Numerical Methods:

Draft 1

## SSG226 - Introduction to Numerical Methods (2 Units)

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## SSG226 - Introduction to Numerical Methods (2 Units)

**Course Description:** This course provides an introduction to various numerical methods used to solve problems in science, engineering, and mathematics. It covers techniques for finding approximate solutions to equations, interpolation, integration, and other mathematical operations.

**Target Audience:** This course is designed for students with a strong foundation in calculus and linear algebra.

**Course Prerequisites:** MTH121 - Calculus I, MTH122 - Calculus II, MTH231 - Linear Algebra

**Learning Objectives:** By the end of this course, students will be able to:

* Apply iterative methods to solve algebraic and transcendental equations.
* Utilize finite difference techniques for numerical analysis.
* Analyze and solve difference equations.
* Perform interpolation for data approximation.
* Apply spline functions for data fitting.
* Solve systems of linear equations numerically using iterative methods.
* Identify and address ill-conditioning in numerical problems.
* Employ matrix analysis methods for matrix inversion.
* Solve for eigenvalues using numerical techniques.
* Implement numerical integration for error functions and elliptic integrals.

**Course Outline:**

**Module 1: Introduction to Numerical Methods (1 Week)**

* Subtopic 1.1: What are Numerical Methods?
  + Importance and applications in various disciplines
* Subtopic 1.2: Errors and Approximations
  + Types of errors (round-off, truncation) and their impact
  + Techniques for error analysis
* Subtopic 1.3: Introduction to Software Tools
  + Brief overview of scientific computing software (e.g., MATLAB, Python libraries)

**Module 2: Iterative Methods for Equation Solving (2 Weeks)**

* Subtopic 2.1: Introduction to Iteration
  + Fixed-point iteration and convergence analysis
* Subtopic 2.2: Newton-Raphson Method
  + Algorithm and convergence properties
* Subtopic 2.3: Other Iterative Methods
  + Bisection method, secant method (brief overview)

**Module 3: Finite Differences and Difference Equations (2 Weeks)**

* Subtopic 3.1: Finite Difference Techniques
  + Forward, backward, central difference approximations
  + Applications to derivatives and integrals
* Subtopic 3.2: Introduction to Difference Equations
  + Formulating difference equations from continuous models
  + Solving difference equations with constant coefficients

**Module 4: Interpolation and Splines (2 Weeks)**

* Subtopic 4.1: Lagrange Interpolation
  + Constructing interpolating polynomials
  + Error analysis
* Subtopic 4.2: Other Interpolation Methods
  + Linear interpolation, spline interpolation (brief overview)
* Subtopic 4.3: Introduction to Splines
  + Types of splines (linear, quadratic) and their properties
  + Applications of splines in curve fitting

**Module 5: Numerical Methods for Linear Systems (2 Weeks)**

* Subtopic 5.1: Direct Methods vs. Iterative Methods
  + Gaussian elimination, LU decomposition (overview)
* Subtopic 5.2: Iterative Methods for Linear Systems
  + Jacobi iteration, Gauss-Seidel iteration
  + Convergence analysis
* Subtopic 5.3: Ill-conditioning and its Impact
  + Identifying ill-conditioned systems
  + Mitigating effects of ill-conditioning

**Module 6: Matrix Methods and Eigenvalue Problems (2 Weeks)**

* Subtopic 6.1: Matrix Inversion Techniques
  + Gaussian elimination with back substitution
  + Matrix inversion using determinants (brief overview)
* Subtopic 6.2: Eigenvalues and Eigenvectors
  + Properties and applications of eigenvalues and eigenvectors
* Subtopic 6.3: Power Method for Eigenvalue Approximation
  + Algorithm and convergence properties

**Module 7: Numerical Integration (2 Weeks)**

* Subtopic 7.1: Numerical Integration Concepts
  + Trapezoidal rule, Simpson's rule
  + Composite integration techniques
* Subtopic 7.2: Numerical Integration for Special Functions
  + Applying numerical integration to error function and elliptic integrals

**Module 8: Course Review and Assessment (1 Week)**

* Subtopic 8.1: Review of Key Concepts
  + Summarizing important methods from each module
* Subtopic 8.2: Course Assessment
  + Midterm exam, quizzes, assignments, and final exam structure

**Additional Resources:**

* Textbook: Numerical Methods for Engineers: <https://www.routledge.com/Chapman--HallCRC-Numerical-Analysis-and-Scientific-Computing-Series/book-series/CHNUANSCCOM> by Steven Chapra
* Online resources:

Draft 2

## SSG226 - Introduction to Numerical Methods (2 Units)

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Draft 2

## SSG226 - Introduction to Numerical Methods (2 Units)

**Course Description:** This course provides an introduction to the fundamental concepts and techniques used in numerical methods. It covers various methods for solving equations, interpolation, approximation, and numerical integration.

