

## BOOKS

1. Applied Numerical Methods with MATLAB for Engineers and Scientists (Applied Numerical Methods with MATLAB for Engineers and Scientists), Steven C. Chapra
2. Numerical Methods for Engineers (Chapra & Canale, 7th ed.)

## COURSE CONTENT

**Course Title:** Numerical Methods for Engineering (Graduate Level)  
**Duration:** 10 Weeks

### Week 1 - Mathematical Foundations & Error Analysis

- Floating point arithmetic
- Round-off and truncation errors
- Taylor series expansions
- Order of accuracy
- Stability vs. convergence
- Conditioning and ill-conditioning

### Week 2 - Nonlinear Equations

- Bisection method
- False position method
- Newton-Raphson method
- Secant method
- Convergence order comparison
- Multi-variable Newton method

Engineering examples: nonlinear stress-strain relations, buckling equations.

### Week 3 - Systems of Linear Equations

- Gaussian elimination
- LU decomposition
- Partial pivoting
- Condition number
- Sparse matrix considerations
- Direct vs iterative solvers

Application: stiffness matrix systems in FEM.

### Week 4 - Iterative Linear Solvers

- Jacobi method
- Gauss-Seidel method
- Successive Over-Relaxation (SOR)
- Convergence criteria
- Spectral radius
- Introduction to Krylov methods (conceptual overview)

Application: large FEM systems.

### Week 5 - Interpolation & Approximation

- Lagrange interpolation
- Newton divided differences

- Polynomial interpolation error
- Spline interpolation
- Least squares approximation
- Overfitting vs numerical stability

Application: experimental data fitting (e.g., composite stress-strain curves).

### **Week 6 - Numerical Differentiation & Integration**

- Forward, backward, central difference schemes
- Higher-order finite difference formulas
- Trapezoidal rule
- Simpson's rule
- Gaussian quadrature
- Error bounds

Application: strain calculation from displacement data.

### **Week 7 - Ordinary Differential Equations (Initial Value Problems)**

- Euler method
- Modified Euler
- Runge-Kutta methods (RK2, RK4)
- Stability of time integration
- Stiff ODEs (conceptual introduction)

Application: vibration problems, transient heat conduction.

### **Week 8 - Boundary Value Problems & Finite Difference Method**

- Shooting method
- Finite difference formulation
- Discretization of second-order ODEs
- Error propagation
- Grid refinement

Application: beam deflection problem.

### **Week 9 - Numerical Methods for Partial Differential Equations**

- Classification of PDEs
- Explicit vs implicit schemes
- Stability (CFL condition)
- 1D heat equation
- Wave equation (conceptual)

Application: heat transfer & diffusion.

# ME537 COURSE DETAILED CONTENT

## 1. NONLINEAR EQUATIONS (2 Students)

### Student 1 - Bracketing Methods

**Theory:** Bisection method; False position method; Convergence order comparison

**Engineering example** Buckling load root from Euler-type buckling equation  $f(P)=0$  (solve for critical load numerically)

**Tool:** Excel (iteration table) + MATLAB (plot + iterations)

### Student 2 - Newton & Secant Methods

**Theory:** Derivation, Convergence order, Convergence order comparison

**Engineering example:** Solve nonlinear stress-strain relation for strain using Newton method.

**Tool:** MATLAB required (function implementation). Excel optional.

## 2. SYSTEMS OF LINEAR EQUATIONS (2 Students)

### Student 3 - Gaussian Elimination

**Theory:** Gaussian Elimination, Partial pivoting

**Engineering example: 2D truss equilibrium** (small nodal force-displacement system  $Ku=f$ )

**Tool:** Excel (manual elimination table) + MATLAB (coded solver without "" operator).

### Student 4 - LU Decomposition

**Theory:** LU Decomposition, Direct vs iterative solvers

**Engineering example: Multiple load cases** on the same stiffness matrix (reuse  $LU$  to solve  $Ku=f_1, f_2, \dots$ )

**Tool:** MATLAB (LU factorization (manual coding), Compare with MATLAB built-in `lu()`)

## 3. ITERATIVE SOLVING OF LINEAR EQUATIONS (2 Students)

### Student 5 - Jacobi Method

**Theory:** Jacobi Method, Convergence Criteria

**Engineering Example:**

- Steady-state temperature distribution in a 1D rod (discretized Laplace equation).

**Tool:** Excel (iteration sheet) + MATLAB (residual vs iteration plot).

### Student 6- Gauss-Seidel

**Theory:** Gauss-Seidel method, Convergence criteria (comparison with Jacobi)

**Engineering example:** Thermal resistor network steady-state solution.

**Tool:** Excel (iteration table) + MATLAB (convergence speed comparison).

## 4. ADVANCED ITERATIVE METHODS

### Student 7 - Successive Over-Relaxation (SOR) Method

**Theory:** Successive Over-Relaxation (SOR), Effect of relaxation parameter

**Engineering Example:** 2D heat conduction grid (study effect of relax.parameter on convergence speed).

**Tool:** Plot iteration count vs  $\omega$

## **5. INTERPOLATION METHODS (2 Students)**

### **Student 8 - Polynomial Interpolation**

**Theory:** Lagrange interpolation, Newton divided differences, Polynomial interpolation error

**Engineering example:** Material property interpolation versus temperature.

**Tool :** Excel (interpolation table) + MATLAB (error comparison).

### **Student 9- Splines & Least Squares**

**Theory:** Spline interpolation, Least squares approximation, Overfitting vs numerical stability

**Engineering example:** Fit composite stress-strain experimental curve.

**Tool:** MATLAB (polyfit, spline) + Excel trendline comparison.

## **6. DIFFERENTIATION & INTEGRATION (2 Students)**

### **Student 10- Numerical Differentiation (HALID ESAD)**

**Theory:** Forward difference, Backward difference, Central difference, Higher-order finite difference formulas

**Engineering example:** Compute strain from displacement measurements.

**Tool:** Excel difference table + MATLAB error vs step size.

### **Student 11- Numerical Integration**

**Theory:** Trapezoidal rule, Simpson's rule, Gaussian quadrature, Error bounds

**Engineering example:** Compute work from force–displacement curve.

**Tool:** Excel area calculation + MATLAB comparison.

## **7. ORDINARY DIFFERENTIAL EQUATIONS (ODE) (2 Students)**

### **Student 12- Euler & Modified Euler**

**Theory:** Euler method, Modified Euler

**Engineering example:** Mass-spring-damper vibration simulation.

**Tool:** MATLAB time-stepping required.

### **Student 13- Runge-Kutta**

**Theory:** Runge-Kutta methods (RK2, RK4), Stability of time integration, Stiff ODEs (conceptual introduction)

**Engineering example:** Transient heat model solved with RK4.

**Tool reminder:** MATLAB required.

## **8. BOUNDARY VALUE PROBLEMS (2 students)**

### **Student 14- Shooting Method**

**Theory:** Shooting method, Shooting method

**Engineering example:** Beam deflection BVP solved via shooting.

**Tool :** MATLAB required.

### **Student 15 - Finite Difference for 2nd Order ODE**

**MATLAB**

- Beam deflection solver

- Matrix assembly

Excel optional (small N only)

## **9. PARTIALLY DIFFERENTIAL EQUATIONS (1 Student)**

### **Student 16 - Classification of PDEs**

**Theory:** Classification of PDEs, Wave equation

**Engineering example:** Compare diffusion vs wave propagation physics.

**Tool:** MATLAB visualization.