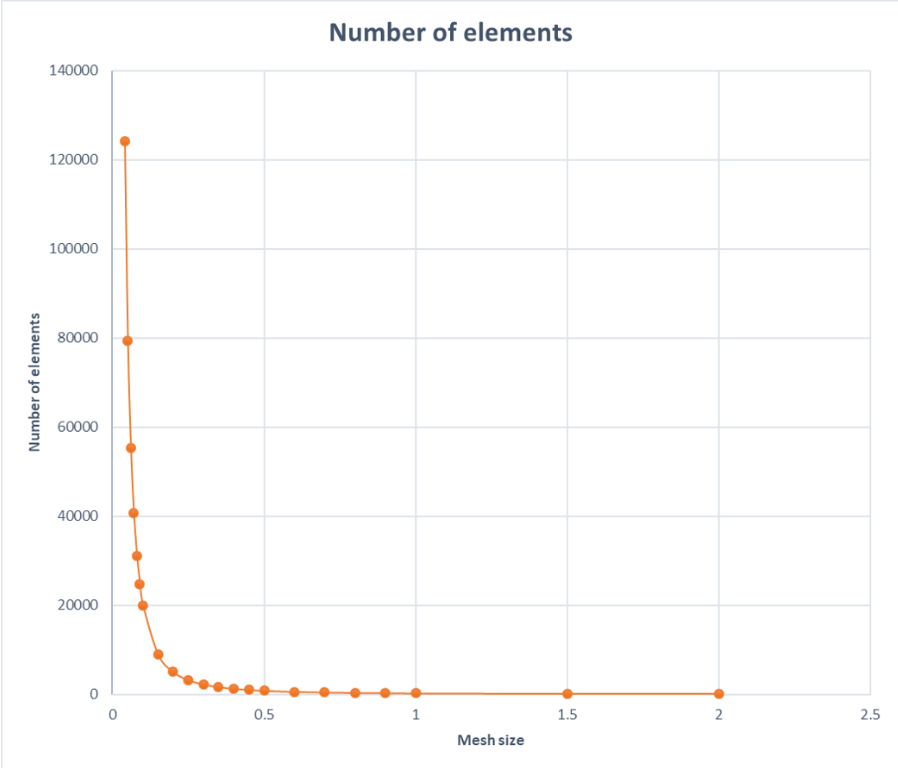


Figure 6: Number of elements as a function of element size.

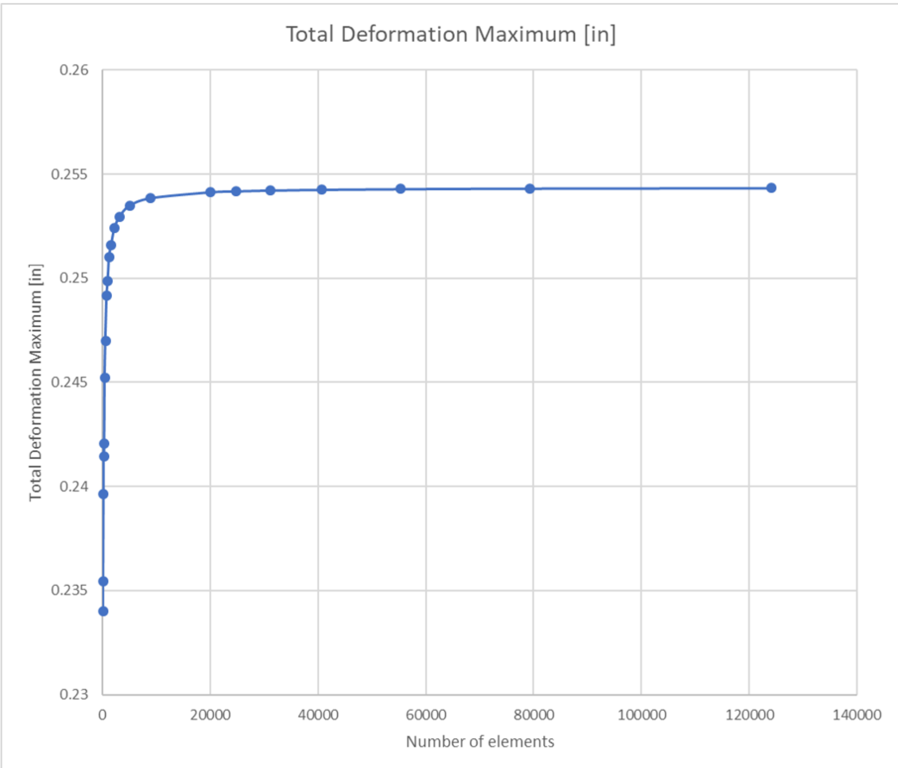


Figure 7: Deformation as a function of number of elements.

Figure 8: von-Mises stress as a function of number of elements.

2 Question 2

Linear beam, shell and solid elements are compared in this question. Figures for deformation and stress are given in Appendix.

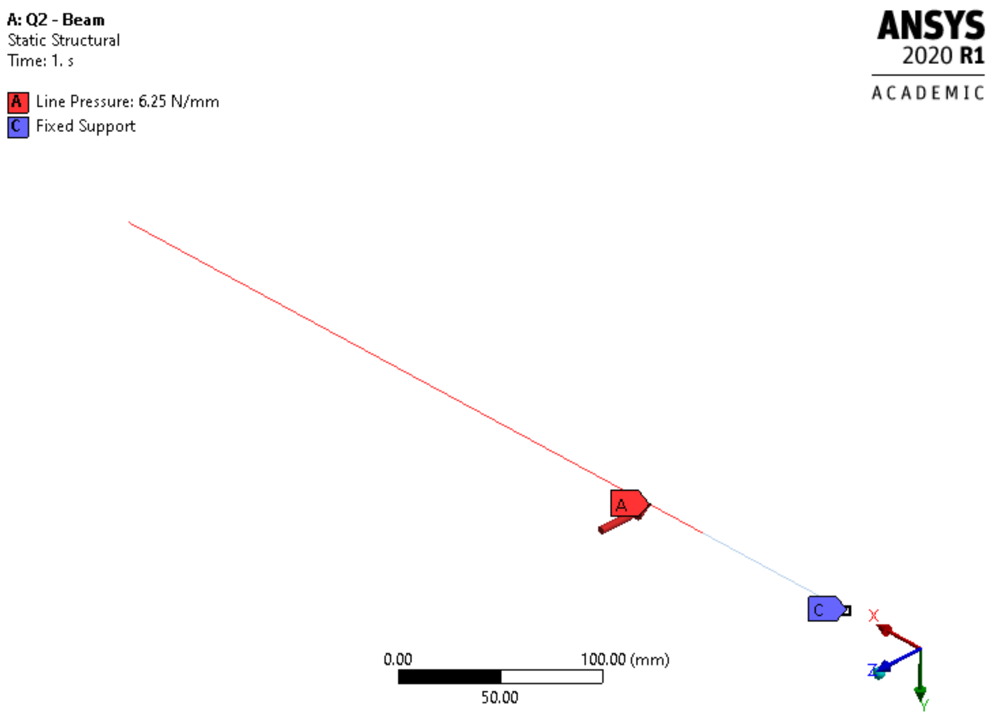
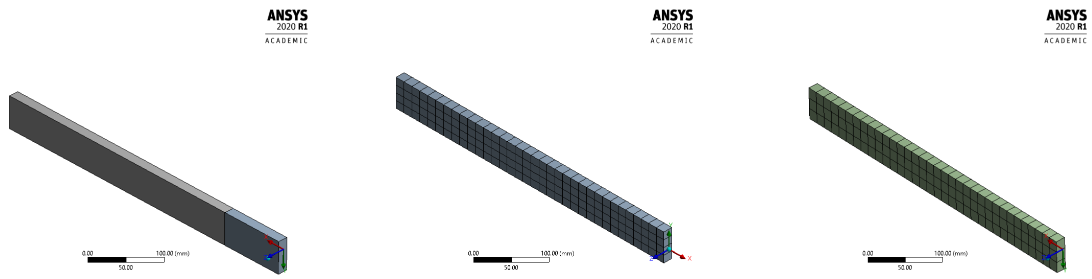
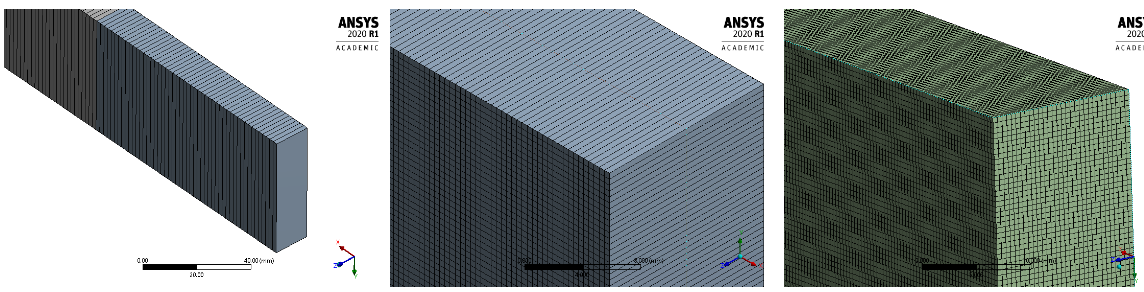


Figure 9: Boundary conditions in Question 2.



(a) Beam elements (b) Shell elements (c) Solid elements

Figure 10: Example for types of mesh used in Question 2 (biggest mesh size).



(a) Beam elements (b) Shell elements (c) Solid elements

Figure 11: Example for types of mesh used in Question 2 (smallest mesh size).

