

**Finite element method – Nonlinear systems**  
**FHL066 – 2016**  
**Division of Solid Mechanics**

**Project 1 – General instructions**

A written report including results/conclusions should be returned to the Division of Solid Mechanics no later than **9/12 2016, 10.00**.

The assignment serves as part of the examination. A maximum of 10 points can be obtained. The task should be solved in groups of two or individually. If two persons work together they will obtain the same amount of points.

The assignment considers an analysis of the nonlinear behavior of a simple structure. To solve the problem Matlab should be used. In the toolbox Calfem, certain general FE-routines are already established and the task is to establish the extra routines needed to solve the nonlinear boundary value problem.

The report should contain a description of the problem, the solution procedure that is needed as well as the results from the calculations in form of illustrative figures and tables. The program codes should be well commented and included in an Appendix.

When writing the text it can be assumed that the reader has basic knowledge of Solid Mechanics, but it has been a while since he/she dealt with this type of analysis. After reading the report, the reader should be able to obtain all the relevant results just by reading through the report, i.e. without using the included program.

The report should be structured and give a professional description of the methods and the obtained results and be no longer than 10 pages (appendix excluded).

## A three-dimensional truss structure

The shallow truss structure, Fig. 1, shows a complex behavior when loaded and is dominated by various types of bifurcations. The geometry is given in Fig. 1, assuming  $E = 1 \text{ MPa}$ ,  $\nu = 0.3$ ,  $A = 1 \text{ mm}^2$ . The load pattern is given by  $A = 1.5F$ ,  $B = F$  and  $C = 1.5F$ .

In the calculations the element commands `bar3ge`, `bar3gs` and `bar3gf` should be used, that have been coded during the exercise sessions.

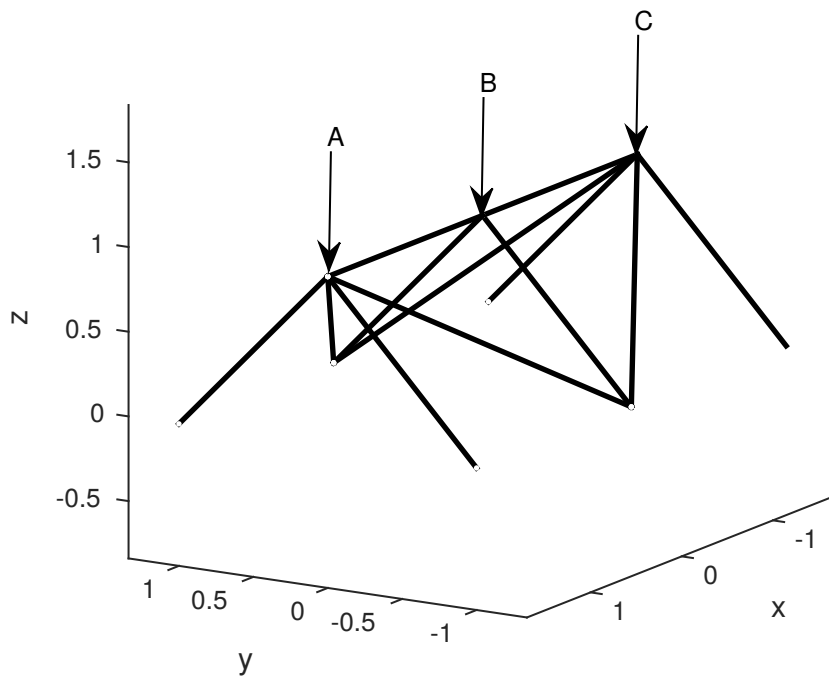


Figure 1: Geometry of the truss structure. The boundary conditions are applied at  $z=0$  and the load is applied in points A,B and C.

The tasks to be considered are

- Write a script file `newt.m` containing the Newton-Raphson loop. Force controlled loading is applied. Assume a linear relation between the second Piola-Kirchhoff stress and Green's strain. Plot the applied load as function of the displacements of nodes A and B in z-direction.
- Write a script file `crisf.m` containing the arch-length method by Crisfield. Generate plots according to Fig. (8.16) in Krenk (2009).
- Assume that the material is described by

$$S = G \left( \Lambda - \frac{1}{\Lambda^2} \right) \quad (1)$$

where  $G = \frac{E}{2(1+\nu)}$  is the shear modulus of the material and  $\Lambda = \frac{l}{l_0}$  is the stretch. Write a script file `crifn.m` using the nonlinear material model when Crisfield's method is used. Generate plots according to Fig. (8.16) in Krenk (2009).

- Plot the true force in a bar as a function of the stretch for the model given by (1). Does this model give a realistic response? Why/Why not?
- Introduce at least two perturbations, one in the geometry and one in the load such that different equilibrium curves branching from the main path becomes visible.

Commands such as `eldisp3`, `eldraw3` and `drawnow` are useful for visualization.