**Target Audience:** This course is designed for students with a strong foundation in mathematics, particularly calculus and linear algebra.

**Course Prerequisites:** MTH121 - Calculus I, MTH122 - Calculus II, MTH231 - Linear Algebra (or equivalent courses)

**Learning Objectives:** By the end of this course, students will be able to:

* Apply iterative methods to solve algebraic and transcendental equations.
* Understand and utilize finite difference techniques for numerical analysis.
* Analyze and solve difference equations.
* Employ interpolation techniques for data approximation.
* Apply spline functions for data fitting and interpolation.
* Solve systems of linear equations numerically using iterative methods.
* Identify and address ill-conditioning issues in numerical computations.
* Utilize matrix analysis methods for matrix inversion.
* Implement numerical techniques for eigenvalue evaluation.
* Apply numerical integration methods to solve error function and elliptic integral problems.

**Course Outline:**

**Module 1: Introduction to Numerical Methods (1 Week)**

* Subtopic 1.1: What are Numerical Methods?
  + Importance of numerical methods in various fields (science, engineering, finance)
  + Limitations of analytical solutions and the need for numerical approaches
* Subtopic 1.2: Errors in Numerical Computations
  + Types of errors (round-off, truncation)
  + Error analysis and propagation
* Subtopic 1.3: Introduction to Software for Numerical Methods
  + Overview of common numerical software packages (MATLAB, Python libraries)

**Module 2: Solution of Equations (2 Weeks)**

* Subtopic 2.1: Iterative Methods for Algebraic and Transcendental Equations
  + Fixed-point iteration method
  + Bisection method
  + Newton-Raphson method
  + Convergence analysis of iterative methods
* Subtopic 2.2: Finite Differences
  + Forward, backward, and central difference approximations
  + Applications of finite differences (derivatives, integrals)

**Module 3: Difference Equations and Interpolation (2 Weeks)**

* Subtopic 3.1: Difference Equations
  + Definition and classification of difference equations (homogeneous, non-homogeneous)
  + Solution techniques for first and second-order linear difference equations
* Subtopic 3.2: Interpolation
  + Lagrange interpolation
  + Newton's divided difference interpolation
  + Error analysis of interpolation methods

**Module 4: Splines and Numerical Linear Algebra (2 Weeks)**

* Subtopic 4.1: Splines
  + Introduction to spline functions
  + Linear, quadratic, and cubic splines
  + Applications of splines in curve fitting
* Subtopic 4.2: Numerical Solution of Linear Systems
  + Direct methods (Gaussian elimination, LU decomposition)
  + Iterative methods (Jacobi iteration, Gauss-Seidel iteration)
  + Ill-conditioning and its impact on numerical solutions

**Module 5: Matrix Methods and Eigenvalue Problems (2 Weeks)**

* Subtopic 5.1: Matrix Analysis
  + Review of matrix operations and properties
  + Methods for matrix inversion (Gaussian elimination with back substitution)
* Subtopic 5.2: Eigenvalues and Eigenvectors
  + Definition and properties of eigenvalues and eigenvectors
  + Power method for eigenvalue approximation
  + QR algorithm for eigenvalue computation

**Module 6: Numerical Integration (1 Week)**

* Subtopic 6.1: Numerical Integration Techniques
  + Trapezoidal rule
  + Simpson's rule
  + Composite integration methods
  + Error estimation in numerical integration
* Subtopic 6.2: Applications of Numerical Integration
  + Numerical evaluation of definite integrals
  + Applications in calculating areas, volumes, and moments

**Assessment:**

* Quizzes (20%)
* Assignments (30%)
* Midterm Exam (25%)
* Final Exam (25%)

**Additional Resources:**

* Textbook: Numerical Methods for Engineers and Scientists by Kenneth S. Karpinski: <https://www.amazon.com/Numerical-Methods-Scientists-Engineers-Mathematics/dp/0486652416>
* Online resources on numerical methods: <https://en.wikipedia.org/wiki/Numerical_analysis>
* Video lectures on numerical methods: <https://www.youtube.com/watch?v=QqhSmdkqgjQ>

This course outline provides a more detailed structure with subtopics for easier comprehension. It also includes learning objectives, assessment methods, and additional resources to enhance student learning.