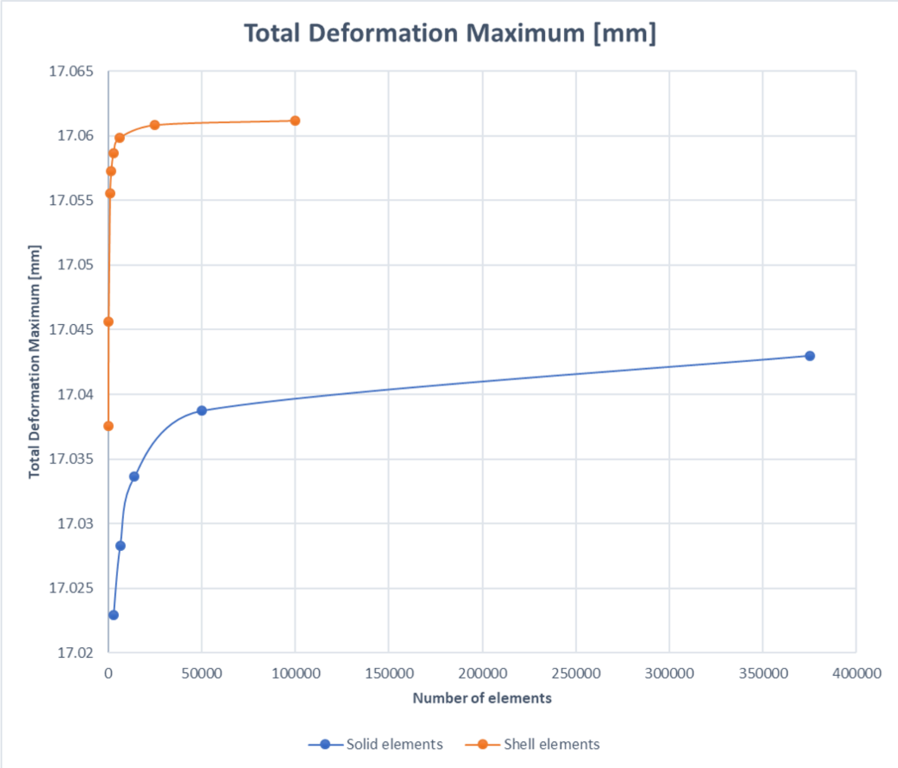


Figure 12: Deformation as a function of number of elements (shell and solid elements).

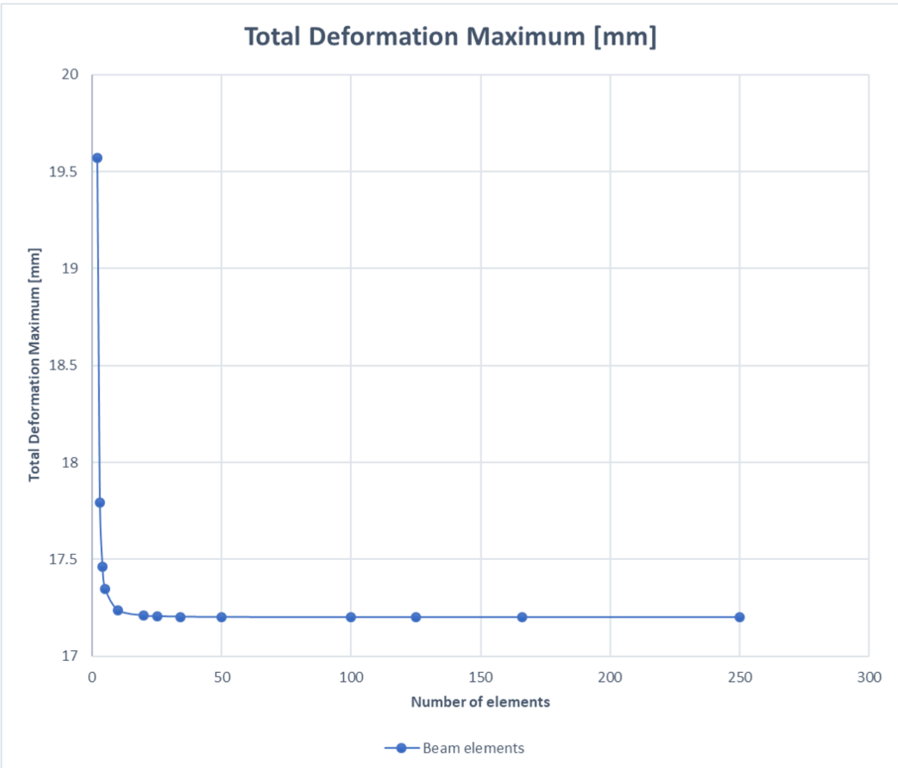


Figure 13: Deformation as a function of number of elements (beam elements).

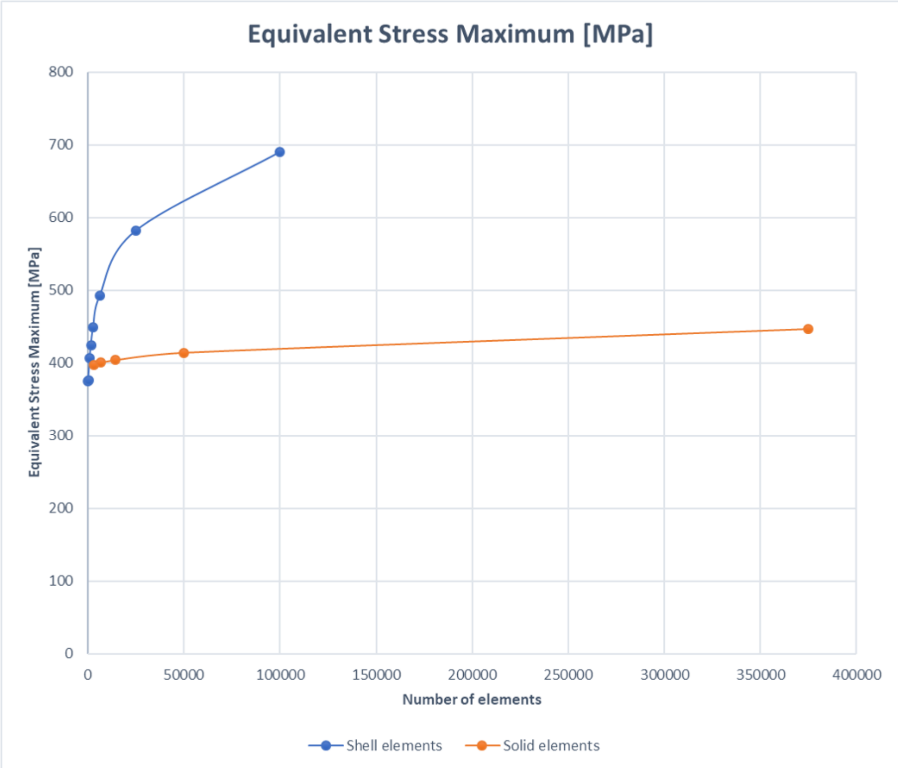
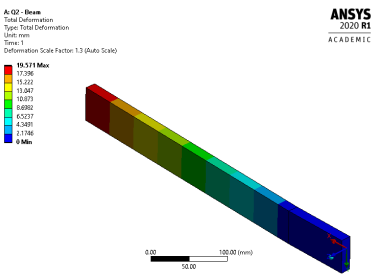
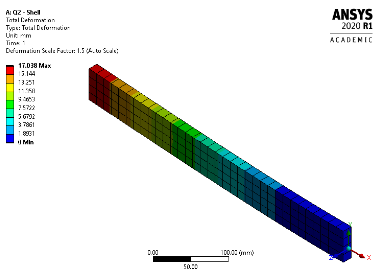


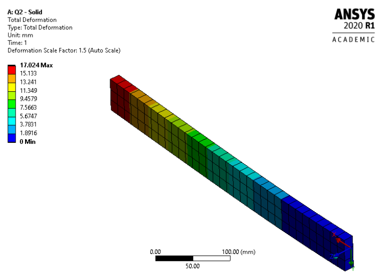
Figure 14: von-Mises stress as a function of number of elements (shell and solid elements).



(a) Beam elements

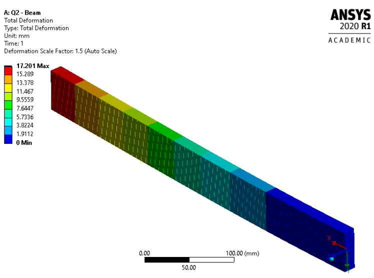


(b) Shell elements

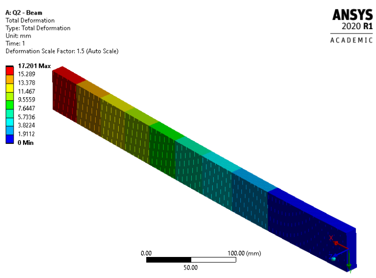


(c) Solid elements

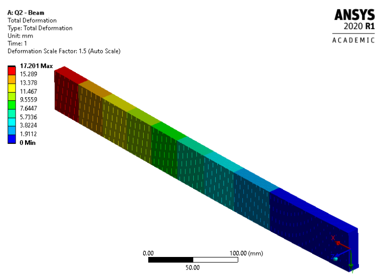
Figure 15: Deformation for the mesh sizes given in figure above (biggest mesh size).



(a) Beam elements



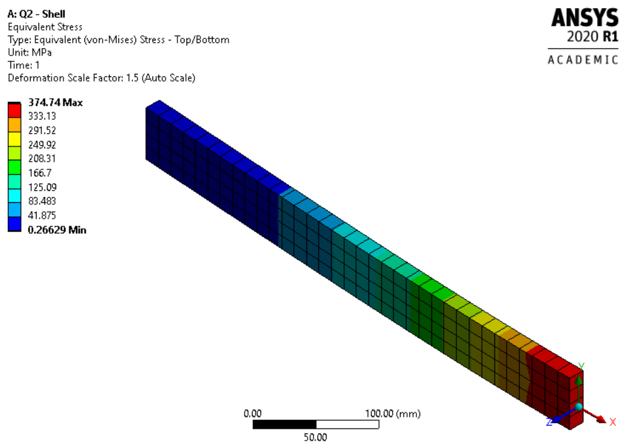
(b) Shell elements



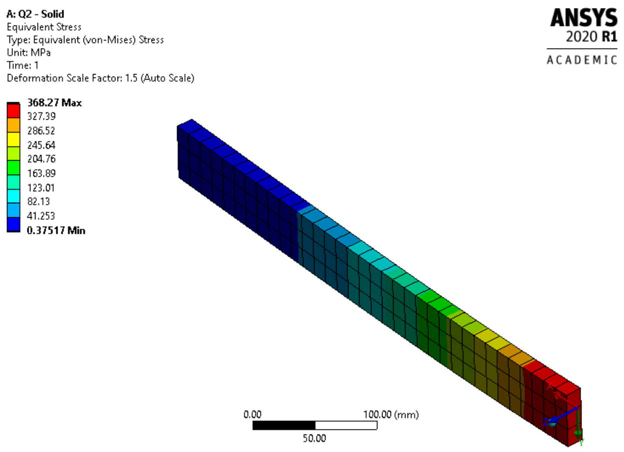
(c) Solid elements

def

Figure 16: Deformation for the mesh sizes given in figure above (smallest mesh size).

