ENME 700 – Advanced Mechanical Engineering Analysis I

Summer II 2020

Instructor: Dr. Reuel Smith

TA: (TBD)

Office Hours: Wednesday 2:00PM – 4:00PM or by appointment

Course Description: Advanced Mechanical Engineering Analysis I is an overview of several mathematical and computational applications to a range of engineering problems. ***Basic knowledge of calculus and linear algebra is recommended and required for this course*** as much of the material will be covering techniques that go beyond that knowledge. The course will train students in recognizing and setting up basic mechanical (and/or general) engineering problems using these mathematical and computational techniques. These techniques include (but are not limited to) matrix manipulation, ordinary linear differential equation analysis, Laplace Transforms, and numerical integration. The course will also utilize application of these mathematical techniques within the scope of common software used in modern mechanical engineering analysis including Excel, MATLAB, R, and Mathematica, which is supplemented by in-class tutorials, discussion, workshops, and research.

Course Prerequisites: Because of the structure of the course, time will be limited to the main topics presented in the course. Therefore, it is ***strongly recommended*** that students have basic knowledge of the following topics:

- Calculus: Integrals, derivatives, log and exponential rules, chain rule, product rule
- Linear algebra: Matrix and vector operation, cross and dot products, plotting vectors, coordinate systems, Eigenvectors and Eigenvalues, determinants
- Excel: Data entry and calculation, plotting
- Research, interpreting, basic-to-intermediate coding, and applying an algorithm

Course Structure: The six-week long course will be of a seminar style and consist mainly of online videos, short lectures, discussions, examples and applications, workshops, and case studies. The classes are held Monday and Wednesday from 5:15PM to 9:00PM. Online students are encouraged to watch lectures live in order to participate in the in-class discussions, exercises, and activities. The overall structure of the course consists of seven main topics and several subtopics.

Module 1: Linear Algebra Review and Eigen Analysis Techniques and Applications

This module briefly goes over certain topics and methods used in linear algebra including matrix and vector operations, determinants, eigenvalues and eigenvectors, and fields. It will also include a research activity covering Green's Theorem as well as other vector-based theorems.

Module 2: Introduction to Ordinary Differential Equations

This is the introduction to ordinary differential equations (ODEs) as well as a brief overview on how they are applied to engineering. ODE's of several orders are covered including first, second, and multiple. With that the class will learn different forms of ODEs, how to set up a differential equation based on the physical properties of an engineering problem, and how to solve the equation using manual calculations and computational techniques aided by MATLAB routines.

Module 3: Power Series Solutions to Ordinary Differential Equations

Differential equations that have variable coefficients cannot be solved using standard algebra. For this there are series solutions that use methods such as the Power Series to form coefficients needed to solve the differential equation. This module goes over some of the more common series solutions as well as more advanced forms of differential equation formats.

Module 4: Laplace Transforms and Fourier Analysis

In addition to algebraic solutions, differential equations and the engineering problems thereof can be solved using Laplace Transforms, operations that involves the simplification of complex differential equations and that is popular among engineers. This module will list several known Laplace Transforms and go over the methods used to solve differential equations using these transforms. The Fourier Series is also discussed in how they are used to solve complex differential equations. Several examples will be addressed that uses direct the Fourier Series as a solution method as well as Fourier Transforms that operate similarly to Laplace Transforms.

Module 5: Review of Boundary Value Problems

This module introduces or reviews boundary value problems (BVPs) where physical systems defined by differential equations are constrained by a given set of boundary conditions. A series of systems and applications including bending beams and oscillating beams will be covered.

Module 6: Partial Differential Equations

This module introduces partial differential equations (PDEs) which are typically used to model more complex physical systems than ODEs which are reserved for simple physical systems. A set of simple physical systems and their relation to PDEs will be introduced and several case studies will be performed.

Module 7: Numerical Methods and Integration Techniques

The final module covers numerical methods that may be used to solve differential equations and perform integration. The module will cover several numerical integration algorithms as well as several MATLAB scripts to aid in application.

