Raudel Avila, Ph.D.
George R. Brown School of Engineering
Department of Mechanical Engineering
Computational Mechanics and Bioelectromagnetic Lab

Mechanical Engineering Building, 224
6100 Main St
Houston, TX 77005-1827
(713) 348-2427
roavila@rice.edu
avila.rice.edu

MECH/CEVE - 417/517: Finite Element Analysis

Spring 2025 (Content Subject to Change)

Instructor: Raudel Avila, MEB 224, x2427, roavila@rice.edu
Class Hours: Tuesday and Thursday from 1:00 – 2:15 PM
Class Location: HRZ 210, (Herzstein Hall 210)
Office Hours: Thursday 3:00 PM – 4:00 PM, and by appointment in office or on zoom.
Teaching Assistants: Cengizhan Taslicay (ct59@rice.edu) and Xin Xu (xx50@rice.edu)
Undergraduate Teaching Fellow: Lily Lee (cl124@rice.edu)

Objectives: By the end of the course, students will be able:

1. To derive, formulate, and apply the fundamental concepts of the finite-element method and its application to solid mechanics, fluid mechanics, heat and mass transfer, biophysics, and electromagnetics.
2. To develop an understanding of the computational aspects of the finite-element method and its application in current and emerging engineering applications.
3. To create introductory finite-element codes in MATLAB and run commercial finite-element codes in ABAQUS for engineering analysis.
4. To deliver a technical report and presentation to effectively communicate and visualize finite-element results.

Outcomes: MECH/CEVE - 417/517 helps students achieve the following PLOs:

1. An ability to apply knowledge of mathematics, science, and engineering.
2. An ability to identify, formulate, and solve engineering problems using the finite-element method.
3. An ability to use the techniques, skills, and modern engineering software necessary for practice.

Textbook: NOT REQUIRED, The following textbooks can be used as reference for the material that would be covered in class. I will follow the book by Fish and Belytschko.

1. “A first course in the Finite Element Method”, Daryl L. Logan, Thomson Publishers.
2. “A first course in finite elements”, Jacob Fish and Ted Belytschko, Wiley Publications.
3. “The Finite Element Method: Linear Static and Dynamic Finite Element Analysis,” Thomas J. R. Hughes, Courier Corporation.
4. “Finite Element Analysis Concepts via SolidWorks”, John E. Akin, World Scientific

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Requirements: Access to MATLAB and ABAQUS (Learning Edition is Free). The class will focus on implementing the finite element codes in MATLAB and ABAQUS. There are many free and commercial finite element codes, I can provide access to tutorials and resources for each one if you are interested but I will not provide any feedback or suggestions to incorporate the class topics into other finite element codes.

Grading Policy:

Deliverables	Percentage
4 Homework Assignments	**30%**
3 Computational Assignments	**30%**
1 Midterm – Open Notes	**20%**
1 Final Project	**20%**

Homework and Computational Assignments: The assignments will be divided between handwritten (4) and computational (3) where you are expected to turn in your OWN work. You are allowed to work in groups or consult with your peers in the class, but these are individual assignments. Further guidance on the formatting and reporting of the computational assignments (which must include the finite element code in MATLAB) will be provided by the instructor.

Final Project: The last third of this class will be evaluated in the form of a final group project, rather than an exam. Groups will consist of ~3 students, and students will evaluate each other as well, which may affect individual grades. The project can be around emerging topics in solid mechanics, heat transfer, mass transfer, biophysics or electromagnetics depending on your interests. However, I must approve the project beforehand. The MECH/CEVE 517 graduate curriculum will follow that of the MECH/CEVE 417 course. However, there will be additional homework and final project components to the course. The additional material is intended to allow the graduate student to investigate the execution of more advanced methods in FEM.

The final project report is due the week of finals.