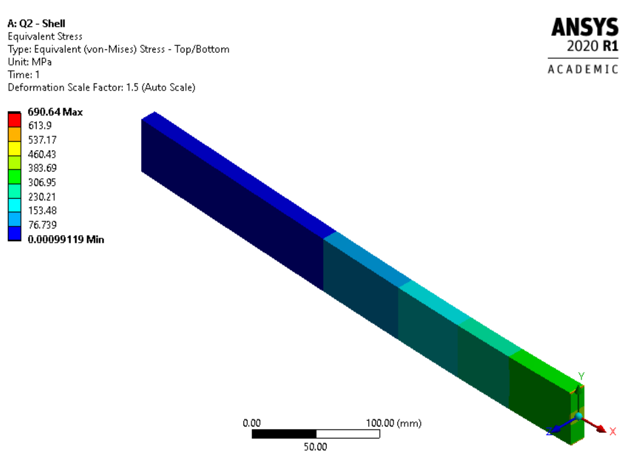


(a) Shell elements

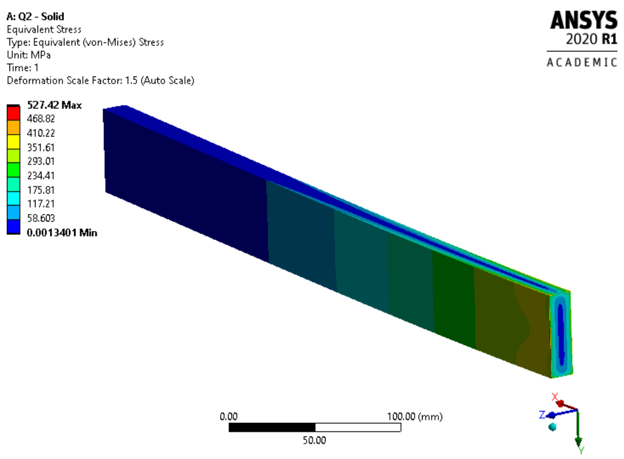


(b) Solid elements

Figure 17: von-Mises stress for the mesh sizes given in figure above (biggest mesh size).



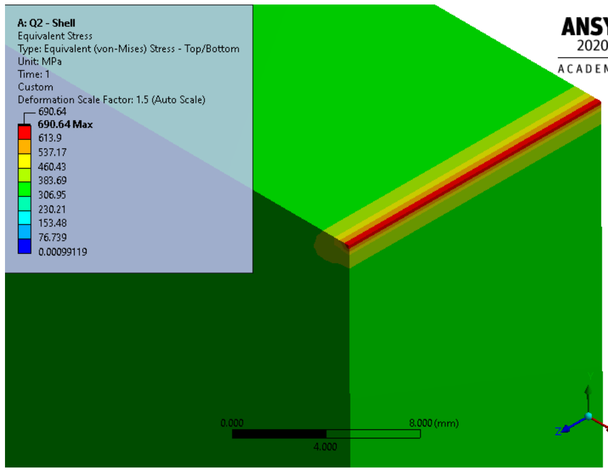
(a) Shell elements



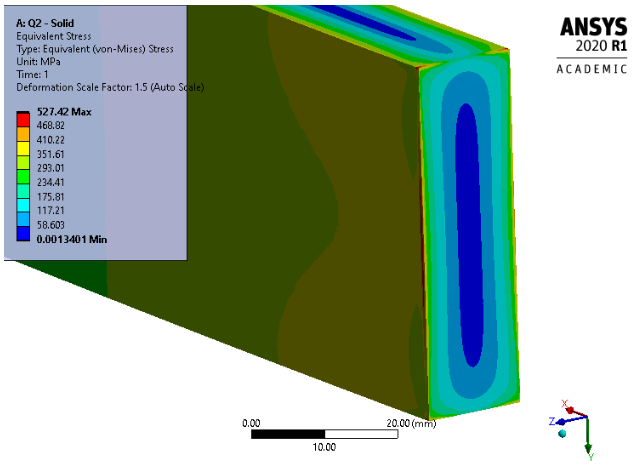
(b) Solid elements

def

Figure 18: von-Mises stress for the mesh sizes given in figure above (smallest mesh size).



(a) Shell elements



(b) Solid elements

Figure 19: Closer look at von-Mises stress for the smallest mesh sizes given in figure above.

3 Question 3

There is an ideal geometry in this question. So there is no distorted elements. Temperatures and heat flux in x-direction is same for every element size (200 mm(1 element), 2 mm(130,000 elements)). Heat flux in y and z-directions are changing with the element size but they are considered numerical errors ($< 10^{-7}$).

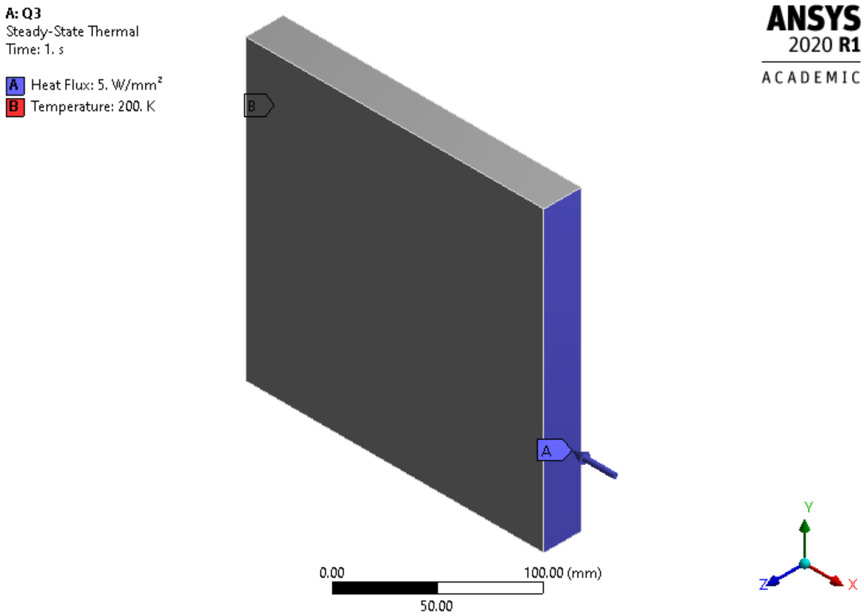
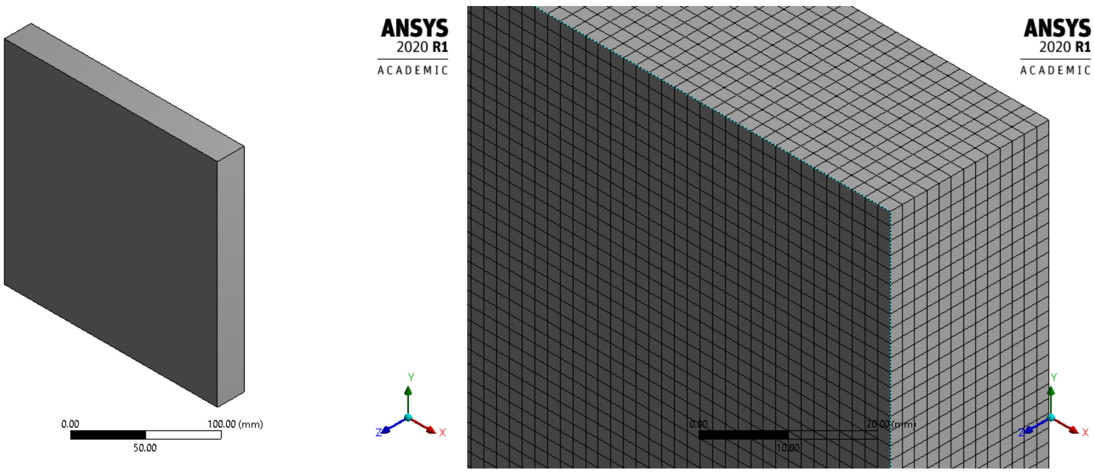


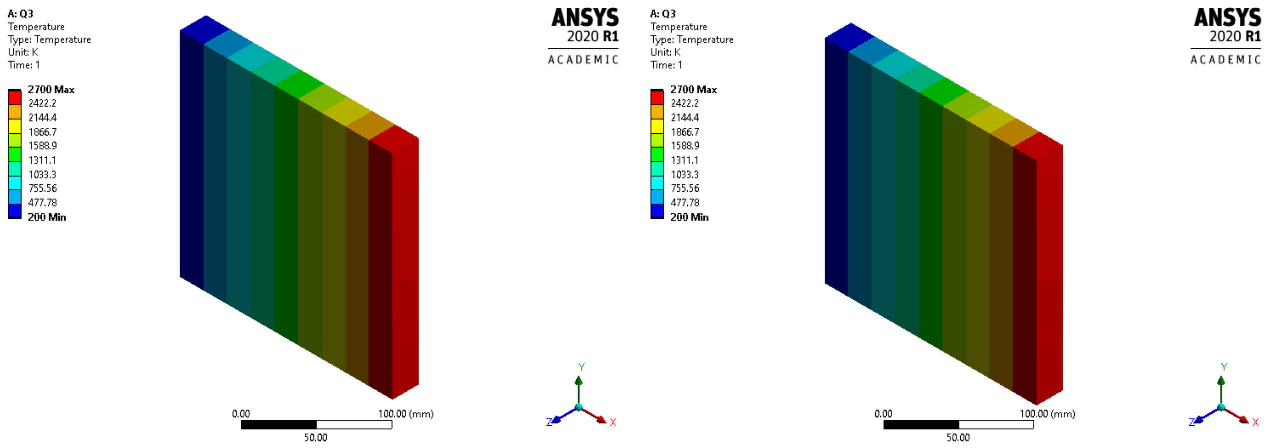
Figure 20: Boundary conditions in Question 3.



