ME 712: Applied Mathematics in Mechanics – Fall 2024

Professor Douglas P. Holmes – *dpholmes@bu.edu*

Lecture - Four Credits
PSY B33
Tuesday & Thursday
9:00a.m. – 10:45a.m.

Office: 730 Commonwealth Ave., EMA 213
Phone: (617) 358-1294
Office Hours: Tue. 11:00a.m.–12:00p.m.
and, arranged over email

Prerequisites: Linear algebra, Multivariate Calculus, Differential equations.

Course Description:
The goal of this course is to give students an introduction to mathematical tools for solving difficult mathematics problems that arise in engineering science and mechanics. Students will learn the process of applied mathematics, which will enable them to take a hard problem, and gain insight into its important characteristics. Analytical theory, approximate techniques, and numerical methods will be used in a complementary manner to solve challenging engineering problems. Students will learn dimensional analysis and scaling, perturbation methods applied to polynomial and differential equations, variational calculus, integral equations, and concepts of stability and bifurcation. Students will apply these methods to mathematical problems in solid mechanics, fluid mechanics, thermodynamics, and dynamical systems.

Goal: The construction, analysis, and interpretation of mathematical models to help us understand the world we live in.

Objectives:

1. Establish some of the **basic mathematical tools** relevant to problems in mechanics.
   - Dimensional analysis & scaling.
   - Perturbation methods.
   - Linear stability analysis
   - Variational calculus
   - Basics of PDEs & Conservation laws
   - Differential geometry *(time permitting)*
   - Integral transforms *(time permitting)*
2. Establish the mathematical ideas underlying **model development**. Topics include:
   - Kinetics.
   - Diffusion.
   - Continuum Mechanics.
   - Solid & Fluid Mechanics.
   - Dynamical Systems

Learning Outcome: Completion of this course will enable you to **derive** and **analyze** mathematical model relevant to problems in theoretical and applied mechanics.

Grading: Homework assignments, class participation, and attendance (20% total), midterm exam (35%), and a project (45%).

Recommended Texts:

Class Notes & Digital Content - *D.P. Holmes*
Notes and code available on the course website: https://www.bu.edu/moss/courses/
Playlist of lectures on YouTube: https://www.youtube.com/watch?v=HYv2cllY4Zs&list=PLM1ijNJVxGFkI1K-j7kskPFgOdDv2fXal

Introduction to the Foundations of Applied Mathematics - *M.H. Holmes*
Mathematics Applied to Deterministic Problems in the Natural Sciences - *C.C. Lin, L.A. Segal*
Applied Mathematics - *J.D. Logan*
Three great books that are most closely aligned with the course objectives.

Scaling, self–similarity, and intermediate asymptotics - *G.I. Barenblatt*
A classic. Dense but essential.

Perturbation Methods - *E.J. Hinch*
Perturbation Methods in Fluid Mechanics - *M. van Dyke*
Excellent depth on an extremely important topic.

The Variational Principles of Mechanics - *C. Lanczos*
Buy any book by Lanczos.

Nonlinear Dynamics and Chaos - *S. Strogatz*
The best book to learn about stability.

A Brief on Tensor Analysis - *J.G. Simmonds*
Einstein Gravity in a Nutshell - *A. Zee*
Visual Differential Geometry and Forms - *T. Needham*
Tensors, Variational Calculus, and Differential Geometry

Ask Me Anonymous Math Questions: http://www.bu.edu/moss/math-questions/

Homework:
We will use the homework to work on both solving and explaining how to solve mathematical problems. On the day that homework assignments are due, I will ask students to volunteer to present the solution to a problem in class at the chalkboard. This will give you an opportunity to both test your understanding and ability to explain your work, as well as an opportunity for you to learn from one another. You are then free to revise your work and resubmit your work.

Midterm:
The midterm will be a mathematical modeling problem which you will be asked to solve and submit a clear write-up describing your work (maximum length: 3 pages). This will be a take-home exam due: **Friday, November 1^{st}**.

Note: You *may not* work together on this assignment.

Final Project:
By the end of this course, my goal is that you will be able to read an understand a research paper that you are unable to follow today because of its mathematical complexity. This paper may be motivated by your own research area, or may simply be a paper you find curious, interesting, or puzzling.

This project will entail:

- Select a paper, and have it approved by me by: **November 14^{th}, 2024**
- Submit a brief, **written report** (maximum length: 2 pages) summarizing the paper, describing its connection to class, and the important takeaways: **December 3^{rd}, 2024**.
- Prepare a very brief **video presentation** to give an overview of the paper to the class. The video should be a maximum of 5 minutes in length, and in it you should summarize the main findings and the applied mathematics techniques used. Due: **December 10^{th}, 2024**.
  - Presentations with Q&A will be given during the **Final Exam** timeslot for this course: TBD.

Academic Conduct & Student Performance:

1. **Academic Honesty:** In engineering, just as in humanities, science, and social science disciplines, plagiarism is unacceptable. Original thought is highly valued in engineering and is expected from students in this course in preparing and completing all course assignments. Students must follow the Academic Conduct Code. Any violation of this conduct code will be reported to the COE Academic Conduct Committee.
2. **Working Together:** Students are permitted to consult with each other regarding approaches to solving problems in these assignments. If you consult with another person, webpage, or a LLM chatbot (*e.g.* ChatGPT), please write "Consulted with <person's name> in preparing this assignment."
3. **COVID 19 & BU Community Health Expectations:** All students are expected to follow all university guidelines with respect to daily symptom checks, testing, social distancing, and mask wearing when they leave their dorm or home. Follow the official BU COVID Policies.
4. **Mental Health:** Diminished mental health, including significant stress, mood changes, excessive worry, or problems with eating and/or sleeping can interfere with optimal academic performance. The source of symptoms might be strictly related to your course work; if so, please speak with me. However, problems with relationships, family worries, loss, or a personal struggle or crisis can also contribute to decreased academic performance. BU provides mental health services to support the academic success of students. Getting help is a smart and courageous thing to do – for yourself *and* for those who care about you.
5. **Inclusion & Belonging:** I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.
6. **Financial Security:** Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live, and believes this may affect their performance in the course, is urged to contact the Dean of Students for support. Please notify the professor if you are comfortable in doing so. This will enable me to provide any resources that I may possess.
7. **Accommodations for Students with Documented Disabilities:** If you are a student with a disability or believe you might have a disability that requires accommodations, requests for accommodations must be made in a timely fashion to Disability & Access Services, 25 Buick St, Suite 300, Boston, MA 02215; 617-353-3658 (Voice/TTY). Students seeking academic accommodations must submit appropriate medical documentation and comply with the established policies and procedures http://www.bu.edu/disability/accommodations/