CE526: Finite Element Methods in Structural Engineering, SPRING 2024
Mondays and Wednesdays 8:30am - 9:45am
136 Monteith Engineering Research Center

Syllabus

INSTRUCTOR:
Dr. Ghadir Haikal
Office: Fitts-Woolard Hall 3343
E-mail: ghaikal@ncsu.edu

Office Hours:
Mondays and Wednesdays:
On-campus students (in person): 10:30a-11:30a
Online students (zoom, #444374): 11:30a-12:30p
or by appointment

TEXTBOOK: *An Introduction to the Finite Element Method, 4th Ed.*, J. N. Reddy, 2018
(recommended) ISBN-13: 978-1259861901 (~ $180.00, also available via All-Access)
There will be no required textbook. A list of additional references will be provided.

COURSE WEBSITE: https://moodle-courses2223.wolfware.ncsu.edu/course/view.php?id=5702
Students are encouraged to check the website frequently for updates and to participate in the online discussion sections.

COURSE DESCRIPTION: Development of the finite element method with an emphasis on understanding the fundamental principles governing the analysis technique. Applications to two-dimensional solids with particular attention to applications in structural engineering. Typical modeling considerations are reviewed and applied to the analysis of a realistic structure.

COURSE OBJECTIVE AND TOPICS: The objective of the course is to introduce students to the Finite Element Method (FEM) for the solution of boundary value problems in structural engineering. The course provides the background and tools necessary to gain a fundamental understanding of variational principles, numerical methods, and FEM technology, and gives the students the opportunity to gain some experience in writing basic FEM code as well as using commercial FEM packages such as ANSYS.
The prerequisite for CE 526 is CE 515: Advanced Strength of Materials or equivalent. Background in vector calculus and linear algebra is expected. Students who have taken courses on solid mechanics and advanced structural analysis (CE 525) are best equipped for the course. All programming assignments (homework and projects) will be executed in Matlab. See tentative outline for a list of topics.

LEARNING OUTCOMES: By the end of this course you will be able to do the following:

- identify the relationship among the **strong**, **weak**, and **virtual work** forms of the governing equations for 2D elasticity and beam theory.

- use **variational principles** and **integration theorems** to obtain **virtual work** statements for **plane-stress and plane-strain 2D elasticity, Timoshenko and Bernoulli-Euler beam theories**.
- incorporate **essential** and **natural** boundary conditions.
- use **numerical discretization techniques** such as the Ritz method
- apply **finite element technology** to derive 1D/2D linear and quadratic finite elements
- perform **numerical integration**
- obtain FEM formulations for **structural elements** such as beams
- **solve** small (1D) FEM problems **by hand**
- **solve** medium sized problems (1D/2D) using **basic Matlab programming**
- **solve** large problems using commercial FEM software - **ANSYS** - with proficiency
- apply stress-smoothing techniques
- assess accuracy and convergence in the FEM solution; identify locking and numerical instabilities.

CONDUCT OF COURSE:

1) **Discussion boards and office hours:** A discussion board will be hosted on Moodle, and will be available to all (online and on-campus) students. The discussion board is a great place to discuss with fellow students, and I will check in every weekday around noon to answer any lingering questions. <u>The online portion of office hours is reserved for distance students exclusively</u>; Distance students planning to participate on zoom should send me an email at least 30 minutes beforehand.
2) **Homework**: Homework problems will be assigned on Wednesdays and will be due by midnight two class periods after they are assigned (not including holidays and canceled classes). For example: homework assigned on Wednesday Jan 17 will be due on Wednesday Jan 24. Using computer software such as Excel, Matlab ...etc is acceptable as long as the solution procedure is explained in full detail and code is included when applicable. Homework assignments will be marked but will not be assigned a numerical grade. They serve as a means of progress self-assessment and to set up background work for the projects.
2) **Midterm Exams**: A midterm exam will be given during class on <u>March 6</u>.
3) **Projects**: all students are required to complete two group projects, and groups will consist of two students. The timeline for the projects is:
   Project 1: due Friday March 29 at 5:00pm
   Project 2: due Wednesday May 01 at midnight

There will be no final exam. Project 2 will serve as a final project and a comprehensive test of student understanding of course topics.

<u>Note to online students</u>: Recorded lectures will be available shortly after class every Monday and Wednesday. Make sure to watch the lectures by the end of the day on Wednesday (homework will be assigned on Wednesdays), and use the zoom office hours to ask any questions you might have about the class content.
Arrangements will be make for you to take the exam with the help of a proctor. I will also team you up with another distance student to work on the homework and projects.

GRADE DISTRIBUTION:

Homework:	15%	the lowest-scoring homework will be dropped
Midterm exam:	25%	
Project 1:	25%	
Project 2 (final):	35%	

Grades will be curved.

LATE SUBMISSION/ABSENCE/CONFLICT POLICY: No late homework submissions will be accepted for any reason. Feel free to exercise the option of skipping a homework set to accommodate any scheduling conflicts or personal or health issues. If you have to miss the mid-term exam for an accepted and documented reason, I will arrange for a final exam (with the same grade percentage) at the class's scheduled final exam time.

GRADING ERROR: If you believe that an error was made in grading, you should write a short justification of your claim and attach it to the ***original*** homework/exam problem in question and return to the instructor within one week for review and potential re-grade. Any falsification will result in a **ZERO** for the assignment.

