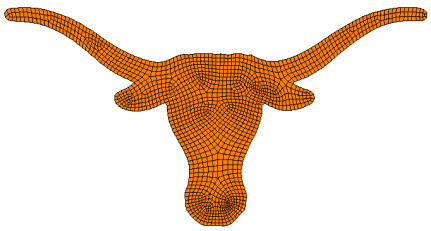

The Finite Element Method

CE 381R (Unique number: 16865)
CSE 393 (Unique number: 65520)

Fall Semester 2022

Instructor: Professor Loukas F. Kallivokas
office: ECJ 4.724
phone: 1-512-232-5769
e-mail: loukas@mail.utexas.edu

Meeting times: MWF 9:00-10:00am

Meeting place: ECJ 3.402

Office hours: W 1:00-3:00pm (on zoom; any time I am in my office with my door wide open; or by appointment)

COURSE OBJECTIVES

This is an introductory course in the finite element method. The course objectives are: (a) to provide the fundamental concepts of the theory of the finite element method; and (b) to expose aspects of the application of the method to realistic engineering problems through programming, and, time permitting, via computational simulations using a major commercial general-purpose finite element code.

COURSE OVERVIEW

To date, the finite element method (FEM) is the most widely used numerical method for solving a variety of problems governed by partial differential equations in all areas of engineering and the sciences. This course provides an introduction to the theory underlying the finite element method, with applications to problems drawn primarily from structural mechanics, but not exclusively.

There are two components to the course: the theoretical part will expose the key concepts (weighted-residual method, weak form, natural vs. essential boundary conditions, basis functions, error measures, etc) and the technical details (element types, integration rules, equation assembly, post-processing, etc). The second component aims at providing hands-on experience with the method through its application to simple problems (bars, beams, membranes, plates, flows, etc) of engineering interest, and to problems that merit the use of a computational tool. Subject to the pace of the class, we will make use of ANSYS™ (a commercial code) throughout the course.

The presentation of the material will be incremental starting from simple one-dimensional problems in order to illustrate and solidify the concepts, and will progress to two- and three-

dimensional linear static and, later on, dynamic problems. The emphasis will be on the basic principles, in the methodology, and in the physical interpretation of numerical results.

COURSE SCHEDULE

The following is a tentative outline of the topics to be covered.

- Introduction to numerical methods
  - Overview – Basic ingredients of the FEM
  - Early comparison with alternative solution methodologies
- The basic concepts in FEM – One-dimensional problems (2-point 2^{nd}-order BVP)
  - Axial deformations of a bar
  - Strong and weak forms
  - Essential vs. natural boundary conditions
  - Variational formulations (Principle of virtual work, principle of minimum potential energy)
  - Approximations (Rayleigh-Ritz & Galerkin)
  - Accuracy – error measures
  - Finite element basis functions (linear and quadratic elements)
  - Assembly
  - Problems with smooth and non-smooth solutions
  - Convergence
- Generalization to two dimensions
  - Membrane, plane strain and plane stress problems
  - Triangular and quadrilateral elements
  - Isoparametric elements
  - Axisymmetric problems
- Generalization to higher-order BVP
  - Flexure of beams
  - Beams on elastic foundation
  - Bending of thin elastic plates
- Three-dimensional elasticity
- Eigenvalue problems
  - Free vibration of elastic systems (natural frequencies, modal response, etc)
  - Buckling
- Dynamic response of elastic systems
  - Elastodynamics
- Numerical/computational issues
  - Solvers
  - Meshing
- Closing view
  - Merits and disadvantages
  - Late comparison with alternative solution methodologies

Software topics to be covered (tentative):

- Using ANSYS
  - Introduction to ANSYS (Steps to modeling using a commercial code)

- Preprocessing (solid modeling, meshing, loads and boundary conditions)
- Solution (solver choices, parameter specification, tolerance issues, etc)
- Postprocessing (stress recovery, visualization, etc)

COURSE REFERENCES

Main reference:

"Finite Elements: An Introduction,"
by E. B. Becker, G. F. Carey and J. T. Oden, Volume I, Prentice Hall, 1981.

Additional references:

"The Finite Element Method: Linear Static and Dynamic Finite Element Analysis,"
by T. J. R. Hughes, Prentice Hall, 1987.

"An Introduction to the Finite Element Method,"
by J. N. Reddy, McGraw-Hill, 1984.

"An Analysis of the Finite Element Method,"
by G. Strang and G. F. Fix, Prentice Hall, 1973.

"The Finite Element Method,"
by O. C. Zienkiewicz, McGraw-Hill, 1979.

"Finite Elements for Structural Analysis,"
by W. Weaver Jr and P. R. Johnston, Prentice Hall, 1984.

"Finite Element Methods in Mechanics,"
by N. Kikuchi, Cambridge University Press, 1986.

"Finite Element Procedures in Engineering Analysis,"
by K. Bathe, Prentice Hall, 1982.

COURSE LOGISTICS

On prerequisites: Desirable prerequisites include calculus, elements of ordinary and partial differential equations, elements of linear algebra, basic courses in mechanics, and computing experience with Windows boxes and widely-used symbolic and numerical packages such as Mathematica, Maple, Matlab, etc.

On Canvas: Course announcements, homework assignments and solutions, and your grades will be posted on Canvas (https://canvas.utexas.edu), to which you all have access using your UT EID.