(a) Mesh with 1 element

(b) Mesh with 130,000 elements

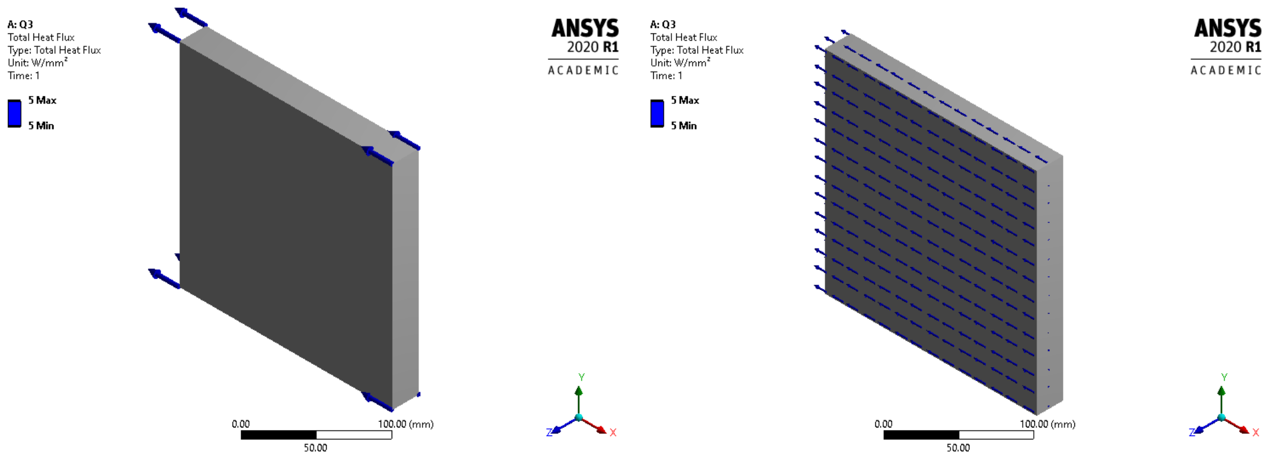
Figure 21: Two different mesh for the problem.



(a) Mesh with 1 element

(b) Mesh with 130,000 elements

Figure 22: Temperatures.



(a) Mesh with 1 element

(b) Mesh with 130,000 elements

Figure 23: Heat flux (x-direction).

4 Question 4

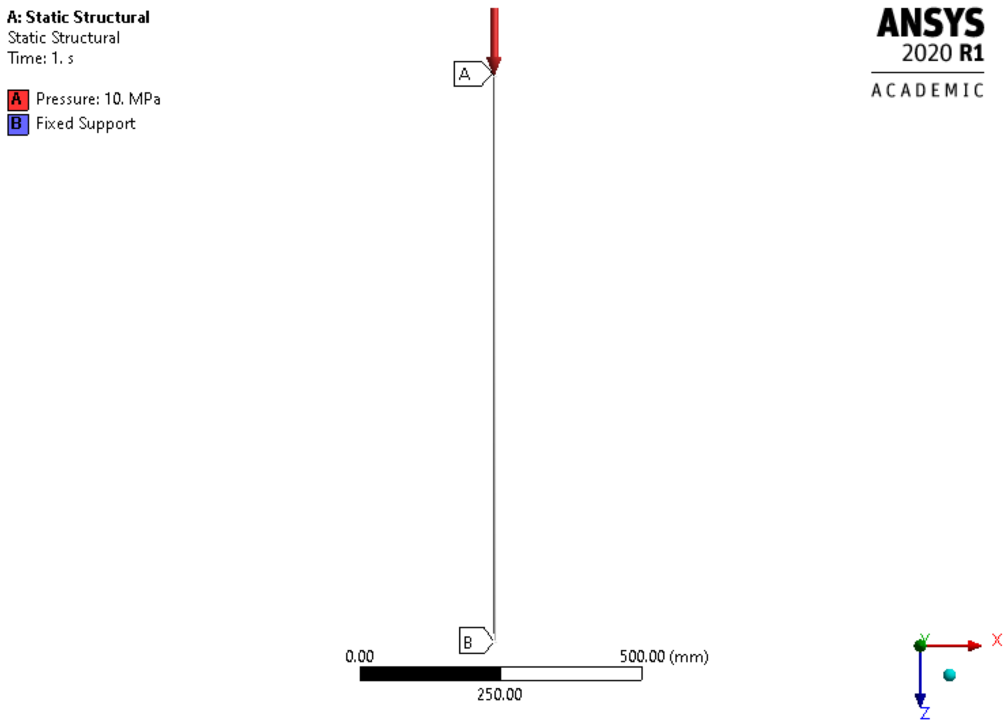
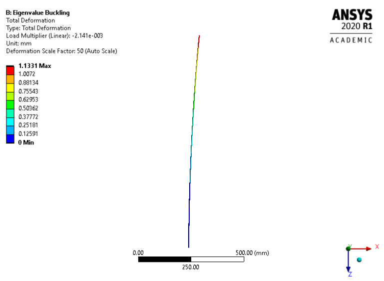
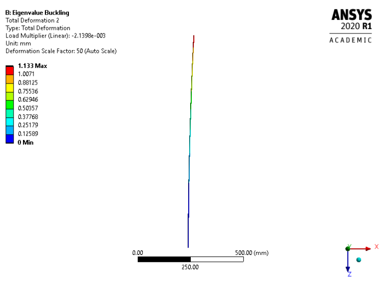


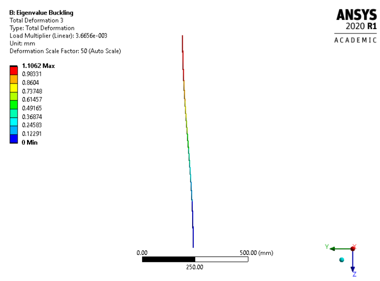
Figure 24: Boundary conditions in Question 4.



(a) Eigenvalue 1



(b) Eigenvalue 2



(c) Eigenvalue 3

Figure 25: Deformation for first three eigenvalues (Load Multipliers) (Quadratic hexahedral).

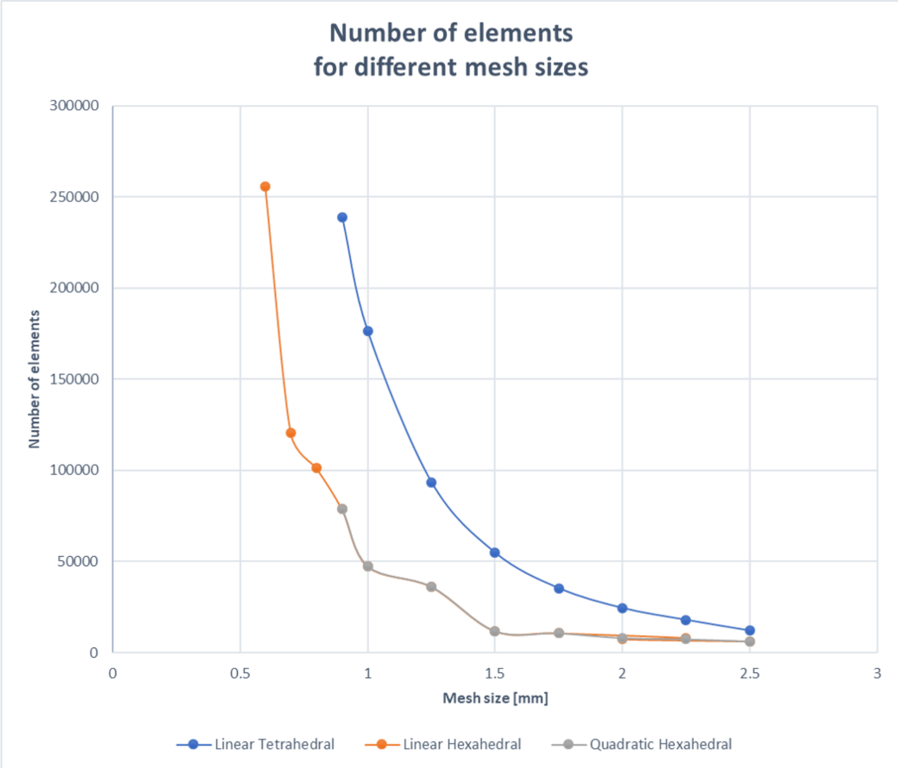


Figure 26: Number of elements as a function of element size.

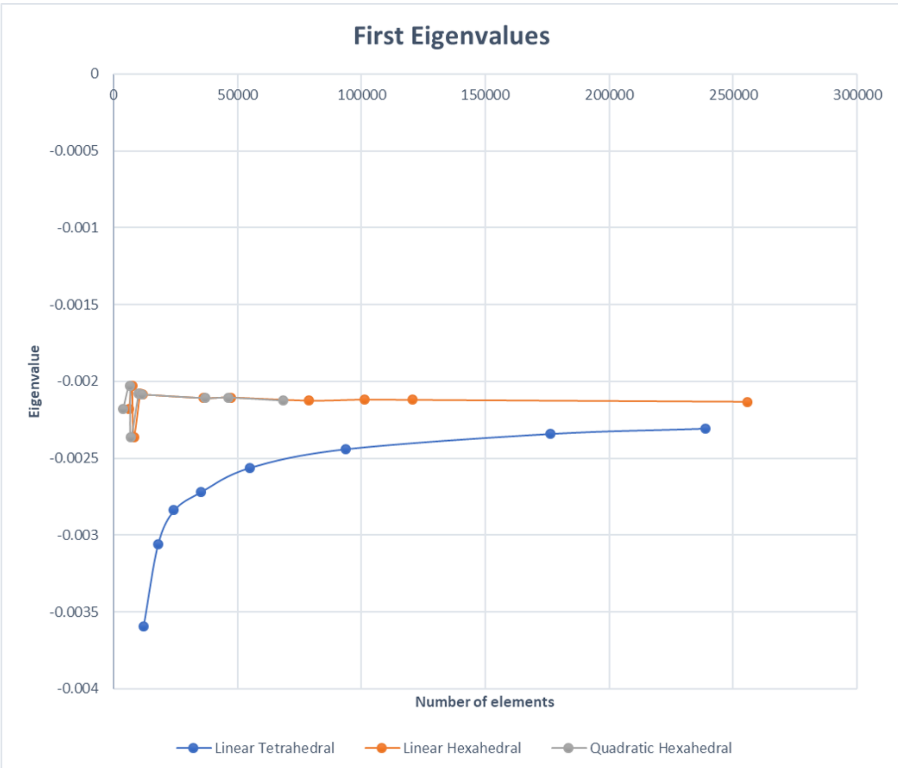


Figure 27: First eigenvalues as a function of number of elements.

