MECH4740 Numerical Methods

Course Code: MECH4740	**Course Title:** Numerical Methods
Required Course Or Elective Course: Elective	**Terms Offered (Credits):** Fall or Spring (3 credits)
Faculty In Charge: Kai Tang	**Pre/Co-Requisites:** MATH1013/MATH1014/MATH1020/MATH1023/MATH1024 and COMP1002/1021/1022P/1022Q

Course Structure:

Lecture: 2.5 hours lecture per week, 14 weeks + final exam week; Lab: 1.5 hours per week

Textbook/Required Material:

1. Class notes
2. "Numerical Methods for Engineers" by S.C. Chapra and R.P. Canale, 6th edition, McGraw-Hill, ISBN 978-007-126759-5

Course Description:

1. The use of numerical methods for the analysis simulation, and design of engineering processes and systems has been increasing at a rapid pace in recent years. Today, it is unthinkable for a person to claim to be an able engineer or a solid scientist without governing the fundamentals as well as the practical software tools of these numerical methods. This necessity of numerical methods covers all the engineering disciplines. A mechanical/aerospace engineer deals with various optimizations all the time in his daily work, without knowing using the right optimization methods such as Newton-Raphson method or gradient method, he will fail his job. An industrial engineer facing a floor-design or inventory-scheduling task has to choose the suitable numerical methods for the task, such as the linear programming method. A chemical engineer assigned to solve the problem of balancing multi-dimensional mass of a reactor must know how to cast the problem as a set of partial differential equations and use the right numerical method to solve them. To an electrical engineer required to analyze the signal response behavior of a newly designed device, he needs to be familiar with various frequency analysis models, such as Fourier transformation, and know how to select the right numerical method to implement them.
2. This course is intended for teaching numerical methods for engineering students at the senior level as well as at the beginning graduate level. The course will have three important objectives: (1) to teach the basic theories and fundamentals of numerical methods; (2) to help the students to acquire skills to implement these methods for computer solution; and finally (3) to provide an environment where the students can familiarize themselves with many today's popular commercial software systems and their use in the solution of engineering problems. On the first objective, the following fundamental aspects will be covered: analysis of errors, roots of equations, linear and algebraic equations, optimizations, curve-fitting and approximation, numerical differentiation and integration, ordinary differential equations, and partial differential equations. On the second objective, computer programming basics as well as certain specific computer languages such as C++ and MATLAB will be introduced. On the last objective, the students will learn how to use MATLAB and Excel VBA to implement their own numerical methods.
3. This course is structured as a 3 credits course with 3 hours of lecture and one hour of lab per week.

Course Topics:

Part One: Modeling, Computers, and Error Analysis
Chapter 1: Mathematical Modeling and Engineering
Chapter 2: Programming and Software
Chapter 3: Approximations and Round-Off Errors
Chapter 4: Truncation Errors and the Taylor Series

Part Two: Roots of Equations
Chapter 5: Bracketing Methods
Chapter 6: Open Methods
Chapter 7: Roots of Polynomials
Chapter 8: Engineering Applications: Roots of Equations

Part Three: Linear Algebraic Equations
Chapter 9: Gauss Elimination
Chapter 10: LU Decomposition and Matrix Inversion
Chapter 11: Special Matrices and Gauss-Seidel
Chapter 12: Engineering Applications: Linear Algebraic

Part Four: Optimization
Chapter 13: One-Dimensional Unconstrained Optimization
Chapter 14: Multidimensional Unconstrained Optimization
Chapter 15: Constrained Optimization
Chapter 16: Engineering Applications: Optimization

Part Five: Curve Fitting
Chapter 17: Least-Squares Regression
Chapter 18: Interpolation
Chapter 19: Fourier Approximation
Chapter 20: Engineering Applications: Curve Fitting

Part Six: Numerical Differentiation and Integration
Chapter 21: Newton-Cotes Integration Formulas
Chapter 22: Integration of Equations
Chapter 23: Numerical Differentiation
Chapter 24: Engg. Applications: Numerical Integration and Differentiation

Part Seven: Ordinary Differential Equations
Chapter 25: Runge-Kutta Methods
Chapter 26: Stiffness and Multistep Methods
Chapter 27: Boundary-Value and Eigenvalue Problems
Chapter 28: Engineering Applications: Ordinary Differential Equations

Part Eight: Partial Differential Equations
Chapter 29: Finite Difference: Elliptic Equations
Chapter 30: Finite Difference: Parabolic Equations
Chapter 31: Finite-Element Method
Chapter 32: Engineering Applications: Partial Differential Equations

Course Objectives:	1. To teach the basic theories and fundamentals of numerical methods. 2. To help the students to acquire skills to implement these methods for computer solution. 3. To provide an environment where the students can familiarize themselves with many today's popular commercial software systems and their use in the solution of engineering problems.
Course Outcomes:	A. The students will have a thorough understanding of the fundamental mathematical theories and algorithms underlying modern numerical methods. B. Become an expert user of an advanced engineering computing system MATLab -- the students will be able to efficiently use the system to implement representative numerical algorithms to solve practical engineering problems, individually or as a team.
Assessment Tools:	Regular homework problems 10% Lab projects 20% Mid-term and Final exams 70%