List of Skills in ENME 700

Module 1	A1	Demonstrate ability to input and manipulate matrices in MATLAB and/or other software	4
	A2	Perform Eigen analysis on a matrix of any size	2
	A3	Perform an Eigen analysis based on the content of a problem statement (be able to validate by MATLAB)	2
	A4	Identify uses for Eigen analysis in engineering	2
	A5	State applications for Green's, Divergence, and Stokes Theorems in your field of engineering	6
	A6	Solve an engineering problem using matrix rotation	2
	A7	Identify uses for rotational matrices (and other vector notation addressed this module) in your field of engineering	2
	A8	Design and demonstrate an engineering problem that uses topics discussed in Module 1	4
Module 2	B9	Use ordinary differential equations (ODEs) to solve an engineering based problem by way of the modeling process	2
	B10	Solve an ODE using separation of variables and exact reduction method. Describe the difference between the two methods.	2
	B11	Solve a homogeneous and nonhomogeneous linear differential equation (LDE) by hand.	4
	B12	Solve a nonhomogeneous LDE using a Wronksian	2
	B13	Solve a system of LDEs two ways: (1) one-by-one and (2) as a group	4
	B14	Set up a Markov Analysis by identifying Markov states and drawing a Markov diagram	2
Module 3	C15	Solve an ODE or LDE using power series	2
	C16	Express and plot a probability distribution as a power series	2
	C17	Code and perform a for-loop operation in MATLAB and successfully solve an associated problem	2
	C18	Identify uses for Legendre polynomials in engineering that have not been covered in class	2
	C19	Solve a set of ODEs or LDEs using Frobenius method	2
Module 4	D20	Find the Laplace transform of a function f(t) and similarly the inverse Laplace transform of a function F(s)	4
	D21	Identify common uses for Laplace transforms in engineering.	2
	D22	Use Laplace transforms to solve an ODE or LDE.	2
	D23	Solve an engineering based problem using Laplace transforms	2
	D24	Find the Fourier transform and inverse Fourier transform	4
	D25	Perform a short literature review to find practical uses of the Fourier transform in engineering.	4
Module 5	E26	Identify the boundary conditions of a given engineering system or problem	2
	E27	Solve a problem requiring boundary conditions by way of previous material or Skills	2
	E28	Repeat Skill E except for an inhomogeneous boundary condition problem	2
	E29	Research and state uses of orthogonal functions in engineering that have not been discussed in class	2
	E30	Demonstrate an engineering application in presentation form of Sturm-Lioville equations	2
Module 6	F31	Identify the three main partial differential equation (PDE) types and state some of their uses	2
	F32	Derive by hand the expression for displacement from any PDE	2
	F33	Plot the modes of a given displacement from any PDE	2
	F34	Animate the motion of a given displacement from any PDE using MATLAB or another program	2
	F35	Design and demonstrate an engineering problem that uses topics discussed in Module 6	2
Module 7	G36	Test and modify numerical method algorithms for a given situation	2
	G37	Identify the effectiveness of a numerical method using additive or multiplicative error	2
	G38	Develop a function from scratch in MATLAB, R, or some other software to execute a numerical method	2
	G39	Use a numerical method to formulate and solve an engineering problem	2
	G40	Formulate and then execute an engineering analysis using numerical integration methods	4

Grading: The list of skills on the last page will be the basis on how you will be graded in this class. Skills can be achieved in the class through a series of assignments and exams that will become available during the semester. There will also be a series of worksheets assigned on a regular basis, but these will be strictly for practice and training and thus will be ungraded. Worksheets consist of some training problems that may be done by hand or coded in MATLAB. I recommend working homework by hand initially and confirming any work by MATLAB. I also recommend setting up study groups amongst yourselves. Try setting up meeting times and places for after class as early as possible. **Please note that while the grade is important, it is *not* as important as your overall understanding of particular skills in the course or your overall well-being**.

- Exams
  - Dates to be determined (TBD)
  - Open book and open notes
  - Test period TBD
- Final Exam
  - Date: August 21st
  - Open book and open notes
  - Test period TBD

Required Textbook:

- Advanced Engineering Mathematics, Wiley, 2011. (10th Ed.) by Erwin Kreyszig

Recommended Textbook:

- Advanced Engineering Mathematics with Mathematic and MATLAB, 1998. (Vol. 1 & 2) by Reza Malek-Madani

Recommended Tools and Applications

- A laptop and Skype or Zoom for site-to-site discussion
- MATLAB (download on Terpware)
- R Software