Course Title: Numerical Methods **Credit: 3**
Course No: CSIT.224 **Number of period per week: 3+3**
Nature of the Course: Theory + Lab **Total hours: 45+45**
Year: Second, Semester: Fourth
Level: B. Sc. CSIT

1. Course Introduction

This course introduces students to a variety of numerical methods and then applies these methods to solve a broad range of scientific problems. These problems include examples from physics as well as several other disciplines, including chemistry, mathematics, economics, and finance. Numerical techniques for solving problems expressed in terms of matrix, differential and integral equations will be developed.

2. Objectives

After completing this course the students should be able to:

- Understand and estimate errors due to round-off and truncation; understand error propagation and numerical instability.
- Use bracketing and non-bracketing techniques to find approximate roots of non-linear equations, and analyze the errors.
- Perform data analysis using interpolation, extrapolation, and curve-fitting, including quantification of the degree of fit.
- Solve linear systems of equations using direct and iterative methods.
- Calculate approximate derivatives and finite integrals.
- Apply numerical techniques to solve ordinary differential equations.

3. Specific Objectives and Contents

Specific Objectives	**Contents**
• Review the mathematical concepts needed to study numerical methods. • Define and Exemplify Errors in Numerical Computation. • Understand Error Propagation and FP Representation.	**Unit I: Mathematical Review and Errors (2)** 1.1. Mathematical Review: Taylors Series, Mean Value Theorem, Asymptotic Notations 1.2. Errors in Numerical Computation: True Error, Relative Error, Approximate Error, Relative Approximate Error, Sources of Error: (Round off Error, Truncation Error) 1.3. Error Propagation, Floating Point Representation
• Understand Nonlinear Equations and their Solution Approaches • Exemplify solution of different iterative methods • Write algorithms and program the iterative methods.	**Unit II: Solution of Nonlinear Equations (8)** 2.1. Nonlinear Equations Solution Approaches: Direct Analytical Method, Graphical Method, Trial & Error Method, Iterative Methods 2.2. Iterative Methods: Bisection Method, False Position Method, Newton-Raphson method, Secant Method, Fixed Point Iteration Method and Proof of their

• Prove and understand convergence rate of iterative methods • Understand and program Horner's method and Remainder Theorem.	Convergences 2.3. Synthetic Division, Remainder Theorem, Horners Method for Polynomial Evaluation, Finding Multiple Roots
• Understand use and applications of interpolation. • Derive and apply different regression and interpolation techniques to solve problems • Design algorithms and program interpolation and regression methods. • Discuss Regression vs interpolation.	**Unit III: Interpolation and Regression (8)** 3.1. Interpolation vs Extrapolation, Lagrange Interpolation, Newton's Divided Difference Interpolation 3.2. Interpolation with Equally Spaced Data: Newton's Forward Difference Interpolation, Newton's Backward Difference Interpolation 3.3. Spline Interpolation: What is Spline? Natural Cubic Splines. 3.4. Regression vs Interpolation, Least Square Methods, Linear Regression. 3.5. Non-Linear Regression: Polynomial Regression, Exponential Regression
• Understand system of linear equations their representation and applications. • Discuss direct methods vs iterative methods • Derive formulae for direct and iterative methods to solve system of equations. • Design algorithms and program the solution of direct and iterative methods • Apply power method to calculate largest eigenvalue and eigenvector.	**Unit IV: Solving Systems of Linear Equations (8)** 4.1. System of equations, Matrix Representation, Existence of Solution 4.2. Direct Methods for Solving System of Equations: Basic Gauss Elimination Method, Gauss-Elimination with Partial Pivoting, Gauss Jordan method, Matrix Inversion 4.3. Matrix Factorization: LU Decomposition, Doolittle LU Decomposition, Cholesky's Method 4.4. Iterative Methods for Solving System of Equations: Jacobi Iteration Method, Gauss-Seidal Method 4.5. Ill-Conditioning, Eigenvalues and eigenvectors, Power Method
• Explain use and applications of derivatives. • Derive and apply formulae to calculate derivative of continuous and discrete functions. • Devise the algorithm and program them for calculating differentiation of discrete and continuous functions.	**Unit V: Numerical Differentiation (5)** 6.1. Numerical Differentiation: Introduction, Real Applications 6.2. Differentiating Continuous Functions: Forward Difference Formula, Backward Difference Formula, Central Difference Formula 6.3. Differentiating Discrete Functions: Derivatives using Newton's Divided Difference Formula, Derivatives using Newton's Forward Difference Formula, Derivatives using Newton's Forward Difference Formula.
• Explain use and applications of integration.	**Unit VI: Numerical Integration (5)** 6.4. Numerical Integration: Introduction, Definite Integral