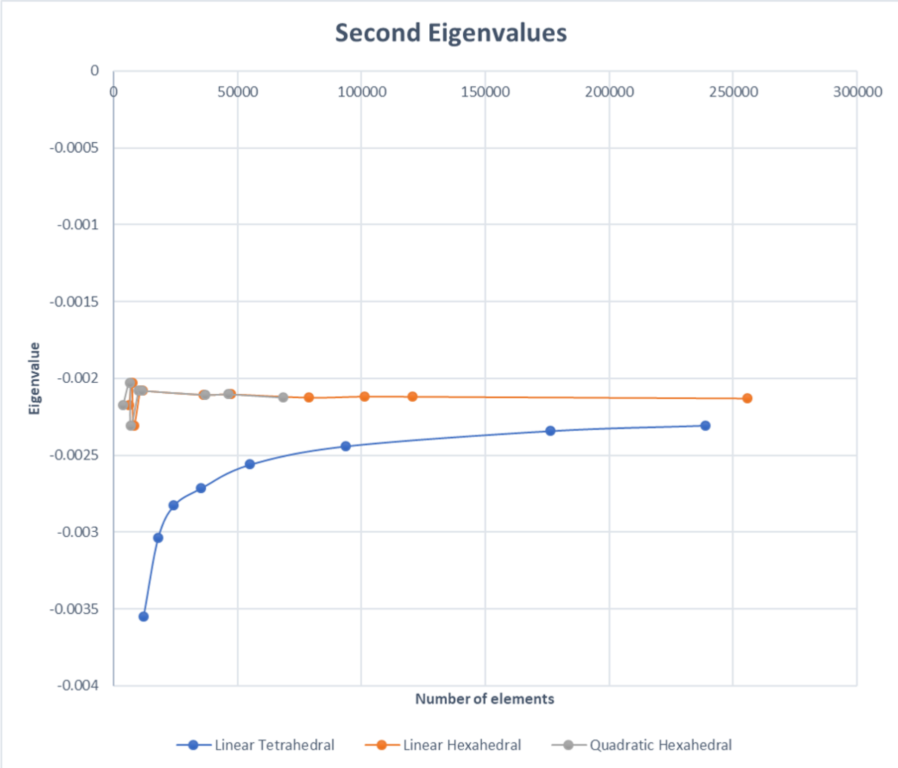


Figure 28: Second eigenvalues as a function of number of elements.

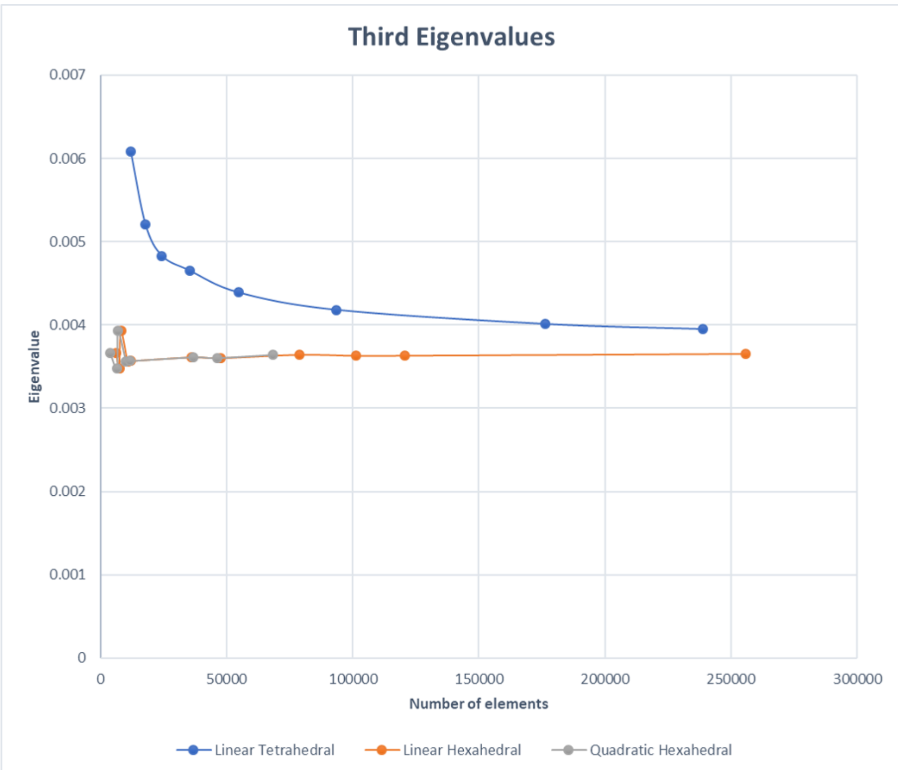


Figure 29: Third eigenvalues as a function of number of elements.

5 Question 5

In Ansys Workbench Mechanical, 2D surface geometry can not be divided into layers. So in this section. 3D linear tetrahedral, hexahedral and quadratic hexahedral elements are used to compere two and four layers. Comperations made in this section:

- **2 layers vs. 4 layers** for quadratic hexahedral (first 5 constrained mode frequencies),
- **Linear hexahedral vs. quadratic hexahedral** for 4 layers (4. and 5. constrained mode frequencies)
- **Linear tetrahedral vs. linear hexahedral** for 4 layers (1., 2., 4. and 5. constrained mode frequencies)

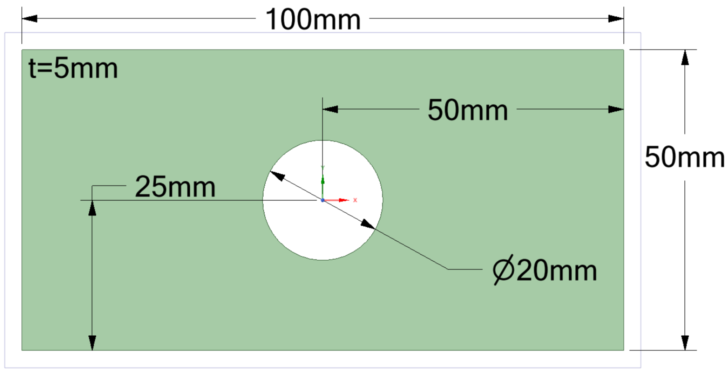
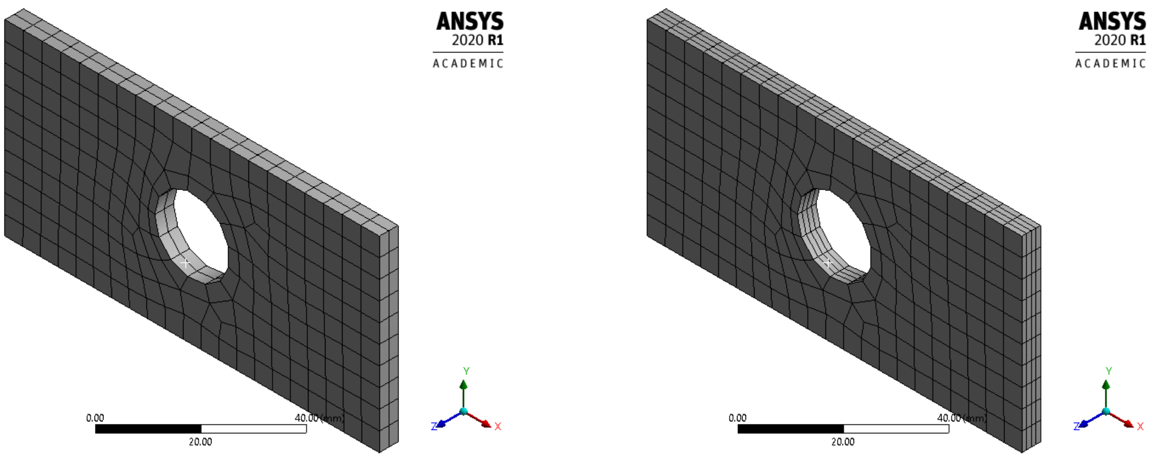


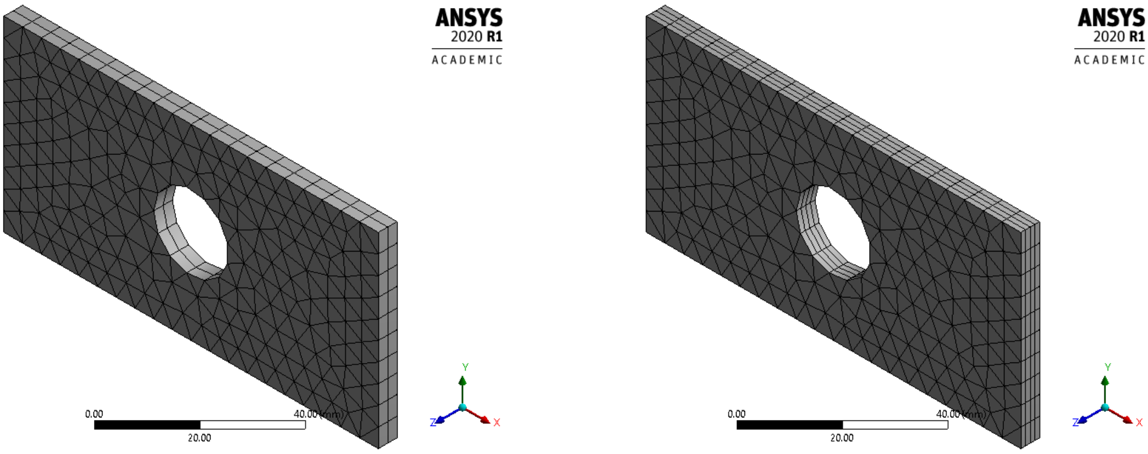
Figure 30: Geometry used in Question 5.



(a) Two layers

(b) Four layers

Figure 31: Example for the two and four layers used in Question 5 (5 mm element size) (Linear hexahedral).



(a) Two layers (b) Four layers

Figure 32: Example for the two and four layers used in Question 5 (5 mm element size) (Linear tetrahedral).

