COURSE SYLLABUS

ME/AE/BME 517

Finite Elements for Engineering Applications

Spring 2014

Course Section:	**001 CRN 29649 (ME 517)**
	001 CRN 29685 (AE 517)
	001 CRN 29686 (BME 517)
Class Time and Place:	**Tuesday & Thursday 12:40-1:55 pm ET, E-110**
Course Credit Hours:	**3**

FACULTY CONTACT INFORMATION:
Instructor: Reza Abedi
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Office Hours: Tuesday 2:15-4:15 pm and Wednesday 2-3 pm ET

I. **COURSE DESCRIPTION**: Modern computational theory applied to conservation principles across the engineering sciences. Weak forms, extremization, boundary conditions, discrete implementation via finite element, finite difference, finite volume methods. Asymptotic error estimates, accuracy, convergence, stability. Linear problem applications in 1, 2 and 3 dimensions, extensions to non-linearity, non-smooth data, unsteady, spectral analysis techniques, coupled equation systems. Computer projects in heat transfer, structural mechanics, mechanical vibrations, fluid mechanics, heat/mass transport.

Comment(s): Bachelor's degree in engineering or natural science required.
Registration Permission: Consent of instructor.

II. **COURSE OBJECTIVE**: The objective of the course is to prepare students to use the finite element method as a computational tool in their current and future works. Also, for those whose research or interest is more on the development of finite element methods, this course serves as a solid background that students can build upon. For these reasons, we do not attempt to derive finite element formulations for a large number of element shapes and/or physics problems. Instead, more emphasis is on providing a deep understanding of the main concepts, demonstrated by perhaps a more limited set of elements.

III. **STUDENT LEARNING OUTCOMES**: Students will be able to:

- Discern the connections between balance laws, governing differential equations and boundary conditions, weak and strong forms, energy methods, and finite element formulation.
- Formulate, and solve a problem using finite element method (FEM formulation, assembly, solution, and error analysis)
- Implement (parts of) a finite element formulation in a computer language.
- Use commercial finite element packages for solid, fluid, and thermal problems.

IV. **TEXTS/MATERIALS/RESOURCES FOR THE COURSE:**

- Course textbook:
  - K. J. Bathe; Finite Element Procedures. Cambridge, MA: Klaus-Jurgen Bathe, 2007. ISBN: 9780979004902 (main textbook).
  - A. J. Baker; Finite Elements: Computational Engineering Sciences, John Wiley & Sons, 2012. ISBN: 978-1-118-36991-3.
- Recommended textbooks:
  - T. J. R. Hughes; The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publications, 2000. ISBN: 978-0486411811.
  - O.C. Zienkiewicz, R.L. Taylor, J.Z. Zhu; The Finite Element Method: Its Basis and Fundamentals, Butterworth-Heinemann; 6th edition, 2005. ISBN: 9780750663205.

V. **COURSE REQUIREMENTS, ASSESSMENT AND EVALUATION METHODS:**

- Exams: There is one midterm exam (20%) and a final exam (30%).
- Assignments: Homework assignments take up 50% of the grade. Assignments typically involve a computational part that requires writing/modifying small computer codes (Matlab, C++) or using commercial packages such as COMSOL. The assignments include challenge problems" that can add up to 5-10% to the final grade.
- Absences and excused grades: Excuses will be given only under the following circumstances:
  - illness
  - personal crisis (e.g. automobile accident, death of a close relative)

  otherwise there is a 15% penalty per day for late assignments.

VI. **UNIVERSITY POLICIES:** The students should abide by the UTK honor statement included on the Campus Syllabus available on the Provost and TennTLC websites, and the online UT catalog. The honor statement includes information about discrimination, scholastic dishonesty, cheating, and plagiarism policies. All the homework assignments and exams are individual assignments unless otherwise noted by the instructor.

VII. **COURSE OUTLINE:** All the concepts in the course outline will be taught with reference to familiar structures such as rigid bodies, bars, beams, and plates.

1. Finite element formulation:
   a. Balance laws
   b. Governing (partial) differential equations (DEs/PDEs) and jump conditions
   c. Essential and Natural boundary conditions
   d. Method of weighted residual
   e. Weak and strong forms
   f. Energy methods
2. Formulation and Derivation of the approximate system of equations (the concepts are taught using the element types given in square brackets)
   a. Types of approximation
   b. Discretization with finite elements
   c. Shape functions and nodal degrees of freedom (d.o.f.)
   d. Local stiffness matrix and load vector [bar element]

   e. Assembly from local to global stiffness matrix and load vector [bar element]
   f. Properties of stiffness matrix
   g. Enforcement of essential boundary conditions (*e.g.* displacement for solid)
   h. Conversion from local to global coordinate systems [bar and truss elements]
   i. Iso-, sub-, and super-parametric elements [triangular, square, tetrahedral, and cubic elements]*
   j. Numerical integration (quadrature)
3. Error analysis, post-processing, and adaptivity
   a. Stability, convergence, and a-priori error estimate
   b. Recovery process and superconvergence*
   c. Adaptivity (*h*-, *p*-, and *hp*-adaptivity)*
4. Solution of the derived equations from finite element method
   a. Time dependent problems (hyperbolic and parabolic)**:
      i. Advancing the solution in time (*e.g.* time stepping)
      ii. Implicit vs. explicit time integration
   b. Solution to a linear system of equations: direct vs. iterative solvers*
   c. Solution methods for nonlinear problems
   d. Brief discussion on problems leading to an eigensolution (natural frequency/mode analysis; buckling (stability) analysis) and their solution methods*
5. Finite element method for thermal (heat conduction) and fluid (incompressible fluid flow) problems
6. Brief comparison of various numerical methods
   a. Finite element method vs. finite difference (FD) and finite volume (FV) methods
   b. Comparison of various finite element methods (spectral, discontinuous Galerkin, X-FEM, *etc.*)*
   c. Mixed finite element methods with applications*
7. Current research trends related to finite element methods*: Brief discussion on
   a. The development of advanced finite element methods that address the current and future computational challenges (*e.g.* large scale, parallel, adaptive, and multiscale)
   b. Some current areas in energy, bioengineering, and material design that can use finite element as a computational tool.

*: These are special topics and depending on the progress of the class they may be only briefly covered or excluded from the syllabus (**2.i, 3.b&c, 4.b & d, 6.b & c, 7**)

**: A Comprehensive discussion of time-dependent problems is beyond the scope of this course; however, the students will be exposed to common issues and solution strategies for these problems.

VIII. IMPORTANT DATES IN THE ACADEMIC CALENDAR SPRING 2014:

Last Day to Add or Drop without a "W"	January 12, 2014
Martin Luther King, Jr. Day (no classes)	January 20, 2014
Spring Break (No Classes)	March 17-21, 2014
Last Day to Drop with a "W"	April 1, 2014
Spring Recess (No Classes)	April 18, 2014
Last Day of Classes	April 25, 2014
Final Exam	TBD