CEE4552 Syllabus

Introduction to Finite Element Method

Section A

3 Credits hours

Fall 2026

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Office Hours: Thursdays

Description

This course introduces the Finite Element Method (FEM), a fundamental numerical technique used to model and analyze physical systems in engineering and science. Engineers and scientists routinely represent real-world phenomena, across civil, mechanical, aerospace, and other disciplines, using mathematical models based on physical laws, often expressed in the form of algebraic, differential, or integral equations.

Historically, these models were simplified to enable analytical solutions. However, with the advancement of computational tools, it is now possible to solve complex, realistic problems using numerical methods. The Finite Element Method transforms governing differential equations of continuous systems into a set of algebraic equations defined over a discretized domain, which can be efficiently solved using computers.

This course introduces the principles of discretization, element formulation, and system assembly, and demonstrates how numerical simulation can be used to approximate the behavior of engineering systems. Emphasis is placed on understanding the theoretical foundation of FEM and its application to practical problems. By the end of the course, students will gain the ability to model and analyze engineering systems using finite element techniques, forming a basis for advanced computational analysis and design.

Part I. Introduction to Matrix Structural Analysis

1. Types of Structures: Trusses.

2. Idealization of Structures and Supports
3. Degrees of freedom
4. Concept of stiffness in structural elements.
5. Element stiffness for trusses.
6. Local and global coordinate systems and transformation.
7. Assembly of global stiffness matrix.
8. Formulation of load vector.
9. Boundary conditions.
10. System Solution and relevant quantities.

Part II. Introduction to Finite Element Methods – Computer Applications

1. Overview – basic ingredient of the FEM
2. Total potential energy
3. The principle of minimum total potential energy
4. Function interpolation and shape functions
5. Natural coordinate system
6. Truss Bar Element
    a. Displacement function and shape functions
    b. Stiffness matrix in local coordinate system
    c. Transformation
    d. Assemblage method
    e. Boundary conditions
    f. Solution of equilibrium system of equations
    g. Reactions and internal forces
    h. 3-D truss bar element

7. **Beam and Frame Element**
    a. Displacement function and shape functions
    b. Stiffness matrix in local coordinate system
    c. Transformation
    d. Assemblage method
    e. Boundary conditions
    f. Solution of equilibrium system of equations
    g. Reactions and internal forces
    h. 3-D frame element
    i. Transformation for 3D frame element

8. **Free Vibration of truss bar, beam, and plane frame finite elements**
    a. One d.o.f. spring-mass system
    b. Axial vibration of two d.o.f. truss bar element
    c. Solution of eigen-value problem

d. Flexure vibration of beam elements
e. Axial-flexure vibration of frame elements

9. Two-Dimensional Continuum Problem-Constant Strain Triangle Element

a. Introduction to 2D continuum problem
b. Finite element modeling
c. Constant Strain Triangle (CST)
d. Potential energy approach
e. Element stiffness matrix
f. Nodal equivalent forces
g. Stress calculations

10. **Project Description:**

This project aims at developing a program in MATLAB to analyze two-and three-dimensional trusses. The project will be similar to the MATLAB assignments in homework assignments. Students will be provided with some components and skeleton files to facilitate their work and unify the development and grading procedure. In this project, at first, students need to become familiar with the components of the MATLAB program. Some of these components are incomplete. The students will be given instructions to help them complete the program functions and obtain a working package. Students also need to submit a written report along with their code that explains the different steps and findings during developing this program.

Report instructions including format and content requirements will be distributed later in the course.

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

- Explain the fundamental concepts and formulation of the Finite Element Method (FEM).
- Describe the basic principles of solid and structural mechanics underlying FEM.
- Apply energy methods in the formulation of finite element models.
- Develop and analyze finite element models for trusses, frames, and two-dimensional structural problems.
- Solve linear static and basic dynamic problems involving truss and frame structures.
- Evaluate the accuracy and reliability of finite element models in representing real-world structural behavior.

