CE594: Structural Mechanics, FALL 2025
Mondays and Wednesdays 11:45am - 1:00pm
2220 Engineering Building 3

Syllabus

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

Office Hours:
On-campus students:
M-W: 1:30pm – 2:45pm (in person)
Online students:
Tu-Th: 6pm -7pm (zoom, passcode: 113366)
or by appointment

TEXTBOOK (required): *Fundamentals of Structural Mechanics, 2nd Ed.*, K D. Hjelmstad, 2005
ISBN-13: 978-0387233307 (~ $100.00, also available online)

COURSE WEBSITE: https://moodle-courses2527.wolfware.ncsu.edu/course/view.php?id=4506
Students are encouraged to check the website frequently for updates and to participate in the online discussion sections.

COURSE OBJECTIVE: New or special course on recent developments in some phase of civil engineering. The objective of this course is to introduce students to the basic principles of three-dimensional elasticity theory for the solution of boundary value problems in mechanics. The course provides the background necessary to gain a fundamental understanding of solid mechanics principles in civil engineering applications and introduces variational principles and numerical methods, setting the stage for advanced analysis using finite element methods. This course provides a foundation for finite element methods and advanced mechanics courses.

COURSE PRERQUISITES: Graduate standing required. Students will need to have taken an undergraduate class in mechanics and analysis (CE225, CE325).

COURSE TOPICS:

1. Mathematical principles
   - Vector operations (addition/subtraction dot, cross and tensor products)
   - Tensors
   - Tensor operations on vectors, addition, multiplication, transpose
   - Eigenvalue problems (orthogonality, repeated eigenvalues, modal decomposition, Cayley-Hamilton theorem)
   - Tensor calculus: gradients and divergence of scalar, vector and tensor fields
   - Cartesian, polar and cylindrical coordinates
   - The divergence theorem

2. 3D Elasticity theory

- Deformations: deformation gradient, 3D strain measures in large deformations, linearized strain. Change in area/volume.
- Stress and equilibrium: equilibrium of forces/moments at a point, Cauchy stress, first and second Piola-Kirchoff stress, tractions with reference to deformed and undeformed configurations
- Constitutive equations: hyperelasticity, isotropy, linear elasticity, orthotropy. Constitutive equations for 3D elasticity in terms of Lame parameters or Young's modulus/Poisson ratio or bulk/shear modulus. Bulk and deviatoric stresses/strains. Defining the elasticity matrix for orthotropic materials/plane stress/plane strain
- Dirichlet, Neumann, mixed and Robin boundary conditions
- Strong form of the governing equations: Total vs updated Lagrangian formulations. Small deformations formulation
- Closed-form solutions for 1D problems.

3. Variational forms for elasticity (Energy (E), weighted residual (WR) and virtual work (VW))
    - WR from SF – weighted residuals, acceptable function spaces
    - SF from WR: the fundamental theorem of the calculus of variations
    - VW from WR and vice-versa: divergence theorem (integration by parts in 1D)
    - Energy methods and the VW
    - Essential vs natural boundary conditions
    - Introduction to numerical discretization (the Ritz method).

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

- write equations of **deformation**, **strains**, **stresses** and **constitutive equations in 3D**
- characterize material behavior under different conditions (**isotropy, orthotropy, linear elasticity**)
- identify different **strains and stress** measures
- identify different types of **boundary conditions**
- make connections to previously known theories such as beams (identify assumptions)
- identify the relationship among the **strong, weak, and virtual work forms** of the governing equations for elasticity.
- use **variational principles** and integration theorems to obtain virtual work statements for 1D, plane-stress and plane-strain 2D elasticity
- incorporate **essential** and **natural boundary conditions**.
- use **numerical discretization** techniques such as the Ritz method
- solve small (1D) elasticity problems by hand
- solve medium sized problems (1D/2D) using basic Matlab programming
- assess **accuracy** and **convergence** in the numerical solution.

CONDUCT OF COURSE:

1) **Course structure and notes:** Except for the first week of class, the course will follow an inverted classroom format. Students are expected to read the assigned book sections before Monday's class every week. Class on Monday will be dedicated to highlighting key concepts while Wednesday's class will be used to solve in-class problems. Reading assignments for each week will be posted on the class website by 5pm on the previous Monday. For example, reading material for content covered the week of Aug 25 will be announced on Aug 18. Students are encouraged to reach out to the instructor to answer any lingering questions.
2) **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 to answer any lingering questions. Feel free to make use of the scheduled office hours or request a separate appointment as needed. The online portion of office hours is reserved for distance students exclusively.
3) **Homework**: Homework will be assigned on Wednesdays and will be due by midnight two class periods later (not including holidays and canceled classes). For example: homework assigned on Wednesday Aug 27 will be due on Monday Sep 8 since Sep 1 is a university holiday. Using computer software like Excel, Matlab ...etc is acceptable if the solution procedure is explained in full detail and code is included when applicable. Homework will be marked but will not assigned a numerical grade. Homework serves as a means of progress self-assessment and to set up background work for the exams/project. Students can work in groups of two.
   The lowest-scoring set for each group will not be included in the final grade.
4) **Exams**: Exams will be given during class on Sep 24, Oct 22, and Nov 12.
   The lowest-scoring exam will not be included in the final grade.
3) **Final Project**: all students are required to complete a group project, and groups will consist of two students. The project is due on Wednesday, Dec 10 at midnight.

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

Note to distance students: 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 made for you to take the exams with the help of a proctor. I will also team you up with another distance student to work on the homework and project. All homework and the final project will be submitted and graded through Moodle.

GRADE DISTRIBUTION:

Homework:	10%	the lowest-scoring homework will be dropped
Exams:	60%	the lowest-scoring exam will be dropped
Project (final):	30%	

Grade assignment will follow standard NCSU guidelines.

LATE SUBMISSION/ABSENCE/CONFLICT POLICY: No late homework submissions or late/early exam requests will be accepted. Feel free to exercise the option of skipping a homework set or an exam to accommodate any scheduling conflicts or personal or health issues.

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 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.

HEALTH POLICIES AND RESOURCES: Students should stay current with public health measures 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.
- 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 matrix displacement 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 --

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TENTATIVE OUTLINE

Week	Date	Topic
1	08/18	Introduction and vector operations
2	08/25	Tensors, tensor operations
4	09/01	Large-deformation kinematics, stretch and strain in 3D, different strain measures
3	09/08	Invariants, tensor calculus, divergence theorem
5	09/15	Change in area and volume, principal strains, spectral decomposition
6	09/22	3D measures of force, tractions, the Cauchy stress tensor
7	09/29	Equilibrium, principal stresses, different stress measures in large deformations
8	10/06	3D constitutive equations: hyperelasticity, isotropy, linear elasticity. Definition of material parameters (Young/Poisson, Bulk/Shear). Deviatoric stress and strain.
9	10/13	Boundary-value problems. Classical solutions in 1D.
10	10/20	Variational forms for elasticity (Energy (E), weighted residual (WR) and virtual work (VW)). Energy methods.
11	10/27	Discretization with the Ritz method
12	11/03	Discretization with the Ritz method
13	11/10	Other topics in elasticity: orthotropic materials, plane stress/plane strain
14	11/17	Connections to structural theories (beams), special topics – as time permits