• Derive and apply formulae to calculate values of definite integrals. • Design and implement algorithm for calculating values of definite integrals.	Applications 6.5. Newton Cotes Integration Formulae, A General Quadrature Formula For Equally Spaced Arguments 6.6. Trapezoidal Rule, Composite(Multi-segment) Trapezoidal Rule, Simpsons 1/3 Rule, Composite(Multi-segment) Simpsons 1/3 Rule, Simpsons 3/8 Rule, Composite(Multi-segment) Simpsons 3/8 Rule.
• Understand basics of ODE's and their solutions. • Apply derived formulae to solve ODE's or system of ODE's • Design and implement the algorithms for solving initial value problems and boundary value problems.	**Unit VII: Solving Ordinary Differential Equations (6)** 7.1. Introduction: ODE vs PDE, Order, Degree and Solution of Differential Equations, Initial Value Problems and Boundary Value Problems. 7.2. Solving Initial Value Problems: Picards Method, Eulers Method, Heun's Method, Forth Order RK Method, 7.3. Solving System of ODE's and Higher Order ODE's by using any Existing Method. 7.4. Solving Boundary Value Problems: Shooting Method, Finite Difference Method.
• Understand basics of PDE's and their categorization. • Solve Laplace and Parabolic equations using finite difference method.	**Unit VIII: Solving Partial Differential Equations (3)** 8.1. Partial Differential Equations: Introduction, Categorization of PDE's: Elliptic, Parabolic and Hyperbolic PDE's. 8.2. Deriving Difference Equations, Solving Laplace Equation, Solving Poison's Equation.

Evaluation System

Undergraduate Programs							
External Evaluation	**Marks**	**Internal Evaluation**	**Weightage**	**Marks**	**Practical**	**Weightage**	**Mark**
End semester examination	60	Assignments	20%	20	Practical Report copy	25%	20
(Details are given in the separate table at the end)		Quizzes	10%		Viva	25%	
		Attendance	20%		Practical Exam	50%	
		Internal Exams	50%				
Total External	60	Total Internal	100%	20		100%	20
Full Marks 60+20+20 = 100							

External evaluation

1. **End semester examination:**

It is a written examination at the end of the semester. The questions will be asked covering all the units of the course. The question model, full marks, time and others will be as per the following grid.

2. **External Practical Evaluation:**
   After completing the end semester theoretical examination, practical examination will be held. External examiner will conduct the practical examination according to the above mentioned evaluation. There will be an internal examiner to assist the external examiner. Three hours time will be given for the practical examination. In this examination Students must demonstrate the knowledge of the subject matter.

Full Marks: 100, Pass Marks: 45, Time: 3 Hrs

Nature of question	Total questions to be asked	Total questions to be answered	Total marks	Weightage
Group A: multiple choice*	20	20	20×1 = 20	60%
Group B: Short answer type questions	7	6	6×8 = 48	60%
Group C: Long answer type question/long menu driven programs	3	2	2×16 =32	60%
			100	100%

Each student must secure at least 50% marks in internal evaluation in order to appear in the end semester examination. Failed student will not be eligible to appear in the end semester examinations.

Internal evaluation

Assignment: Each student must submit the assignment individually. The stipulated time for submission of the assignment will be seriously taken.

Quizzes: Unannounced and announced quizzes/tests will be taken by the respective subject teachers. Such quizzes/tests will be conducted twice per semester. The students will be evaluated accordingly.

Attendance in class: Students should regularly attend and participate in class discussion. Eighty percent class attendance is mandatory for the students to enable them to appear in the end semester examination. Below 80% attendance in the class will signify NOT QUALIFIED (NQ) to attend the end semester examination.

Presentation: Students will be divided into groups and each group will be provided with a topic for presentation. It will be evaluated individually as well as group-wise. Individual students have to make presentations on the given topics.

Mid-term examination: It is a written examination and the questions will be asked covering all the topics in the session of the course.

Discussion and participation: Students will be evaluated on the basis of their active participation in the classroom discussions.

Instructional Techniques: All topics are discussed with emphasis on real-world application. List of instructional techniques is as follows:

- Lecture and Discussion
- Group work and Individual work
- Assignments
- Presentation by Students
- Quizzes
- Guest Lecture

Students are advised to attend all the classes and complete all the assignments within the specified time period. If a student does not attend the class(es), it is his/her sole responsibility to cover the topic(s) taught during that period. If a student fails to attend a formal exam/quiz/test, there won't be any provision for re-exam. Unless and until the student clears one semester he/she will not be allowed to study in the following semesters.

Laboratory Work

Student should write programs, prepare lab sheet for each of the topics discussed in classes. Minimum 3 lab hour per week in required. Nature of programming problem can be decided by instructor. Lab sheet of around 35 programming problems is recommended.

Prescribed Text

- C.F. Gerald and P.O. Wheatley, "*Applied Numerical Analysis*", 4th Edition, Addison Wesley Publishing Company, New York.
- W.H. Press, B.P. Flannery et.al., "*Numerical Recipes in C*", 1st Edition, Cambridge Press, 1988.

References

- **S.S. Shastry,** "Introductory Methods of Numerical Analysis" Fifth Edition, PHI Leraning Pvt Limited, 2012.
- **Arjun Singh Saud, Bhupendra Singh Saud,** "Numerical methods with Practical Approach", First Edition, kriti Books and Publishers Pvt Limited, 2014