Instructor: Spyros A. Kinnas
Office: ECJ 8.610
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Course time: Tuesdays and Thursdays, 9:30 - 11:00 am

Place: ECJ 1.324 ; **Face-to-face**

Office hours: Fridays 2-3 pm or by appointment

Course web site: *https://cavity.caee.utexas.edu/kinnas/COURSES/bem.html*

Objectives: Understand the *fundamentals* of boundary element methods and their *application* to problems in fluid mechanics, structural analysis, and solid mechanics.

Philosophy: Understand the basics through theory, examples, and *hands-on experience* by coding a method from scratch, rather than using an of-the-shelf BEM code.

Prerequisites: Graduate standing or consent of instructor.

Computer: Knowledge of any programming language (Fortran, C, Matlab, Python, etc.) is expected. Most homework assignments and the term project will require considerable computer programming.

Required Textbook: None. Class-notes to be posted in the class web-site regularly.

At CHL-ECJ 8.502:
1. Theoretical and Computational Aerodynamics by Moran.
2. Boundary Elements - An Introductory Course by Brebbia and Dominguez.
3. Boundary Element Methods in Engineering and Sciences - Edited by M.H. Aliabadi & P.H. Wen- Imperial College Press 2011.
4. The Boundary Element Method - Volume 1: Applications in Thermo-Fluids and Acoustics by L.C. Wrobel, Wiley 2002.
5. The Boundary Element Method - Volume 2: Applications to Solids and Structures by M.H. Aliabadi, Wiley 2002.

Class format: Lectures supplemented with outside reading, homework, term project, and one test.

Class outline: See attached.

Grading: Homework: 50%; Test: 28%; Term Project: 22%. Any problems, personal or otherwise, affecting grades should be brought to the instructor's attention.

Homework policy: Original assignments must be submitted by each student. Students must submit their solutions on Canvas by 11:59pm on the assigned due date. Late assignments will not be accepted. Some of the problems will require moderate amounts of computer programming. Graphs in the students' homework solutions should be *computer generated*. The homework has to be *neat and orderly*.

Term Project policy: Each student should provide, after consultation with the lecturer and their advisor, a 2 page proposal (including the governing equations with the boundary conditions, and the numerical approach to be utilized) for their term project by **Monday, October 17, 2022**. This project should address an application of BEM on a realistic problem in the areas of fluid mechanics, structural analysis, solid mechanics, or other. It can be an integral part of the student's thesis or research. Considerable effort must be devoted in the formulation of the problem, numerical implementation, programming, interpretation of the results, convergence studies of the results of the proposed method, and comparisons with analytical solutions, results of other methods, or data from existing experiments (if available). Each of the students must submit a comprehensive report (typed) on his or her project.

Examinations: (tentative dates)

- Test: week of November 28, 2022 (tentative)
- NO Final Exam (pending approval by the Dean's office)

Failure to attend an exam will lead to a mark of zero. The only exception will be for documented medical emergencies.

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

Scholastic Dishonesty Policy: Sharing of Course Materials is Prohibited: No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University's Student Honor Code and an act of academic dishonesty. I am well aware of the sites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course. For more information on Academic Dishonesty, UT Honor Code (or statement of ethics), and an explanation of what constitutes plagiarism, see the Dean of students' website and University General Information Catalog at: http://deanofstudents.utexas.edu/conduct/ and http://catalog.utexas.edu/general-information/appendices/appendix-c/student-discipline-and-conduct/

Attendance: Highly recommended.

COVID Caveats: Important Safety Information: COVID-19 Update: While we will post information related to the contemporary situation on campus, you are encouraged to stay up-to-date on the latest news as related to the student experience: https://protect.utexas.edu/

Dropping policy:

- *Graduate students:* 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.**

IMPORTANT NOTE:

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, Disability & Access, 512-471-6259 (email: access@austin.utexas.edu) or http://diversity.utexas.edu/disability/.

COURSE OUTLINE

1. Introduction

- What are the boundary element methods?
- Where do they apply?
- Some of their advantages

2. Review of fundamentals
a Mechanics of solids

- The stress and strain tensors
- Equilibrium of stress equations
- Constitutive relations - Elasticity equations
- Elasticity equations in terms of displacements
- Natural and essential boundary conditions

b Fluid mechanics

- Velocity, pressure and shear stresses of fluid flow
- Conservation of momentum equations

- Constitutive relations - Navier-Stokes equations
- Inviscid/irrotational flow - Velocity potential - Bernoulli's equation
- Kinematic boundary condition
- Lifting flows - Kutta condition

3. Formulation of boundary element methods - Fluids

- Green's theorem
- The Green's "source" function
- Green's identity - Integral equation for the potential on the boundary
- The Neumann and Dirichlet boundary conditions
- Velocity vs. potential formulations
- Equivalence of the dipole and vorticity distributions

4. Formulation of boundary element methods - Solids

- Green's theorem - The Galerkin vector/"concentrated load" function
- Somigliana's identity
- The displacement and the traction boundary conditions
- Direct vs. indirect formulations

5. Numerical implementation

- Discretization of boundary into panels
- Approximation of singularity distributions on the boundary
- Galerkin vs. collocation approach
- Matrix of influence coefficients
- Evaluation of influence coefficients - The self-influence coefficient
- Low-order (constant) vs. high-order (linear, quadratic) methods
- Boundary shape discontinuities (corners)
- Hydrofoil trailing edge - Morino Kutta condition
- Error vs. number of panels and vs. computing time

6. Applications

- Flow about a 2-D non-lifting body

- Torsion of a prismatic beam
- Flow about a 2-D lifting hydrofoil
- Rectangular thin beam problem

7. Free-surfaces - Cavities

- The dynamic boundary condition
- Implementation of the dynamic boundary condition
- Linear vs. non-linear approach

8. Cracks - Wake sheets

- Branch cuts
- The Hilbert problem
- Singular integral equations - Cauchy principal value
- Hyper-singular integrals
- Vortex roll-up - Numerical stability
- Unsteady flow problems - Convection of vorticity

9. Other topics (if time allows)

- Viscous/inviscid flow coupling
- Other fields of application
- Hybrid BEM/FEM's methods
- Dual reciprocity
- Stokes flows
- Limitations