Course Code	MTH373/MTH573
Course Name	Scientific Computing
Credits	4
Course Offered to	UG/PG
Course Description	This is an overview course to be offered to 3rd and 4th year undergraduate, and postgraduate students. The course is structured to systematically build on and provide an overview of several ideas and topics that comprise the basics of discretizations of continuous mathematics. In this setup, we will concern ourselves with computational as well as stability analyses of both methods and algorithms. We will begin with an introduction to scientific computing. Then we will analyze and study methods in numerical linear algebra: matrix factorizations, direct solution of linear systems, solutions of linear least square problems, and solutions to eigenvalue problems. This will be followed by solutions of nonlinear equations in 1d and then more generally. We will apply this learning to unconstrained optimization in 1d and again more generally. We will also delve into some constrained optimization and nonlinear least squares problems. The next part of the course will discuss polynomial interpolation (including using splines) of discrete data in 1d. This will be utilized in methods for numerical differentiation of sampled data, and for numerically carrying out integration in 1d (also known as quadrature). The last part of the course will deal with numerical solutions of initial and boundary value ordinary differential equations in 1d. This will be followed by a foray into numerical solution of model partial differential equations. A student registering for the MTH573 version of the course will be required to work on an additional Pass/No Pass project for getting the course credits. Graduate students, in particular, will not be allowed to register for the 373 listing of this course.

Pre-requisite (Mandatory)	**Pre-requisite (Desirable)**	**Pre-requisite(other)**	**anti-requisite**	
MTH100 (Linear Algebra)	MTH204 (Maths IV: ODEs/PDEs), MTH203 (Maths III), MTH240 (Real Analysis I), or some familiarity with those topics. An exposure to a high-level programming language; Python or Julia preferred.		Numerical Methods	
*Please insert more rows if required				

Post Conditions

CO1	**CO2**	**CO3**	**CO4**	**CO5**
Students understand notions of accuracy, conditioning and stability. They can apply this to analyzing linear	Students know how to find roots of equations of the form $f(x) = 0$, apply this to solving unconstrained optimization	Students can interpolate a point data set using polynomials and piecewise	Students learn about ordinary differential equations, their numerical	Students learn to derive and analyze finite difference methods for solving

Weekly Lecture Plan

Week Number	**Lecture Topic**	**COs Met**	**Assignment/Labs/Tutorial**
Week 1	Introduction: computer arithmetic, round-off, error propagation, stability of algorithms; Linear systems;	CO 1	Quiz 1
Week 2	Overview of iterative methods for linear systems, Linear least squares, existence and uniqueness, sensitivity and conditioning, normal equations, QR factorization (Householder, Givens and Gram-Schmidt)	CO 1	Assignment 1
Week 3	Singular value decomposition, eigenvalue problems, existence and uniqueness, sensitivity and conditioning, similarity transformation, power iteration and variants, deflation, QR iteration	CO 1	Quiz 2
Week 4	Krylov subspace methods; generalized eigenvalue problems, nonlinear equations, existence and uniqueness (contraction mapping theorem), sensitivity and conditioning, bisection, fixed point iteration, Newton's method and variations (all in 1d)	CO 1 and CO 2	Assignment 2
Week 5	Methods for system of nonlinear equations (Newton's, Broyden's); Optimization problems, existence, uniqueness, sensitivity, and conditioning; unconstrained optimization (steepest descent, Newton's, BFGS, conjugate-gradient), nonlinear least squares (Gauss-Newton, Levenberg-Marquardt)	CO 2	Quiz 3
Week 6	Constrained optimization (sequential quadratic and linear programming); Interpolation: existence, uniqueness and conditioning; polynomial and piecewise polynomial interpolation	CO 2 and CO 3	Assignment 3
Week 7	Integration: existence, uniqueness and conditioning; numerical quadrature (Newton-Cotes, Gaussian, progressive and composite quadrature); numerical differentiation (finite difference and Richardson extrapolation)	CO 3	Quiz 4
Week 8	Initial value problems for ordinary differential equations (ODEs): existence, uniqueness and conditioning, Euler's methods, accuracy and stability, stiffness, higher-order single-step methods, Runge-Kutta methods (Heun's, RK4), multistep methods (Adams-Bashforth, Adams-Moulton); methods for systems of ODEs	CO 4	Assignment 4
Week 9	Boundary value problems for ODEs: existence, uniqueness, and conditioning; shooting method, finite differences, collocation, Galerkin's method; overview of sparse linear solvers	CO 4	Quiz 5
Week 10	Partial differential equations: introduction and classification; time-dependent problems, finite-difference schemes for one-dimensional parabolic and hyperbolic model problems (heat, advection and wave equations)	CO 5	Assignment 5
Week 11	Consistency and stability (Lax equivalence theorem), CFL condition, von-Neumann analysis and stability condition	CO 5	Quiz 6
Week 12	Time-independent problems, boundary conditions, finite difference methods for one- and two-dimensional Poisson's	CO 5	Assignment 6
Week 13	Linear finite element method for one- and two-dimensional Poisson's	CO 5	

*Please insert more rows if required

Weekly Lab Plan

Week Number	**Laboratory Exercise**	**COs Met**	**Platform (Hardware/Software)**

*Please insert more rows if required

Assessment Plan

Type of Evaluation	**% Contribution in Grade**
Quizzes	10
Midsem	20
Endsem	30
Assignments (Theory + Programming)	40

*Please insert more row for other type of Evaluation

Resource Material	
Type	**Title**
Textbook	Scientific Computing (Second Edition) by Michael Heath
Rererence	Numerical Mathematics and Computing (Seventh Edition) by Ward Cheney and David Kincaid