- basic principles of numerical analysis, intro FEM
basic principles of numerical analysis, intro FEM
- idealization, equilibrium, solutions, interpretation of results
- types of numerical engineering problems
- continuous vs discrete systems
- direct stiffness approach
- differential & variational formulation
- introduction to Patran/Nastran
Course outline

- Basic principles of numerical analysis, intro FEM
- From PDEs to numerical modeling
  - Differential formulation of the physical problem
  - Numerical analysis suitable formulation
  - Boundary conditions (essential, natural, mixed)
  - Analysis of engineering system with trusses, beams, solids
course outline

- basic principles of numerical analysis, intro FEM
- from PDEs to numerical modeling
- variational formulation
  - minimum of potential energy
  - element formulation
  - numerical interpolation / differentiation / integration
  - element assembly
  - plane stress / plane strain / 3D solid models
course outline

- basic principles of numerical analysis, intro FEM
- from PDEs to numerical modeling
- variational formulation
- properties of the numerical model/numerical solution
  - solution of the governing linear system of equations
  - solution properties / solution quality
  - convergence properties / error measure
  - convergence test, verification, validation
course outline

- basic principles of numerical analysis, intro FEM
- from PDEs to numerical modeling
- variational formulation
- properties of the numerical model/numerical solution
- linear statics and dynamics
  - time dependent problems / equations of motion
  - modeling of masses and damping / damping effects
  - explicit and implicit solution methods
  - mode superposition / modal analysis / eigenvalue problems
  - modal analysis / explicit & implicit solution methods
problem types considered – classification

- **boundary value** problems (static / steady state)
  - stationary heat flow
  - linear elasticity (truss systems, beams, slabs, ...)
  - ...

- **initial value** problems (time dependent propagation)
  - instationary heat flow
  - vibration problems
  - incremental solution geometric nonlinearities
  - ...

- **eigenvalue** problems
  - frequency analysis of structures
  - stability
  - algebraic properties of elements
  - modal decomposition
  - ...

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FEM – literature (selection)

- K.-J. Bathe
  *Finite Element Procedures*
  Prentice Hall, 1995

- R.D. Cook, D.S. Malkus, M.E. Plesha
  *Concepts and Applications of Finite Element Analysis*
  John Wiley & Sons, 1989

- T.J.R. Hughes
  *The Finite Element Method – Linear Static and Dynamic FEA*
  Prentice Hall, 2000

- B.A. Szabó, I. Babuška
  *An Introduction to FEA: Formulation, Verification and Validation*
  Prentice Hall, 2011

- O.C. Zienkiewicz and R.L. Taylor
  *The Finite Element Method – The Basis (vol 1) & Solid Mechanics (vol 2)*

...
### discrete vs continuous

**discrete**  \(\rightarrow\) reduction of complexity  \(\rightarrow\) **continuous**

- physical problem described by a set of ***algebraic equations***
- physical response at a **finite** number of points

- physical problem described by a set of ***differential equations***
- physical response at an **infinite** number of points

**finite element model**

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discrete vs continuous

differential form
- method of weighted residuals
  - collocation
  - least square approach
  - Galerkin approach

variational form
- variational principles
  - minimum potential energy
  - Hellinger Reissner \((\sigma, u)\)
  - Hu-Wahizu \((\varepsilon, u)\)

governing integral form

finite element method
- discrete system
- algebraic form
- solution of a system of equations

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