Draft 3

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## SSG226 - Introduction to Numerical Methods (2 Units)

**Course Description:** This course provides an introduction to various numerical methods used to solve problems in science, engineering, and mathematics. It covers techniques for solving equations, interpolation, approximation, and numerical integration.

**Target Audience:** This course is designed for students with a strong foundation in calculus and linear algebra.

**Course Prerequisites:** MTH121 - Calculus I, MTH222 - Linear Algebra

**Learning Objectives:** By the end of this course, students will be able to:

* Apply iterative methods to solve algebraic and transcendental equations.
* Utilize finite difference techniques for numerical analysis.
* Solve difference equations using appropriate methods.
* Implement interpolation for data approximation.
* Apply spline functions for data fitting.
* Solve systems of linear equations numerically, including iterative methods.
* Identify and address ill-conditioning in numerical problems.
* Employ matrix analysis methods for solving linear systems.
* Apply numerical techniques to evaluate eigenvalues.
* Utilize numerical integration methods to approximate definite integrals, including error function and elliptic integrals.

**Course Outline:**

**Module 1: Introduction to Numerical Methods (1 Week)**

* Subtopic 1.1: What are Numerical Methods?
  + Importance of numerical methods in various fields
  + Limitations of analytical solutions
* Subtopic 1.2: Errors in Numerical Methods
  + Types of errors (round-off, truncation)
  + Error analysis and propagation
* Subtopic 1.3: Introduction to Software for Numerical Methods
  + Overview of common numerical software packages (e.g., MATLAB, Python libraries)

**Module 2: Iterative Methods for Equation Solving (2 Weeks)**

* Subtopic 2.1: Introduction to Iteration
  + Fixed-point iteration method
  + Convergence analysis
* Subtopic 2.2: Newton-Raphson Method
  + Algorithm and convergence properties
  + Anwendungsbeispiel (applied example) in a relevant field
* Subtopic 2.3: Other Iterative Methods
  + Brief introduction to alternative methods (e.g., bisection method, secant method)

**Module 3: Finite Differences and Difference Equations (2 Weeks)**

* Subtopic 3.1: Finite Difference Methods
  + Forward, backward, central difference approximations
  + Applications: derivatives, integration
* Subtopic 3.2: Difference Equations
  + Modeling with difference equations
  + Methods for solving difference equations (e.g., recursion, iteration)

**Module 4: Interpolation and Approximation (2 Weeks)**

* Subtopic 4.1: Lagrange Interpolation
  + Constructing interpolating polynomials
  + Error analysis
* Subtopic 4.2: Other Interpolation Methods
  + Brief introduction to alternative methods (e.g., Newton's interpolation, spline interpolation)
* Subtopic 4.3: Numerical Differentiation and Integration
  + Approximation of derivatives and integrals using interpolation methods

**Module 5: Numerical Linear Algebra (2 Weeks)**

* Subtopic 5.1: Direct Methods for Linear Systems
  + Gaussian Elimination
  + LU decomposition
* Subtopic 5.2: Iterative Methods for Linear Systems
  + Jacobi iteration, Gauss-Seidel iteration
  + Convergence analysis
* Subtopic 5.3: Matrix Eigenvalues and Eigenvectors
  + Power method for eigenvalue approximation

**Module 6: Numerical Integration (1 Week)**

* Subtopic 6.1: Numerical Integration Techniques
  + Trapezoidal rule, Simpson's rule
  + Composite integration methods
* Subtopic 6.2: Special Integrals
  + Numerical evaluation of error function and elliptic integrals

**Assessment:**

* Quizzes (throughout the semester)
* Midterm Exam
* Final Exam
* Programming Assignments (applying numerical methods to solve problems)

**Additional Resources:**

* Textbook: Numerical Methods for Engineers by Steven C. Chapra: <https://www.amazon.com/Numerical-Methods-Engineers-Steven-Chapra/dp/1260232077>
* Online resources: <https://math.nist.gov/>

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