Instructor Information	
Name	
Room NO.	
Phone Number	
E-mail	
Office Hours	

Course Information	
Course Name	Advanced Numerical Methods
Course Number	0905731
Perquisites	
Credit Hours	3
Semester	
Class Meeting	

Course Description	
Course Objectives	• To introduce students to a wide range of easily accessible numerical methods that will be useful in practice. • To make students confident in looking up and selecting additional methods when they are needed. • To help students become familiar with MATLAB and other convenient numerical software, and with simple programming techniques & skills. • To give students some understanding of how the algorithms work and to help them understand why numerical algorithms sometimes fail to converge or give unexpected results.
Text Books	
References	U. M. Ascher, **2008**, Numerical Methods for Evolutionary Differential Equations.SIAM, Philadelphia. 2. K. J. Beers, **2007**, Numerical Methods for Chemical Engineering: Applications in MATLAB. Cambridge University Press, Cambridge. 3. M. Schäfer, **2006**, Computational Engineering – Introduction to Numerical Methods. Springer-Verlag Berlin Heidelberg. 4. J. Kiusalaas, **2005**, Numerical Methods in Engineering with MATLAB. Cambridge University Press, Cambridge. 5. W. Y. Yang, W. Cao, T.-S. Chung & J. Morris, **2005**, Applied Numerical Methods Using MATLAB. John Wiley & Sons, Inc., New Jersey. 6. E. E. Toro, **1999**, Riemann Solvers and Numerical Methods for Fluid Dynamics: A Practical Introduction. Springer-Verlag Berlin, Heidelberg. 7. J. E. Jr. Dennis, R. B. Schnabel, **1996**, Numerical Methods for Unconstrained Optimization and Nonlinear Equations. SIAM. 8. B. A. Finlayson, **1992**, Numerical methods for problems with moving fronts. Ravenna Park Publishing, Inc., Seattle, Washington. 9. M. E. Davis, **1984**, Numerical Methods and Modeling for Chemical Engineers. John Wiley & Sons, Inc., New York. 10. B. A. Finlayson, **1980**, Nonlinear analysis in chemical

	engineering. McGraw-Hill, New York.

Course Assessment		
Project	20.0%	
Midterm	30.0%	
Final Exam	50.0%	

Course Contents

Topic 1: Solving system of linear algebraic equations: Ax = b

- Review of matrix operations
- Elimination methods with pivoting for solving Ax = b
- Matrix factorization: LU, Cholesky & QR decomposition
- Tridiagonal systems and Thomas algorithm
- Iterative methods for solving Ax = b
- Numerical algorithms: Numerical errors, ill-conditioning & tolerances

Topic 2: Systems of Nonlinear algebraic equations:

- Multivariable Newton’s method
- The approximate Jacobian & Quasi-Newton’s Method
- Robust reduced-step Newton’s method
- Trust region Newton’s method
- Iterative methods for solving large Nonlinear system of algebraic equations
- Applications using MATLAB solvers
- Homotopy
- Biforcation analysis

Topic 3: Eigenvalue analysis

- Orthogonal matrices
- Eigenvalues and eigenvectors (definition)
- Eigenvalues and existence/ uniqueness properties of linear systems
- Gershgorin’s Theorem: matrix norm, spectral radius & condition number
- Numerical calculation of eigenvalues using QR method.
- Singular Value Decomposition (SVD)
- MATLAB applications

Topic 4: Review of polynomial interpolation & Numerical integration:

- Lagrange, Newton & Hermite interpolating polynomials
- Numerical integration: Newton-Cotes & Gaussian Quadrature integration methods
- Applications using MATLAB

Topic 5: Numerical solution of ODEs: IVP

- Explicit & Implicit single step methods
- Explicit & Implicit multistep step methods
- Stiffness and choice of integration method
- Stiff stability of BDF
- Differential-algebraic equation (DAE) and parametric continuation
- MATLAB Applications

Topic 6: Numerical solution of PDEs: BVP

- BVP and conservation principles
- Finite differences
- Treatment of Dirichlet & von Neumann BCs
- Convective-Diffusion equation: Central difference and upwind difference schemes

- The finite volume method
- Numerical solution in MATLAB

Topic 7: Modern numerical methods for fluid flow

- Finite difference schemes for linear hyperbolic scalar problems: Upwind & central difference schemes
- Consistency, stability and convergence
- The Two-Step Lax-Wendroff Scheme
- The modified equation
- Nonlinear scalar problems: Discontinuity, weak solution, nonuniqueness & the entropy condition
- Strategies to enforce the entropy condition: Artificial viscosity & the first-order Godunov method.

Prerequisite

Student who attend this course **MUST** be familiar with

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Responsibilities

Expected Course Outcomes

Regulations

I. Attendance:

Attendance of classes is obligatory. Absence must be verified according to the university's regulation, ***please take it serious***.

II. Quizzes and homework

All students are required to finish their homework assignments, and submit them on time. Late homework ***will not be accepted*** under any circumstances. Popup quizzes will be given without any prior notice. You need to come prepared to class. A hand calculator is recommended to be available in every class**.** In addition to the final exam, there will be one midterm exam. These exams will be challenging and comprehensive during the class

IV. Conduct in classroom:

While in the class room, all cell phones, Laptops need to be turned off.