Rice Honor Code: In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at http://honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

ADA Notice: If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with the Disability Resource Center (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

Mental Health Statement: The wellbeing and mental health of students is important; if you are having trouble completing your coursework, please reach out to the Wellbeing and Counseling Center. Rice University provides cost-free mental health services through the Wellbeing and Counseling Center to help you manage personal challenges that threaten your personal or academic well-being. If you believe you are experiencing unusual amounts of stress, sadness, or

anxiety, the Student Wellbeing Office or the Rice Counseling Center may be able to assist you. The Wellbeing and Counseling Center is located in the Gibbs Wellness Center and can be reached at 713-348-3311 (available 24/7).

Office Hours: "*Office hours are not a terrifying time when I am going to yell at you about not understanding things in the class; rather, they are a time when you can gain more knowledge, ask questions you don't want to ask in front of the whole class, or just check up on things in general.*" – credit to Prof. Laura Shaefer. You are welcome to stop by my office if my door is open or schedule an appointment via email for an in-person meeting or zoom meeting.

Statement on AI: Before collaborating with an AI chatbot (ChatGPT) on your work for this course, please request permission by sending me a note that describes (a) how you intend to use the tool and (b) how using it will enhance your learning. Any use of AI to complete an assignment must be acknowledged in a citation that includes the prompt you submitted to the bot, the date of access, and the URL of the program.

Latest Revision – 01/12/2025

Course Tentative Schedule: The topics and schedule below are only a guide for the course and are subject to change based on the instructor's judgement.

Date	Week	Content	Homework Assignment
01/09 Tuesday	1	Introduction to the finite element method and review of linear algebra	
01/11 Thursday	1	Introduction to the finite element method and review of linear elasticity	
01/16 Tuesday	2	Direct approach – single spring element	
01/18 Thursday	2	Direct approach – assembly and linear systems	**HW1**
01/23 Tuesday	3	Direct approach – truss elements	
01/25 Thursday	3	Direct approach – beam elements	**HW2**
01/30 Tuesday	4	Strong and weak form in 1D – Part 1	**CA1**
02/01 Thursday	4	Strong and weak form in 1D – Part 2	
02/06 Tuesday	5	Strong and weak form in 1D – Part 3	
02/08 Thursday	5	**NO CLASS**	**Spring Recess**
02/13 Tuesday	6	Construction of shape functions in 1D for higher order elements – Part 1	
02/15 Thursday	6	Construction of shape functions in 1D for higher order elements – Part 2 Gauss Quadrature in 1D	**CA2**
02/20 Tuesday	7	Finite element formulation with shape functions and B matrix for arbitrary Boundary Conditions – Part 1	
02/22 Thursday	7	Finite element formulation with shape functions and B matrix for arbitrary Boundary Conditions – Part 2	**HW3**
02/27 Tuesday	8	Class review of covered material	
02/29 Thursday	8	Midterm exam – (open notes)	
03/05 Tuesday	9	Convergence and Error of Finite Elements	
03/07 Thursday	9	2D Elements Shape Functions (Tri and Quad)	
03/12 Tuesday	10	**NO CLASS**	**Spring Break**
03/14 Thursday	10	**NO CLASS**	**Spring Break**
03/19 Tuesday	11	2D Isoparametric Elements – Part 1	**CA3**
03/21 Thursday	11	2D Isoparametric Elements – Part 2	**HW4**
03/26 Tuesday	12	FEM for Multidimensional Problems Theory and Implementation– Part 1	**Project Proposal**
03/28 Thursday	12	FEM for Multidimensional Problems Theory and Implementation – Part 2	
04/02 Tuesday	13	Deep Dive into ABAQUS Implementation	
04/04 Thursday	13	Deep Dive into ABAQUS Implementation	**CA4**
04/09 Tuesday	14	Theory of Elasticity in FEM	
04/11 Thursday	14	Fracture Mechanics in FEM	
04/16 Tuesday	15	Non-linear Elasticity in FEM	
04/18 Thursday	15	Bioelectronics in FEM	