ESO 208A: Computational Methods in Engineering
Course Outline

Introduction: Introduction to numerical methods and analysis. Engineering Systems, Physical and Mathematical Modeling. *Error Analysis*: Approximations; Round off and Truncation errors. Error Propagation and Backward Error Analysis. Condition number of problem and algorithm.

Roots of Non-Linear Equations: Method of Bisection, Regula Falsi, Secant Method, Fixed point Method, Newton Raphson method, Multiple roots. Analysis and order of convergence Polynomials: Mueller's method, Bairstow's method.

Solution of System of Linear Equations: Dense, Sparse and Banded systems, Direct Methods - Gauss Elimination, Gauss- Jordan, LU decomposition, Thomas Algorithm. Perturbation analyses of direct methods, matrix and vector norms, condition number of matrix, effect of round-off errors. Iterative improvement of solution by direct methods. Iterative methods: Jacobi and Gauss-Seidel iteration, convergence criteria for Jacobi and Gauss Seidel iterative methods, rate of convergence of iterative methods. Successive over Relaxation. Scaling and equilibration.

Solution of System of Nonlinear Equations. iterative methods, Fixed Point iteration, Newton-Raphson method.

Eigenvalues and Eigenvectors: Power method, inverse power method and inverse power method with shift. Fadeev-Leverrier method for the formulation of the Characteristic polynomials, QR decomposition.

Approximation Theory: Weirstrass approximation theorem. Basis functions, norms and semi-norms, inner product, orthogonal basis functions, formulation of least square problem, derivation of normal equations. Approximation of Continuous functions using polynomial basis functions: simple, Tchebycheff and Legendre polynomials. Polynomial regression of discrete data. Transformation of nonlinear problems to linear approximation problems, multiple variables, statistics of regression: mean, standard deviation, variance, standard error, regression coefficient. Approximation of periodic functions, Fourier series representation – continuous and discrete. Interpolating polynomials: Newton's divided difference polynomial, Lagrange polynomials. Interpolation using spline functions: linear, quadratic and cubic splines.

Numerical Differentiation: Introduction to finite difference approximations, Derivation of generalized finite difference approximation of any order and accuracy, truncation error analysis, phase error analysis by modified wave number. Finite difference approximations on irregular grid. Richardson's extrapolation.

Numerical Integration Rectangular rule, Trapezoidal Rule and Simpson's rule. Local and global error analysis. Romberg Integartion. Gauss Quardrature, Improper Integrals.

ODE, Initial Value Problems: Euler's method, improvement of Euler's method, Runge - Kutta Methods, Multi-Steps Methods. Predictor Corrector Methods. Stiff ODEs. Introduction of Gear's Method. Consistency by TE analysis. Stability Analysis. *Boundary Value Problems*: Decomposition into Linear System of ODEs, Shooting Method, Direct Method.