Georgia Institute of Technology
School of Civil &Environmental Engineering
Finite Element Methods CEE 6504 – Spring 2022

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Office hours: Wed, 4:00 - 5:00 pm- Online via BlueJeans
Classroom: Mason 3132
Class period: Tuesday, Thursday, 2:00 - 3:15 pm

Introduction
One of the most important things engineers and scientists do is to model physical phenomena. Virtually every phenomenon in nature, whether civil, aerospace, biological, chemical, geological, or mechanical can be described, with the aid of laws of physics or other fields in terms of algebraic, differential, and/or integral equations relating various quantities of interest. These analytical descriptions of physical phenomena and processes are called *mathematical models*.

The processes to be studied, until the advent of electronic computation, were drastically simplified so that the governing equations can be solved analytically.

Over the last four decades, however, *computers* have made it possible, with the help of suitable *mathematical models* and *numerical methods,* to solve many practical engineering applications. Numerical methods typically transform differential equations governing a continuum to a set of algebraic equations of a discrete model of the continuum that are to be solved using computers.

The use of numerical methods and a computer to evaluate the mathematical model of a process and estimate its characteristics is called *numerical simulation*.

The Finite Element Method and its generalizations are the most powerful computer oriented numerical methods ever devised to analyze practical engineering problems.

Course Objectives:
This course is intended to provide graduate students with the theory and applications of the linear finite element analysis of problems from solid and structural mechanics. At the end of the course one would have acquired knowledge of finite element analysis of many typical linear problems of structural mechanics. Also one of the major objectives is that the students by the end of the course to acquire the appropriate knowledge to provide assurance that the finite element model produced gives a reasonably reliable representation of the "real life" structure being analyzed.

Course Contents

- **Background: Introduction to numerical methods**
    - Overview - basic ingredients of the FEM
    - Review of matrix structural Analysis
    - Fundamental concepts of solid mechanics

- **The basic concepts in FEM one-dimensional problems**
    - Interpolation and shape functions
    - Axial deformations of a bar
    - Strong and weak forms
    - Essential vs. natural boundary conditions
    - Integral statements (Principle of virtual displacements, principle of minimum potential energy)
    - Methods of approximations (Ritz & Galerkin methods)
    - Accuracy error measures
    - Finite element approximation functions (linear, quadratic and cubic elements)
    - Assembly of element equations
    - Illustrative examples and discussion of results in light of physical response

- **Numerical Integration**
    - Background
    - Natural coordinated
    - Approximation of Geometry
    - Isoparametric formulations
    - Numerical integration

- **Generalization of the basic concepts to two dimensions**
    - Plane elasticity (plane strain and plane stress) problems
    - Elements types (triangular and quadrilateral elements)
    - Subparametric, isoparametric and superparametric formulations
    - Axisymmetric problems

- **Extension of the concepts to higher-order boundary value problems**
    - Flexure of beams (Euler-Bernoulli and Timoshenko)
    - Bending of thin and thick elastic plates

- **Three-dimensional elasticity problems**

- **Eigenvalue problems**
    - Free vibration of elastic systems (natural frequencies, modal response etc.)
    - Buckling

- **Dynamic response of elastic systems**
    - Elastodynamics
    - Time integration procedures
    - Explicit dynamic integration
- **Numerical/computational issues**
    - General modeling considerations
    - Different solution schemes
    - Meshing and errors in modeling
    - Adaptive meshing

The sequence of the actual contents may be different to facilitate a smooth transition from topic to topic

Text: - **An Introduction to the Finite Element Method**
J. N. Reddy
3rd edition, McGraw Hill, (ISBN# 0-07-246685-5). Free access to the e-copy through GT library
- **Introduction to Finite Elements in Engineering**
T. R. Chandrupatla and A. D. Belegundu
4th edition, Pearson (ISBN-10#0-13-216274-1

Additional readings:
- Concepts and applications of Finite Element Analysis, R. D. Cook, D. S. Malkus, M. E. Plesha, and R. J Witt, Wiley.
- The Finite Element Method O. C. Ziekiewicz and R. L. Taylor, Vo1,2, McGrawHill.
- Finite Element Procedures, Klaus-Jürgen Bathe, Prentice Hall.
- Introduction to Finite Element Methods, Carlos A. Felippa, University of Colorado at Boulder.

Policy:
- The students are expected to gradually implement their acquired knowledge of Finite Element into a fully operational MATLAB programs for each stage of the course.

Course grading:

	Homework :	30%
	Project:	40%
	Mid-Term:	30%

- **Office hours:** In addition to the announced office hours you can request a meeting by email.
- ***Withdrawal Deadline****: last day to withdraw from the course with "W" grade is by March 18, 2022, 4:00 pm EST.*
- **Mid-Term Exam on Thursday, April 14, 2022.**
- **Final project presentation will be during the final exam period. Thursday April 28th. 2:40 – 5:30 pm**

- Homework must be turned in by 1:30 pm of the due date. After then, it will be considered late with a deduction of 15% per day including weekends as long as the solution is not posted.
- In order to receive a passing grade in the class, you must receive a passing grade on the Projects.

- **Georgia Tech's code of academic integrity will be strictly enforced:**
  See complete text at https://osi.gatech.edu/content/honor-code