FALL SEMESTER, 2024
MAE 533/001 (on campus)/601(EOL)
2207 EB III, 8:30 M/W
Introduction to the Finite Element Method
Instructor: Dr. M.A. Zikry
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This course will provide a general preparation in computational solid mechanics for graduate engineering, science, and mathematics students with an emphasis on theory and engineering applications for research in areas related to elasticity, plasticity, fracture mechanics, structural mechanics, mechanical design, and numerical analysis. Basic functional analysis and variational calculus approaches will be introduced to understand the fundamentals of the Finite Element Method in addition to applied physical examples and applications.

Strongly recommended prerequisites: Advanced Strength of Materials, Elasticity, or Continuum Mechanics, Linear Algebra, PDEs, and use of MATLAB or equivalent, proficiency in Fortran, C++, or equivalent.

Week 1 An Introduction to the Use of Finite Element Procedures: Physical problems and mathematical models; Applications of FEM in engineering and physics.

Weeks 1-2 Basic Mathematical Methods: Introduction to matrices; vector spaces; Basic tensors.

Weeks 3-5 Basic Concepts of Engineering Analysis and the Finite-Element Method: Structural Matrices; Mathematical basis of FEM method and weak formulations; Discrete mathematical models: steady state solutions, eigenvalue problems; Continuous system mathematical models: differential formulations, variational formulations, weighted residual methods, Ritz method, Galerkin formulations; Principle of Virtual Displacements; Energy methods.

Weeks 6-7 Formulation of the FEM-Linear Analysis in Solid and Structural Mechanics: Formulation of the Displacement-Based FEM: General derivation of finite-element equilibrium equations, imposition of displacement boundary conditions, generalized coordinate models, lumping of structure properties and loads; Convergence analysis of results: Criteria for monotonic convergence, properties of finite-element solutions, rate of convergence, calculation of stresses and the assessment of error; Incompatible and mixed FEM: Incompatible displacement based models, mixed formulations, mixed interpolation, incompressible analysis.

Weeks 7-8 Formulation of Isoparametric Finite Element Matrices: Isoparametric derivation of stiffness matrix; Formulation of continuum elements: Quadrilateral elements, triangular elements; Convergence considerations; Element matrices in global coordinate system; Displacement/pressure based elements for incompressible media; Numerical integration: Interpolation polynomials, Newton-Cotes formulas, Gauss formulas; integrations in two and three dimensions; appropriate order of numerical integration. Modeling considerations

Weeks 9-10 Solution of Equilibrium Equations in Static Analysis: Direct Solutions: Gauss Elimination; Cholesky factorization; Computer implementation; Positive definitenesses and Sturm sequence property; Iterative Solutions: Gauss Seidel Method and Conjugate Gradient

methods with preconditioning; Solution Errors

Weeks 11-12 Specialized Integration Methods: Reduced, Selective, and B-bar methods for incompressibility, bending, and thin structures

Weeks 12-13 Plate/Shell formulations: Thin/thick plate formulation, solution methods

GRADING

Exams-Midterm and Final (each 25%) **50%**

HWs/Projects **50%**

Projects/HWs Submitted/graded on Moodle: Time windows strictly enforced
No emailed submissions!

Exam # 1: Midterm October 16th (take home)

Exam # 2: Final 12/9/2024, 8:30 AM

Grading: Will be based on class curve

Knowledge of Fortran, C, C++, MATLAB, or other programming languages is essential.

Class Notes, PDF files and relevant papers will be handed out and will form the main core of the lectures. Lectures will be on tape and will be available to on campus students

Books on Reserve in Library

Concepts and Applications of Finite-Element Analysis by Cook, Malkus, Plesha

Finite-Element Procedures, Bathe

Office HRs: 10-11:00 M/W or by appointment

Expectations, Policies and Attendance

Academic Integrity

I will strictly enforce NC State's standards of academic honesty. I expect that you will neither give nor receive unauthorized aid on any tests. Please refer to the following website for further details:http://www.ncsu.edu/policies/student_services/student_discipline/POL1.1.35.1.php.

Disability

Accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. http://www.ncsu.edu/provost/offices/affirm_action/dss/ For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation(http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.1.php).