Course Number: ME 504 **Approval: 9th senate meeting**
Course Name: Numerical Methods for Engineering Computation
Credits: 3-0-0-3
Prerequisites: -

Intended for: UG/PG
Distribution: - Elective
Semester: Odd/Even

Preamble: Computational analysis of mathematical models is an essential facet of engineering practice and research. Numerical methods enable effective solution of problems which are not amenable to simple analytical treatment. A comprehensive introduction to the subject fundamentals provides for the handling of common mathematical problems and prepares a foundation for the learning of advanced paradigms such as finite element and finite volume analysis.

Course Outline: The course introduces fundamental concepts of numerical analysis for handling of mathematical problems frequently encountered in engineering computations. The course lays a special emphasis on the development of programming skills via CPP implementation of numerical schemes to analyze common engineering problems. The exercise is expected to make the learner adept in handling mathematical problems using self-designed routines and in gaining insights into the related aspects of computational efficiency and accuracy.

Course Modules:

1. **Introduction:** Differential equations in engineering applications. Analytical vs. Numerical solution of a mathematical model. Computer representation of numbers. Errors in numerical computation. Review of CPP programming concepts - Program structure, data types, arrays, structures, functions, file handling using simple problems: Second moment of area, analysis of beams, basic statistics etc. **(3 contact hours)**

2. **Systems of linear algebraic equation:** Gauss elimination, Gauss Jordan, LU decomposition, and Gauss-Seidel methods. Thomas algorithm for tri-diagonal and Cholesky decomposition for symmetric matrices. Matrix inversion methods. CPP programs for the mentioned schemes. **(6 contact hours)**

3. **Eigen problem:** Eigenvalues and Eigen vectors. Properties. Methods of estimation of Eigenvalues and Eigenvectors – Power Iteration Methods, Jacobi Iteration, QR algorithm; Application of these concepts towards Matrix Inversion and solution of linear simultaneous equations. **(5 contact hours)**

4. **Curve fitting:** Linear regression, polynomial regression, nonlinear regression. CPP program for constitution of normal equations. **(4 contact hours)**

5. **Finite differences and interpolation:** Taylor's series, Forward, backward and central differences, Difference tables, Finite difference operators, Newton's forward and backward interpolation formulae, Stirling's, Bessel's and Laplace-Everett's interpolation formulae. Lagrange's polynomial and Newton's divided difference formula. CPP programs for implementing interpolation schemes. **(6 contact hours)**

6. **Numerical differentiation and integration:** Derivatives using forward, backward and central difference formulae. Newton-Cotes integration formulae – Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule. CPP programs for implementing numerical integration schemes. **(6 contact hours)**

7. **ODEs:** Description of initial and boundary value problems. Taylor's series, Picard's, Euler's, Runge-Kutta and Milne's methods. Finite difference solution of boundary value problems.
(6 contact hours)

8. **PDEs:** Description of Elliptic, Parabolic and Hyperbolic PDEs. Solution of Laplace's and Poisson's equations. Solution of linear heat transfer equation - CPP programs for implementation of explicit and implicit schemes. Conditions for stability. **(6 contact hours)**

Text books:

- Numerical methods for engineers by Steven C. Chapra and Raymond P. Canale. McGraw-Hill. 2015.
- Numerical methods with C++ programming by Nita H. Shah, PHI. 2009.

Reference books:

- Numerical methods for engineers and scientists by Joe D. Hoffman. Marcel Dekker, Inc. 2001.
- Numerical methods with programs in C by T. Veerarajan and T. Ramachandran. Tata McGraw-Hill. 2006.