Required Course Materials

1. **Instructor's lecture notes** will be available for the students in pdf format.
2. **Finite Element Structural Analysis**, TY. Yang, Prentice-Hall, Inc., Englewood, New Jersey, 1986. Copy right reserved to the author with permission from the author to be available to the students and to be used only in the class (available in pdf for free).

Additional suggested textbooks:

1. - **An Introduction to the Finite Element Method,** J. N. Reddy, 3rd edition, McGraw Hill, (ISBN# 0-07-246685-5). Electronic copy is available in Georgia Tech library for free.
2. **Introduction to Finite Elements in Engineering,** T. R. Chandrupatla and A. D. Belegundu, 4th edition, Pearson (ISBN-10 # 0-13-216274-1.

Grading Policy:

All exams will be closed book and administered during the regular class schedule. The final exam will consist of a **project presentation** conducted during the Institute's official final exam period.

Homework	**25**%
Midterm 1	**20**%
Midterm 2	**30**%
Final Exam (project)	**25**%

Your final grade will be assigned as a letter grade according to the following scale:

- A 90 – 100 %
- B 80 – 89 %
- C 70 – 79 %
- D 60 – 69 %
- F 0 – 59 %

Final grades are calculated based on weighted average of homework assignments, midterm exams, and the final exam.

Assignments

List all graded components clearly:

- Homework (weekly) – 25 %: All homework assignments are equally weighted.
- Midterm Exam 1 – 20% (closed book).
- Midterm Exam 2 – 30% (closed book).
- Final Exam (project) – 25%.

Attendance and/or Participation

- Attendance is expected.
- Participation is encouraged.

Academic Integrity

- Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. Review Georgia Tech's Honor Code and the student Code of Conduct.
- Any student suspected of cheating or plagiarism on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodation for Students with Disabilities

- If you are a student with learning needs that require special accommodation, contact the Office of Disability Services (404-894-2563) as soon as possible to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Student-Faculty Expectations Agreement

- In this course, we aim to maintain a respectful and productive learning environment. Students can expect clear instruction, timely communication, fair grading, and support during office hours. In return, students are expected to attend class regularly, come prepared, submit assignments on time, uphold academic integrity, and engage respectfully with others. Mutual respect and professionalism are essential to achieving a positive and effective learning experience.

Pre- &/or Co-Requisites

- Prerequisites:

Collaboration, Group Work, and Use of Generative AI

  - Students can discuss concepts.
  - AI is allowed for learning.

Late Assignments & Missed Exams

- Homework Assignments: Assigned every Friday and due by 11:59 PM on the following Friday. All submissions must be uploaded to Canvas (canvas.gatech.edu) by the deadline**.**
- Late Policy: Late homework will be accepted for up to 1 day after the due date with a 20% penalty. Late submissions are allowed no more than two times during the semester and will not be accepted after solutions are posted.
- Solutions: Homework solutions will be posted weekly on Canvas.
- Exams: If you are unable to take an exam on the scheduled date, you must notify and discuss it with the instructor in advance to make appropriate arrangements.

Extensions Inclement Weather and Digital Learning Days

- In the event of inclement weather or changes to campus operations, updates regarding class cancellations or a transition to digital learning will be announced on Canvas (canvas.gatech.edu). Students are responsible for checking Canvas regularly for course updates.

Campus Resources for Students

Student Academic Success Resources:

- Academic Support: Academic Success and Advising (a unit in the Office of Undergraduate Education & Student Success) provides free support for your

courses. Students can attend scheduled supplemental review (PLUS) sessions, stop by Drop-In Tutoring, or schedule a one-on-one appointment through Knack. To explore what options work best for you, please visit us online at success.gatech.edu/tutoring, email us at tutoring@gatech.edu, or come see us at Clough Undergraduate Learning Commons, Suite 283.

Student Well-Being:

- At Georgia Tech, we are concerned about your overall physical, social, and mental well-being. A comprehensive list of wellness related resources has been compiled and maintained by the Office of the Vice President for Student Engagement and Well-being (student-resource-guide (gatech.edu)