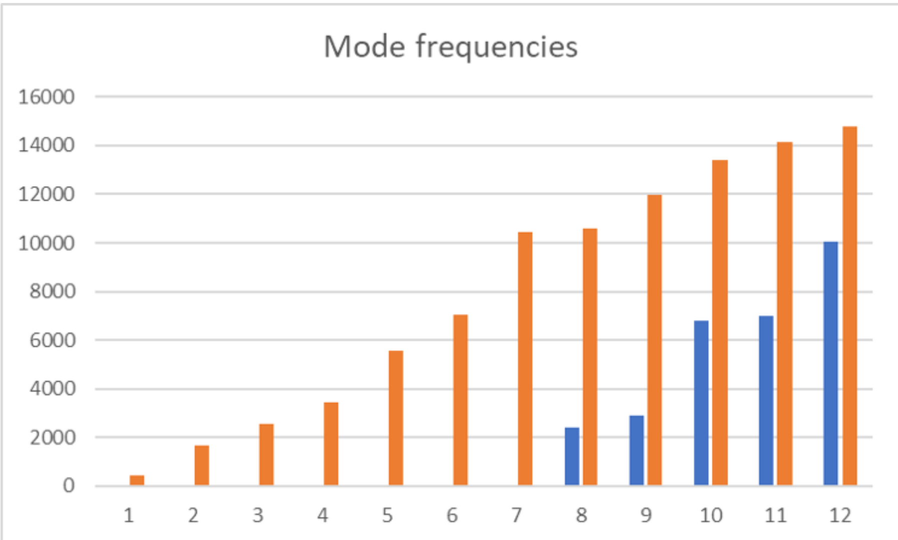
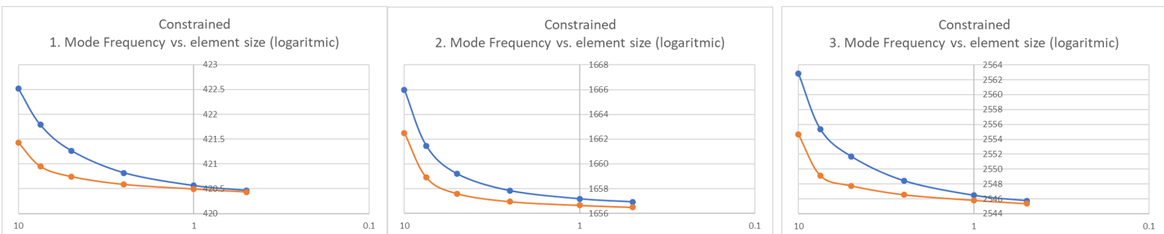
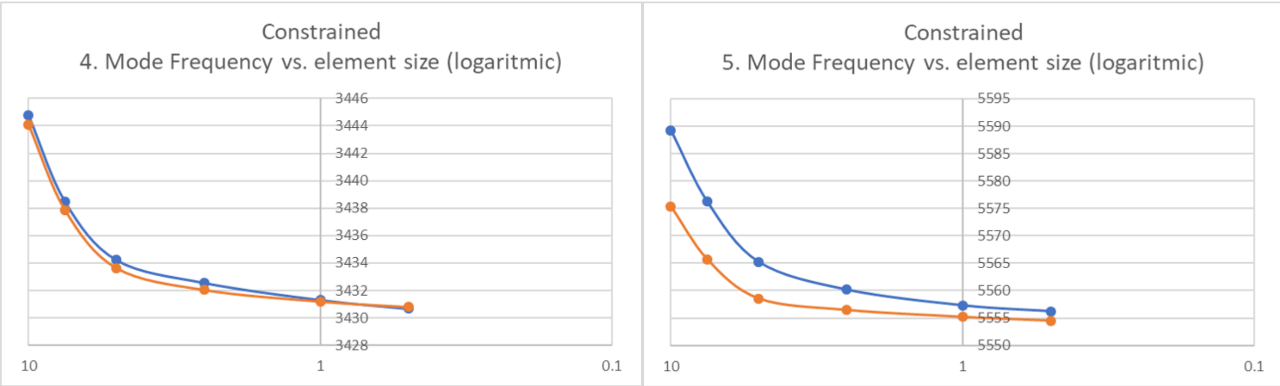


Figure 33: First 12 natural frequencies for normal (blue) and constrained (orange) modes.



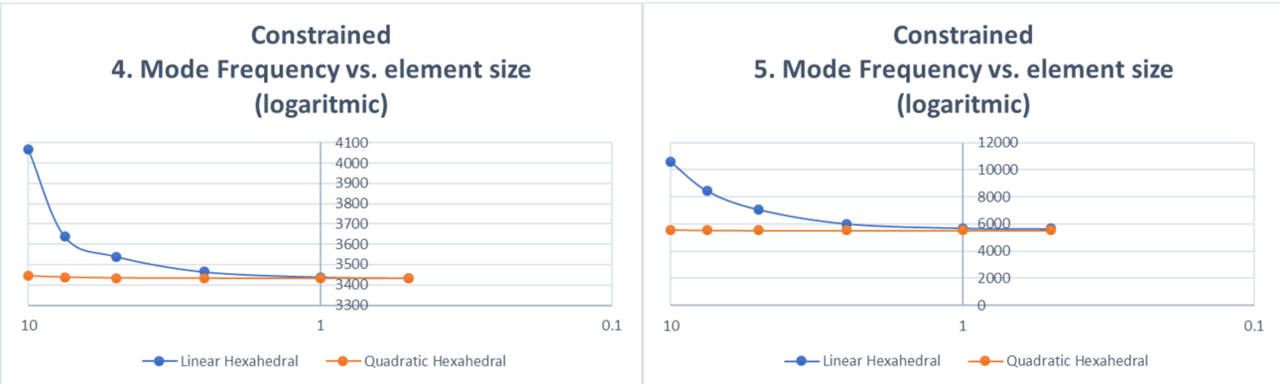
(a) 1. mode (b) 2. mode (c) 3. mode

Figure 34: **2 layers (blue) vs. 4 layers (orange)** for quadratic hexahedral.



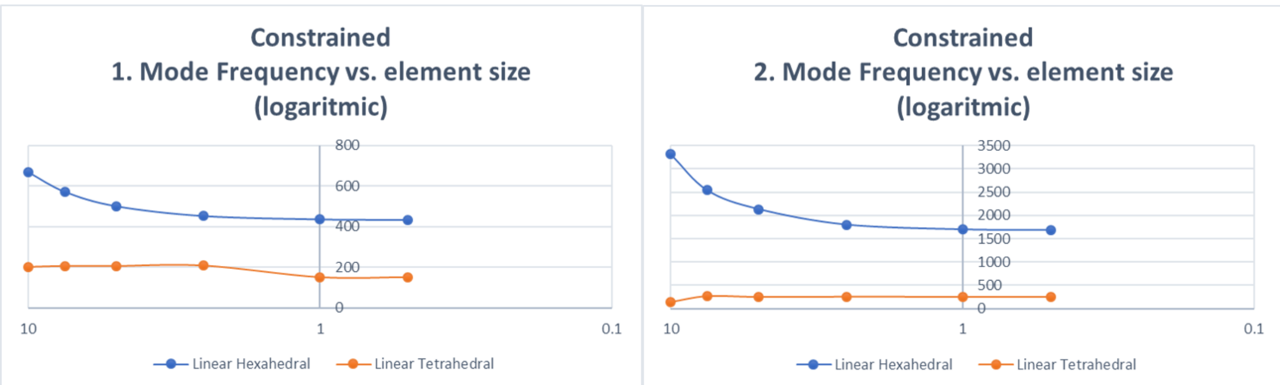
(a) 4. mode (b) 5. mode

Figure 35: **2 layers (blue) vs. 4 layers (orange)** for quadratic hexahedral.



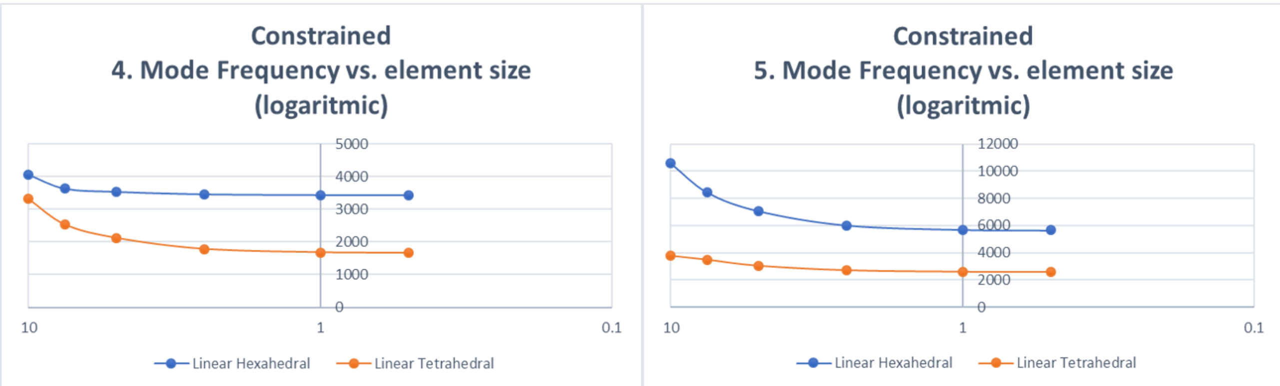
(a) 4. mode (b) 5. mode

Figure 36: **Linear hexahedral vs. quadratic hexahedral** for 4 layers.



(a) 1. mode (b) 2. mode

Figure 37: **Linear tetrahedral vs. linear hexahedral** for 4 layers.



(a) 4. mode

(b) 5. mode

Figure 38: **Linear tetrahedral vs. linear hexahedral** for 4 layers.

