

# ME 280A: Introduction to FEM

Fall Semester 2018

**Units:** 3

**Lectures:** Tu/Th 5:00-6:30 LeConte 2

**Instructor:** Prof. Tarek I. Zohdi, 6117 Etcheverry Hall, zohdi@berkeley.edu

**GSI:** Erden Yildizdag, yildizdag@berkeley.edu

**Discussion sessions:** TBA

**Office hours:** TBA

**Text:** Zohdi, T. I. (*Book*) A finite element primer for beginners. Second Edition. Springer-Verlag.

The pdf version of this text is available for free here: <https://www.springer.com/us/book/9783319704272>

**Grading:** The course grade will be based on the following scheme:

6 – 8 homework projects 50%
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Final exam : 50%
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There is no required programming language. However, you are encouraged to use Matlab.

## Tentative topics to be covered

- 1 Weighted residuals and Galerkins method for a generic 1-D problem
  - 1.1 Introduction: Weighted Residual Methods
  - 1.2 Galerkins method
  - 1.3 An overall framework
- 2 A model problem: 1-D elastostatics
  - 2.1 Introduction: a model problem
  - 2.2 Weak formulations in one-dimension
  - 2.3 An example
  - 2.4 Some restrictions
  - 2.5 Remarks on nonlinear problems
- 3 A finite element implementation in one dimension
  - 3.1 Introduction
  - 3.2 Weak Formulation
  - 3.3 FEM approximation
  - 3.4 Construction of FEM basis functions
  - 3.5 Integration and Gaussian quadrature
    - 3.5.1 An example
  - 3.6 Global/local transformations
  - 3.7 Differential properties of shape functions
  - 3.8 Post processing
  - 3.9 A detailed example
    - 3.9.1 Weak form
    - 3.9.2 Formation of the discrete system

- 3.9.3 Applying boundary conditions
- 3.9.4 Massive data storage reduction
- 3.10 Quadratic elements
- 4 Accuracy of the finite element method in one-dimension
- 4.1 Introduction
- 4.2 The Best Approximation theorem
- 4.3 An error bound
- 4.4 The Principle of Minimum Potential Energy
- 4.5 Simple estimates for adequate FEM meshes
- 4.6 Local mesh refinement
- 5 Iterative solutions schemes
- 5.1 Introduction: minimum principles and Krylov methods
- 5.1.1 Krylov searches and minimum principles
- 6 Weak formulations in three dimensions
- 6.1 Introduction
- 6.2 Hilbertian Sobolev Spaces
- 6.3 The Principle of Minimum Potential Energy
- 6.4 Complementary principles
- 7 A finite element implementation in three dimensions
- 7.1 Introduction
- 7.2 FEM approximation
- 7.3 Global/local transformations
- 7.4 Mesh generation and connectivity functions
- 7.5 Warning: restrictions on elements
- 7.5.1 Good and bad elements: examples
- 7.6 Three-dimensional shape functions
- 7.7 Differential properties of shape functions
- 7.8 Differentiation in the referential coordinates
- 7.8.1 Implementation issues
- 7.8.2 An example of the storage scaling
- 7.9 Surface Jacobians and Nansons formula
- 7.10 Post processing
- 8 Accuracy of the finite element method in three dimensions
- 8.1 Introduction
- 8.2 The Best Approximation theorem
- 8.3 A bound on the error
- 8.4 Simple estimates for adequate FEM meshes-revisited for three-dimensions
- 8.5 Local error estimation and adaptive mesh refinement
- 8.5.1 A-Posteriori Recovery Methods
- 8.5.2 A-Posteriori Residual Methods
- 9 Time-dependent problems
- 9.1 Introduction
- 9.2 Generic time-stepping
- 9.3 Application to the continuum formulation
- 10 Summary and advanced topics: parallel processing and domain decomposition