On homework and class format: There will be three one-hour lectures per week. Assignments will be given, on average, every week. Assignments are due online on the posted date/time, unless modified by the instructor. *Late assignments will not be accepted for any reason*. Students are strongly encouraged to discuss course and homework topics among themselves, since such discussions are an important part of the learning process. However, each student must carry out assignments independently. Working on assignments constitutes, very likely, the best way for digesting the material and learning the concepts (roughly speaking, most of us learn by *doing*, rather than by *listening* or *reading*). It is thus, in my opinion, imperative that appropriate care be taken to consistently complete the assignments throughout the semester.

Your assignments should be well written. I expect all to adhere to a "reasonable person's" presentation standards, without anyone having to describe or define these standards for you.

On exams and projects: There will be two in-class or take-home exams (dates to be announced) and one final project. **Alternative dates for the exams will not be arranged for anyone under any circumstances**. I reserve the right to have only one midterm exam, or more than two, during the course of the semester, depending on my assessment of the class's performance. The final project will be due on the last day of classes (Monday, December 5, 2022 at 9:00am). No final exam will be given.

Students requiring exam accommodations: If a student requires or expects to require special accommodations during an exam, the pertinent request-for-accommodations letter, signed by the appropriate University officer, should be submitted to the instructor no later than Monday, September 12, 2022. Any request-for-accommodations letters submitted past the above deadline will not be honored.

On attendance and participation: In my experience, there is a high correlation between a low course grade or course failure, and scarce class attendance. I intend to file absence/fail reports for students who will be repeatedly absent. I will be asking questions during class, and I expect your active participation.

Important: I reserve the right to enter a Q or F grade, or otherwise terminate, a student's class registration for excessive absences, or for any other reason that I believe to be disruptive to the learning process of the student or of the class.

On auditing the course: No auditors are allowed.

Alternate course modalities:

If at any time during the semester, there is need to transition to an online course modality, the following apply:

- No hybrid modality will be offered.
- For lectures held via zoom: you are expected to attend every lecture at the scheduled time; moreover, you should have your camera on, and keep the camera on for the entire duration of the lecture.
- The lectures will not be recorded. Furthermore: unauthorized recordings may violate FERPA rules, and are thus prohibited.

Sharing of course materials: No materials used in this course, including, but not limited to, lecture notes, assignments and their solutions, exams and their solutions, notes and materials posted on Canvas, tutorials, etc, may be posted online or shared in any way, shape, or form with anyone outside of the class participants, unless I provide my explicit permission in writing. I intend to report any unauthorized sharing of course material.

On grading: Homework assignments (H) carry a 15% weight; class participation (P) carries a 5% weight; the two mid-term exams (Q1 & Q2) carry a cumulative 50% weight, and the final project (F) a 30% weight. Thus, the final grade G is G=0.15*H + 0.05*P + 0.23*min(Q1,Q2) + 0.27*max(Q1,Q2) + 0.30*F. Homework assignments will be checked for completeness, but will not be graded in detail; points will be deducted for incorrect, incomplete, or poorly presented assignments. Students are responsible for checking the correctness of their submitted assignments against the posted solutions.

I intend to assign letter grades according to the following scale:

A	for	$93 \le G \le 100$
A-	for	$90 \le G < 93$
B+	for	$87 \le G < 90$
B	for	$83 \le G < 87$
B-	for	$80 \le G < 83$
C+	for	$77 \le G < 80$
C	for	$73 \le G < 77$
C-	for	$70 \le G < 73$
D+	for	$67 \le G < 70$
D	for	$63 \le G < 67$
D-	for	$60 \le G < 63$
F	for	$G < 60$

The scale shown on the left is based on minimum bounds. I reserve the right to change these bounds. Any adjustment to the bounds will depend on the class's performance.

Course/Instructor evaluation: An evaluation of the course and instructor will be conducted at the end of the semester using the approved UT Course/Instructor evaluation forms.

Course add/drop policy: From the 1st through the 4th class day, graduate students can drop a course via the web and receive a refund. During the 5th through 12th class day, graduate students must initiate drops in the department that offers the course and receive a refund. After the 12th class day, no refund is given. No class can be added after the 12th class day. From the 13th through the 20th class day, an automatic Q is assigned with approval from the Graduate Advisor and the Graduate Dean. From the 21st class day through the last class day, graduate students can drop a class with permission from the instructor, Graduate Advisor, and the Graduate Dean. **Students with 20-hr/week GRA/TA appointment or a fellowship may not drop below 9 hours.**

On collaboration and academic integrity:

Students are strongly encouraged to discuss among themselves the course material and the assigned homework. I view this practice as an integral part of the learning process. **However, all turned-in homework and exams should reflect the work exclusively of the student who will be receiving the credit. Copying from previously posted solutions to assignments should be avoided: it constitutes scholastic dishonesty.**

All students are responsible for upholding the University rules on scholastic dishonesty. Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including the possibility of failure in the course and/or dismissal from the University. Since such dishonesty harms the individual, all students, and the integrity of the University, policies on scholastic dishonesty will be strictly enforced. For further information, visit http://catalog.utexas.edu/general-information/appendices/appendix-c/student-discipline-and-conduct/, and the General Information Catalog information http://catalog.utexas.edu/general-information/.

Students with disabilities: The University of Texas at Austin provides, upon request, appropriate academic accommodations for qualified students with disabilities. For more information, contact the Division of Diversity and Community Engagement, Services for Students with Disabilities, 512-471-6259 (Videophone: 512-410-6644) or http://diversity.utexas.edu/disability/

Observance of religious holy days: According to UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day.

University policies: For other university policies not explicitly included on this syllabus please consult the General Information Catalog: http://catalog.utexas.edu/general-information/.

Important Safety Information:

> **COVID-19 Update: You are encouraged to stay up-to-date on the latest news related to the student experience: https://protect.utexas.edu/**