5.1 Deformations

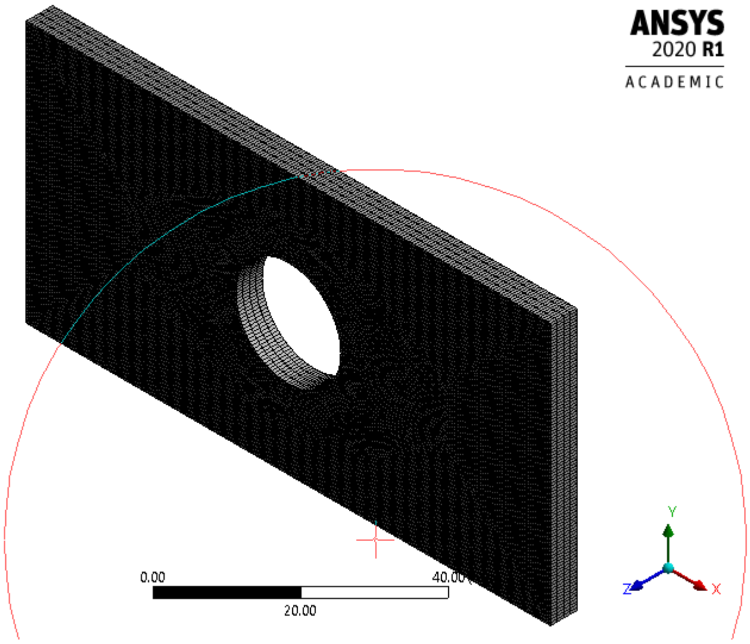
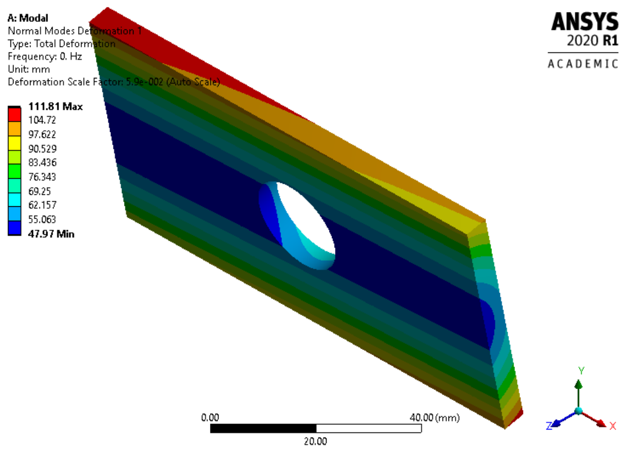
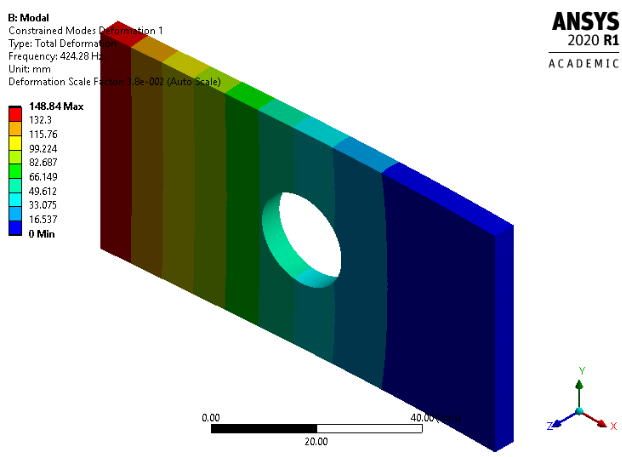


Figure 39: Deformations are given with this mesh (5 mm Linear tetrahedral).

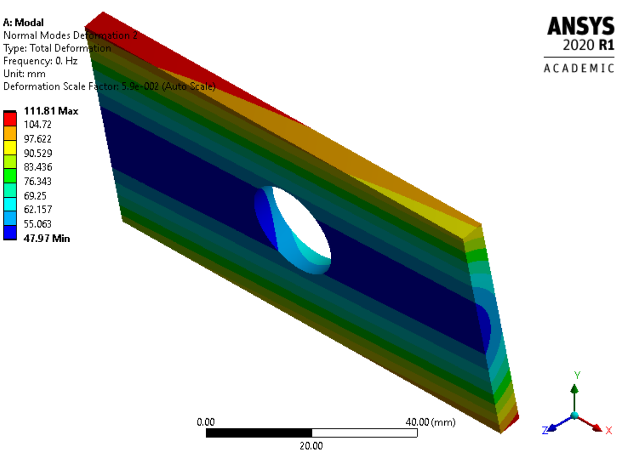


(a) Normal mode

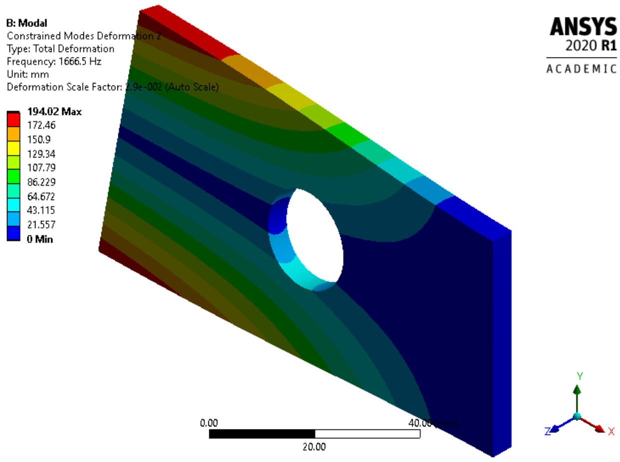


(b) Constrained mode

Figure 40: Deformation for 1. modes (Linear tetrahedral - four layer).

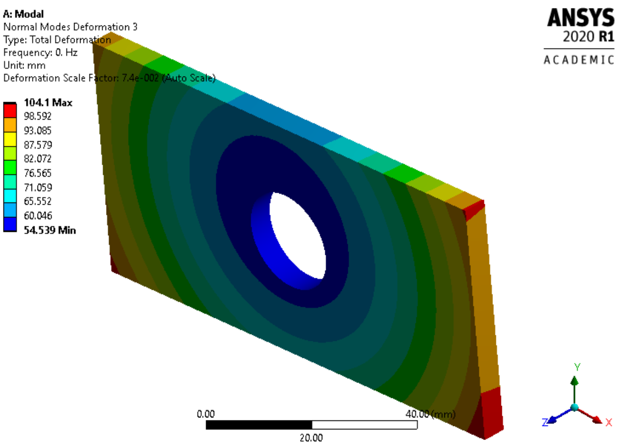


(a) Normal mode

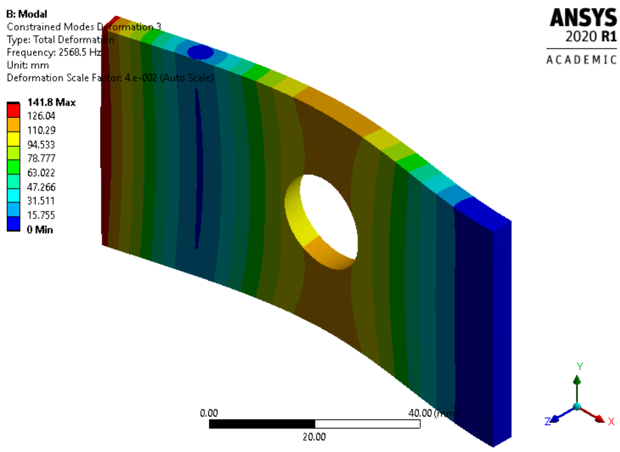


(b) Constrained mode

Figure 41: Deformation for 2. modes (Linear tetrahedral - four layer).

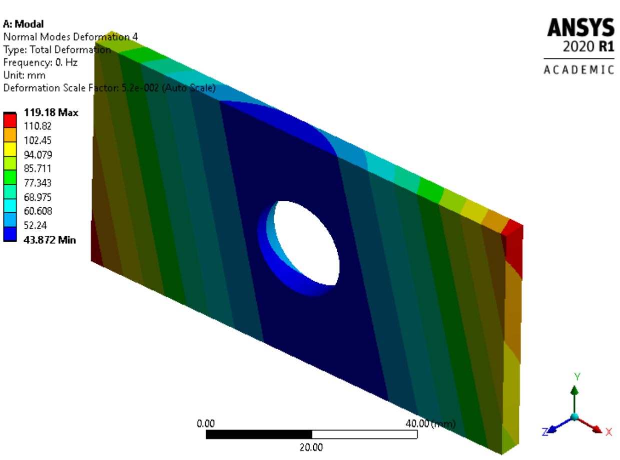


(a) Normal mode

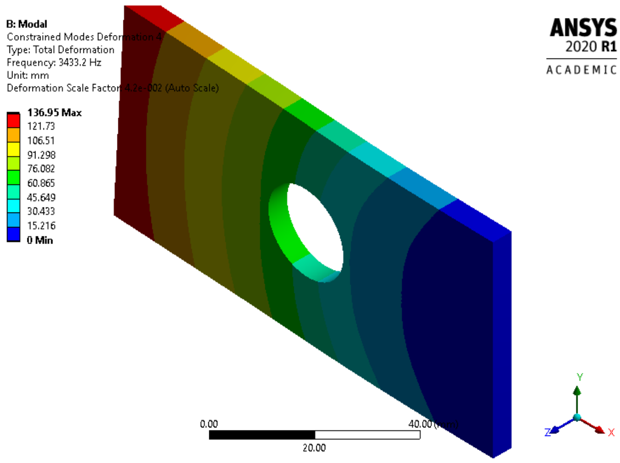


(b) Constrained mode

Figure 42: Deformation for 3. modes (Linear tetrahedral - four layer).

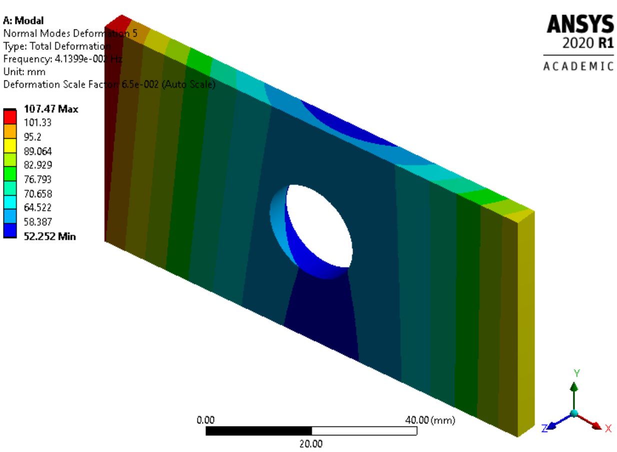


(a) Normal mode

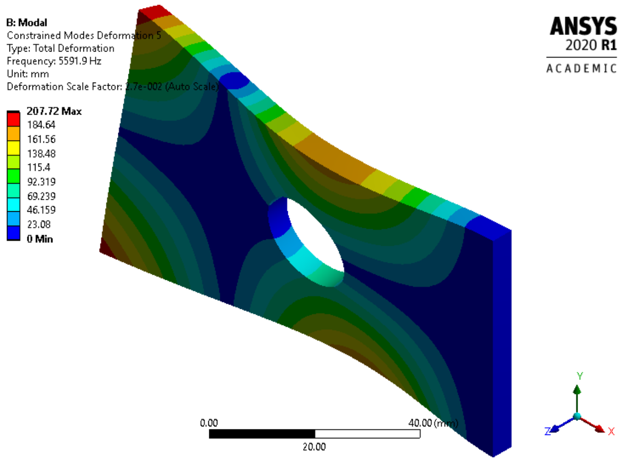


(b) Constrained mode

Figure 43: Deformation for 4. modes (Linear tetrahedral - four layer).

