EM 4123/6123: Introduction to the Finite Element Method
CRN 11388/11391/13403 Spring 2010

INSTRUCTOR: Dr. James C. Newman III
Associate Professor of Aerospace Engineering
316D Walker Engineering Building
Phone: ASE (HPC^2) 325-7292 (7722)
E-mail: newman@ae.msstate.edu

OFFICE HOURS: MWF 11:00 – 12:00 or by appointment

CATALOG DATA: (Prerequisites: Consent of Instructor). Introduction to the mathematical theory, formulation, and computer implementation of the finite element method. Application to one-and two-dimensional problems in engineering mechanics.

TEXTBOOK: Reddy, J.N., 2005, An Introduction to the Finite Element Method, 3rd Edition, McGraw-Hill.

ADDITIONAL REFERENCES:

Zienkiewicz, O.C., and Tayor, R.L., The Finite Element Method, Volume 1: Basic Formulations and Linear Problems, McGraw-Hill.

Cook, R.D., Malkus, D.S., and Plesha, M.E., Concepts and Applications of Finite Element Analysis, 3rd Edition, Wiley.

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

ASSESSMENT:

Homework/Quizzes	15%
Tests	60%
Final	25%

ACADEMIC HONESTY AT MSU:

Academic honesty will be strictly enforced in this course. All assignments are considered individual work. Policies and procedures concerning Academic Misconduct can be found in the University Handbook or on the University website.

TENTATIVE COURSE TOPICS:

1. *Integral Formulations and Variational Methods*: Introduction to the weak-formulation of boundary value problems; variational methods of approximation; Raleigh-Ritz method; and the method of weighted residuals.

2. *Basic Steps of Finite Element Analysis (FEA)*: Discretization of the domain, derivation of element equations, connectivity of elements and assembly of element equations, imposition of boundary conditions, solution of equations, and post-processing and interpretation of results.
3. *FEA of One-Dimensional Problems*: Second-order boundary value problems in heat transfer, fluid mechanics, and solid mechanics. Fourth-order boundary value problem in solid mechanics (bending of beams).
4. *Finite Element Error Analysis*: Measures of error, accuracy, and convergence of solution.
5. *Numerical Integration and Computer Implementation*: Isoparametric formulation using natural coordinates; selection of interpolation function for rectangular, triangular, and serendipity elements; numerical integration/quadrature; modeling considerations.
6. *FEA of Two-Dimensional Problems*: Solution to boundary value problems from heat transfer, fluid mechanics, solid mechanics, and plane elasticity.

Details of Topics Covered:

- Mathematical Preliminaries
- Integral Formulations and Variational Principles
- One-Dimensional Problems

  Second-order boundary value problems
  Derivation of Interpolation functions (Lagrange family)
  Derivation of element stiffness matrix and source (load) vector
  Boundary conditions, continuity, and discretization
  Radially symmetric problems
  Applications:
  Solid Mechanics- Axial deformation of bars/rods
  Heat Transfer- Longitudinal heat conduction in a rod/fin
  Fluid Mechanics- Flows through pipes/channels (Poiseuille Flow)

  Fourth-order boundary value problems
  Derivation of Interpolation functions (Hermite family)
  Derivation of element stiffness matrix and source (load) vector
  Boundary conditions, continuity, and discretization
  Euler-Bernoulli frame elements
  Timishenko (shear deformation) beam and frame elements
  Applications:
  Solid Mechanics- Planar trusses and frames

  Numerical Integration
  Coordinate transformation
  Approximation of the geometry: Isoparametric formulation
  Newton-Cotes quadrature
  Gauss-Legendre quadrature

- Error Analysis
  Types and origins of errors
  Measures of errors/accuracy of solution
  Convergence of solutions
  A priori error estimation

- Two-Dimensional Problems

  Second-order boundary value problems
  Derivation of Interpolation functions (triangle, quadrilateral, serendipity elements)
  Derivation of element stiffness matrix and source (load) vector
  Boundary conditions, continuity, and discretization
  Axisymmetric problems

Applications:
- Solid Mechanics- Torsion of members of constant cross-section
- Heat Transfer- Heat conduction in a slab/plate
- Fluid Mechanics- Irrotational flow of an ideal fluid

Numerical Integration
- Coordinate transformation
- Approximation of the geometry: Iso-, sub-, super-parametric formulations
- Gauss-Legendre quadrature

Plane Elasticity
- Governing Equations (Static)
  - Equations of Equilibrium
  - Strain-Displacement relations (small strain/small displacement; i.e., linear)
  - Constitutive Relations (Plane stress/Plane strain)
  - Derivation of element stiffness matrix and source (load) vector
- Boundary conditions, continuity, and discretization
- Symmetry

Viscous, Incompressible Flows (Time Permitting)
- Governing Equations
  - Conservation of Mass
  - Conservation of momentum
- Velocity-Pressure finite element model
- Penalty-Finite element model
  - Penalty function method
  - Lagrange multiplier method