24703/12703 – NUMERICAL METHODS IN ENGINEERING SPRING 2025
Final Project

Task
Perform numerical analysis on a mechanical-engineering motivated problem of your choice (based on geometric modeling, mesh generation, machine learning, solid mechanics, fluid dynamics, heat transfer, manufacturing, etc.). The analysis must include **a technique (or techniques) not covered** in the homework, and/or an extension of a technique from class. Due to the large number of students, you could work in groups (1-2 students in each group).

Prepare a report (8-12 pages) and give a presentation (10-12 minutes) to the class.

Each group will also prepare a one-page summary of another group's presentation. I will tell you which group you are responsible for.

Evaluation
The project is worth 25% of your final grade. The written report is worth 15%, the oral presentation is worth 7%, and the one-page summary of another presentation is worth 3%. You are free to divide up the tasks in your group. Each group member will get the same grade.

Choice of Topic
Ideally, your project will be on a topic related to your research and/or general interests. The mathematics involved should not have an analytical solution (but you may want to consider analytical solutions of simpler problems to check any code you develop). Here are some suggested numerical techniques you may want to investigate:

- Statistical methods and machine learning
- Image processing such as filtering, classification, segmentation and registration
- Geometric modeling and finite element mesh generation
- Advanced finite element method such as isogeometric analysis, XFEM, and Immersed FEM (or Cartesian-based FEM)
- Adaptive stepping in the Runge-Kutta method or numerical integration
- Solving systems of ODEs using a multistep/multivalue technique
- QR decomposition to find eigenvalues
- Advanced techniques in linear regression analysis
- Singular value decomposition for linear systems
- Efficient multi-dimensional integration routine, importance sampling in integration
- Numerical differentiation
- Solving partial differential equations (parabolic, hyperbolic, or elliptic)
- Fast Fourier transform

For many of these topics, *Numerical Recipes* is a great place to look. You are also welcome to use other reference sources (the internet, books, research papers, etc). I would rather that people not choose the same topic as others, but will deal with this issue once everyone has told me what they want to do. As long as you can pose a good question, which can be investigated in the time frame of the course and with your abilities, your topic should be suitable.

Time Line
Mar. 19 (Wed): A half-page summary of your planned work is due at 10:00am (submit to Canvas). Please include the title of your topic and the group member names in your summary.

Mar. 24/25 (Mon, Tue): Meeting with each group in zoom to discuss their topic. A sign-up sheet will be available online on Mar. 19.

Apr. 16 (Wed): A two-page progress report is due at 10:00am (submit to Canvas).

Apr 16, Apr 21, and Apr 23: Presentations will take place in class. Each group will give a 10-12 minute talk, and have 5 minutes of questions. Your talk should contain a description of the problem you are studying, the analysis plan you are following, and some preliminary results. You will be graded on the presentation itself, and not directly on the content. I hope that the questions and feedback from other students will help in the preparation of the final report.

Apr. 25 (Fri): Your 1-page summary of another presentation is due by 5PM. Please submit the electronic version to the Canvas.

Apr. 28 (Mon): Final reports are due by 5PM, please submit the electronic version to the Canvas. Your report should be 8-12 pages. The organization is up to you. The use of tables, figures, images, etc, is strongly encouraged. The report should address the following issues:

- The motivation behind the project (i.e., what is the mechanical engineering system you are studying).
- Specific details about what numerical techniques you used. There should be a discussion of the theoretical background and implementation issues. Where applicable, talk about how the time needed to run your programs scales with the "size" of your system.
- Your results, discussion, and conclusions.

In doing the project, you can use computational whatever tools you need. However, I request that you not use built-in functions in the math programs for the "new" work that you do. You can certainly use such programs to check your results.