ETHICS:

There may be some homework problems (and even exam problems) where the final answer is known, e.g. an answer may be given in the back of the book for a homework problem, or a test question may be to derive a stiffness term that appears on the equation sheet. In these cases, ***if your work does not give you the correct answer, but you say that it does***, you will get a **ZERO** on that problem, regardless of your mistake. It is a breach of ethical conduct to write down something that you know is based on an incorrect analysis. If your work does not lead to the known solution, the proper response is to write down your (presumably incorrect) answer and then state that it is different from the known (presumably correct) solution.

ATTENDANCE POLICY:

Attending lectures is expected for on-campus students. Online students are expected to view the lectures by the end of day on Wednesday of every week. Students are responsible for all material presented in every class, and digital notes will be posted online after each class. See https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/ for more information. Any changes in attendance policy due to the ongoing COVID-19 pandemic will be communicated to students by email and via the course website.

ACADEMIC INTEGRITY STATEMENT:

Students will adhere to the academic policy set forth by University Code of Student Conduct (http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php).
Plagiarism and cheating are attacks on the very foundation of academic life, and cannot be tolerated within universities. Section eight (8) of the Code defines academic dishonesty and provides information on potential sanctions for violators of academic integrity. You will be asked to sign the following statement on each exam and on the final: "I have neither given nor received

any unauthorized aid on this test." All cases of academic misconduct will be submitted to the Office of Student Conduct.

STUDENTS WITH DISABILITIES:
NC State University is committed to providing reasonable accommodations for students with verifiable disabilities. In order to take advantage of available accommodations, students must officially register with the Disability Resource Office (DRO) located at Holmes Hall Suite 304, 2751 Cates Avenue, Raleigh, NC 27695-7509, (919) 515-7653. https://dro.dasa.ncsu.edu
For more information on NC State's policy on working with students with disabilities, please see http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.1.php

DIGITAL COURSE COMPONENTS:
Course material (lectures, homework, ... etc.) will be made available through the class website on Moodle. Students may be required to disclose personally identifiable information to other students in the course, via digital tools, such as email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

COVID-19 POLICIES AND RESOURCES:
Due to the COVID-19 pandemic, public health measures continue to be implemented across campus. Students should stay current with these practices and expectations through the *Protect the Pack* website (https://www.ncsu.edu/coronavirus/).

DIVERSITY AND INCLUSION:
NC State values diversity, equity, inclusion and justice. As a public university - a university of the people - it's essential that we welcome and support everyone in our community. That's why a commitment to a stronger and more inclusive institutional culture is enshrined in our strategic plan.
Diverse experiences and perspectives enrich our lives. They give students the insights required to succeed in today's global marketplace, and they make all of us more conscientious global citizens. We expect everyone in the wider Wolfpack to champion this work and to give of their time, effort and talent to support it.

SUPPORTING FELLOW STUDENTS IN DISTRESS:
As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a healthy and safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you, either for the classmate's well-being or yours. When this is the case, I would encourage you to report this behavior to the NC State's Students of Concern website: http://go.ncsu.edu/NCSUcares. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.

INSTRUCTORS' COMMITMENT:
You can expect your instructor/TA to be safe, courteous, punctual, well-organized, and prepared for lecture; to answer questions clearly; to be available during office hours or to notify your beforehand if they are unable to keep them; to provide a suitable guest lecturer when they are traveling; and to grade uniformly and consistently according to posted guidelines.

HOW TO MAXIMIZE YOUR LIKELIHOOD OF GETTING AN A IN THIS COURSE:

- Preview the material before attending class by reading the textbook and notes posted online.
- Ask questions in class or during office hours on anything that is not clear.
- Rework the example I do in class and the examples given in the textbook. You should get to the point where you can solve them without looking at the notes. Ask questions if you have trouble.
- Be sure that as an individual you understand and can solve any of the homework problems worked out by your team. Team cooperation is encouraged to facilitate the learning process and prepare you for real-world engineering workplace scenarios.
- In addition to the homework problems (which are really the minimum amount of practice needed), look at as many other problems as you can and work through, or at least think through, their solutions. Ask questions if you have trouble.
- Be excited about the subject matter for this course, if you put in the required effort to learn and implement the finite element method, you will have the necessary knowledge and state-of-the-art toolbox for solving a variety of problems encountered in modern, real-world structural analysis/engineering.

Welcome Back Wolfpack, looking forward to an enriching and productive semester with you all!

-- The instructor reserves the right to modify the syllabus as needed throughout the semester --

CE526: Finite Element Methods in Structural Engineering, SPRING 2024
Mondays and Wednesdays 8:30am - 9:45am
136 Monteith Engineering Research Center

Tentative Course Outline

Week	Date	Topic
1	01/08	Introduction and review of matrix methods
2	01/15	Solid mechanics review – elasticity
3	01/22	1D Boundary Value Problems- strong form, essential and natural BCs
4	01/29	Variational formulations, Weighted residuals, Virtual work, Energy approach
5	02/05	the Ritz method of approximation, 1D Finite element formulation
6	02/12	Implementation, numerical integration, error estimates, convergence, stresses
7	02/19	Beam theory review, weighted residuals, virtual work for beams
8	02/26	Beam finite element technology, implementation, locking, reduced integration
9	03/04	Review and midterm
		- no class SPRING BREAK have fun!
10	03/18	2D Elasticity, weighted residuals, virtual work
11	03/25	2D Element technology, implementation, numerical int., stress averaging
12	04/01	Error estimates, convergence, ANSYS tutorial
13	04/08	Issues in FEM solutions: locking, reduced integration
14	04/15	Higher-order elements, “node-less” degrees of freedom – as time permits

--The schedule is subject to change and will be modified as needed throughout the semester--