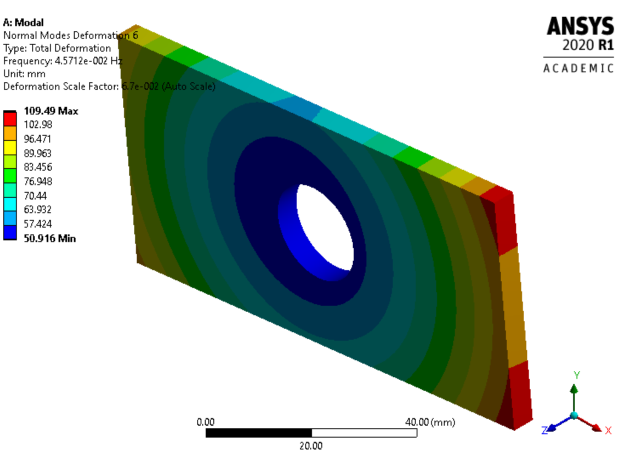


(a) Normal mode

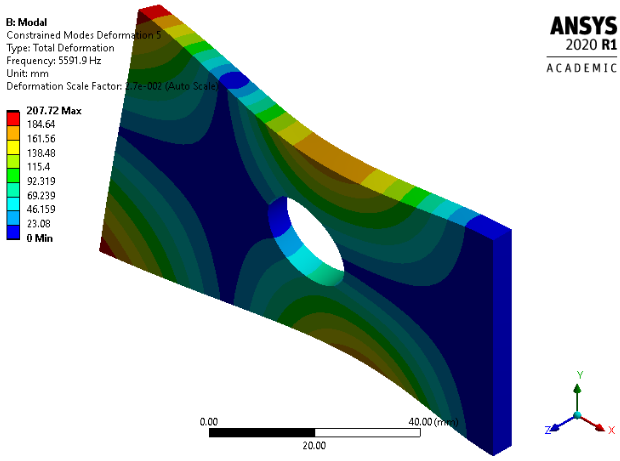


(b) Constrained mode

Figure 44: Deformation for 5. modes (Linear tetrahedral - four layer).

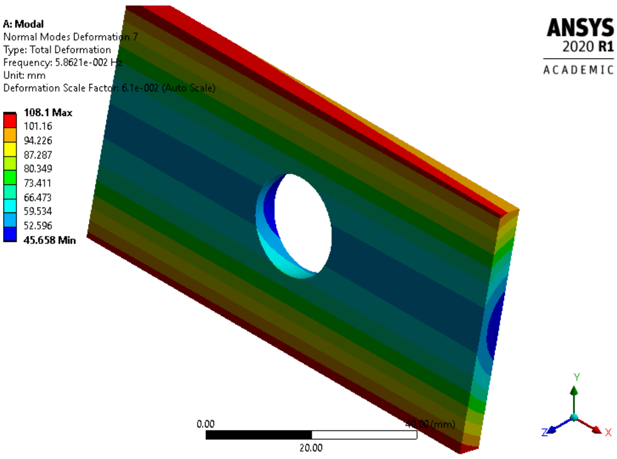


(a) Normal mode

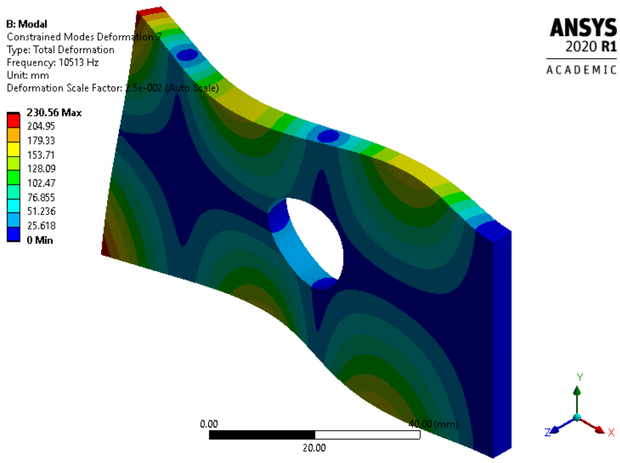


(b) Constrained mode

Figure 45: Deformation for 6. modes (Linear tetrahedral - four layer).

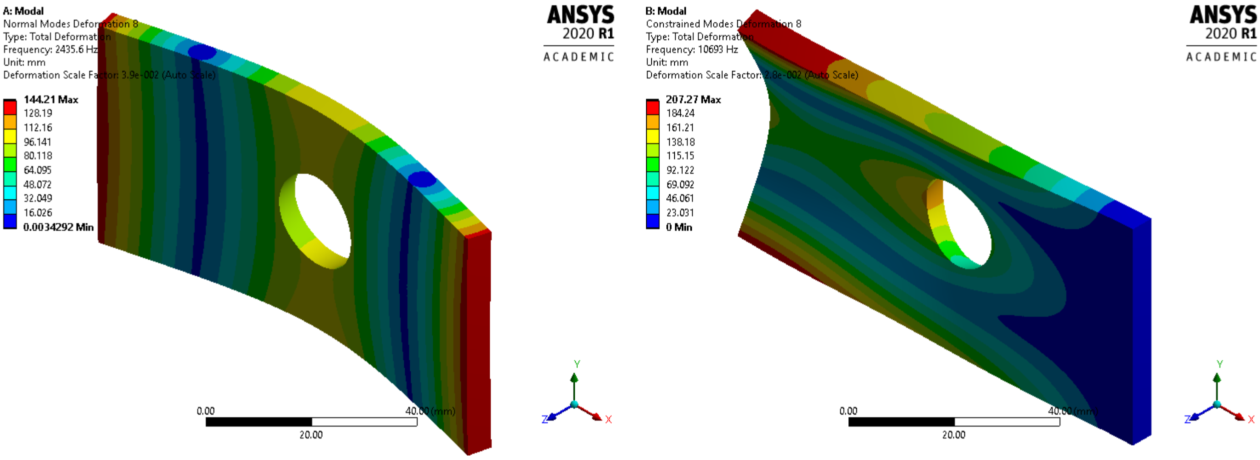


(a) Normal mode



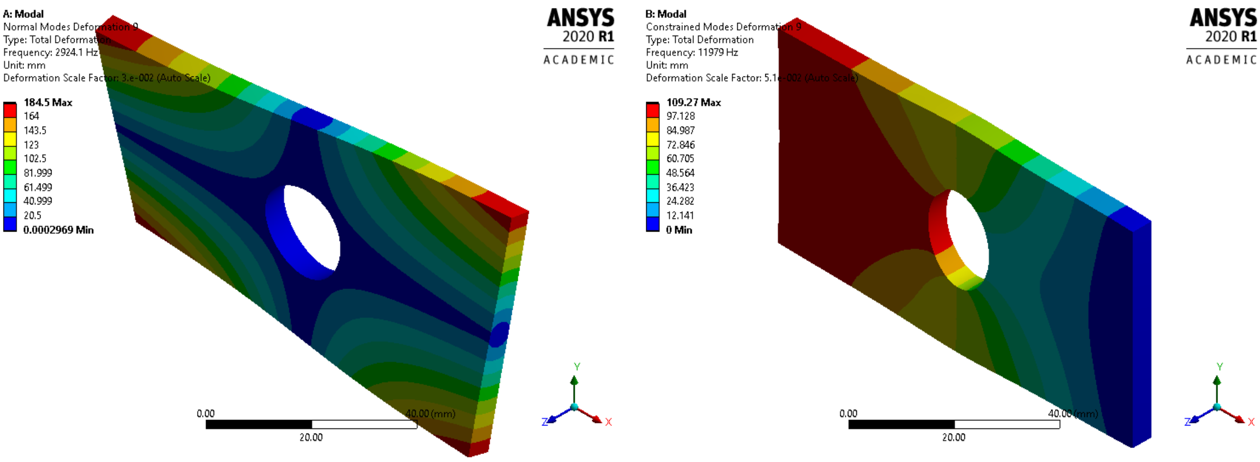
(b) Constrained mode

Figure 46: Deformation for 7. modes (Linear tetrahedral - four layer).



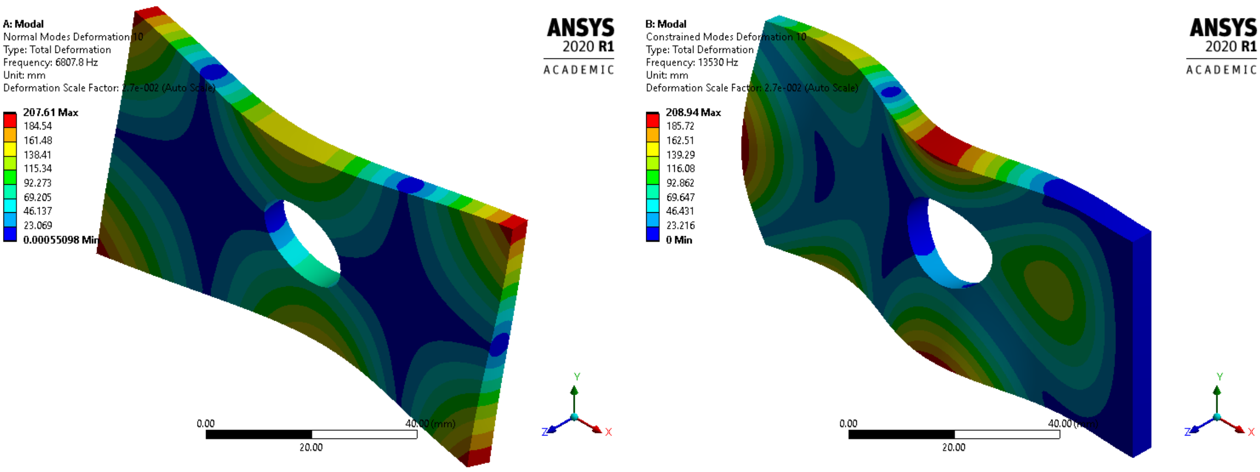
(a) Normal mode (b) Constrained mode

Figure 47: Deformation for 8. modes (Linear tetrahedral - four layer).



(a) Normal mode (b) Constrained mode

Figure 48: Deformation for 9. modes (Linear tetrahedral - four layer).



(a) Normal mode (b) Constrained mode

Figure 49: Deformation for 10. modes (Linear tetrahedral - four layer).