ME 6150: Numerical methods in Thermal Engineering

Instructor(s)

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General information

- 4 credit course
- 2 lecture hours per week: 'A' slot
  - Tuesdays 12–12:50 PM
  - Thursdays 11–11:50 AM
  - Venue: MSB
- 3 lab hours per week
  - Tue–Thurs: 2–5 PM
  - Venue: HPCF-B
- Announcements via moodle

Learning Outcomes

- Implement solution procedures for solving linear and non-linear algebraic equations, ordinary differential equations (ODEs), and partial differential equations (PDEs) on a computer.
- Acquire working knowledge of computational complexity, accuracy, stability, and errors in solution procedures.

Syllabus

1. *Solution to Linear Algebraic Equations*
   (a) Gaussian elimination
   (b) LU decomposition
   (c) Pivoting strategies
   (d) Operation Count
   (e) Matrix inversion
   (f) Special cases
      i. Tridiagonal systems
      ii. Block tridiagonal systems
   (g) Well conditioned and Ill conditioned system
   (h) Matrix and Vector norms
   (i) Condition Number and its implications

2. *Solution to Non-linear Algebraic Equations*
   (a) Bisection, Newton-Raphson, and Secant method
   (b) System of non-linear equations

3. *Basics of finite difference method*
   (a) Discretization of spatial and time derivatives using Taylor's series
   (b) Truncation error and order of discretization
   (c) Fourier (von Neumann) accuracy analysis

4. *Solution to Ordinary Differential Equations*
   (a) Initial Value problems
      i. Euler explicit and implicit methods
      ii. Runge-Kutta method
      iii. Predictor-Corrector methods
   (b) Boundary value problem
      i. Shooting method
      ii. Finite difference method applied to pin fin heat dissipation
   (c) Stiff problems
      i. Meaning of stiffness
      ii. Further insights into stiffness by the application of Euler explicit and implicit method to a stiff problem
      iii. Solution to stiff problem
      iv. Example - Chemical kinetics

5. *Solution to Partial Differential Equations*
   (a) *Classification of PDEs and characteristics of a PDE*
   (b) *Solution to Elliptic Partial Differential Equations*
      i. Physical problems governed by elliptic PDE's
      ii. Five-point and nine-point discretization of Poisson's equation
      iii. Iterative methods
         A. Point Iterative methods - Jacobi, Gauss-Seidel, and SOR
         B. Detailed theory of the convergence of iterative methods
         C. Global Iterative methods - Steepest Descent and Conjugate Gradient
   (c) *Solution to Parabolic Partial Differential Equations*
      i. Physical problems governed by parabolic PDE's
      ii. Operator splitting and ADI methods

Suggested Textbooks

- *Matrix Computations* – G. H. Golub, Johns Hopkins University Press
- *Numerical Recipes* – W. H. Press *et al.*
- *Numerical Solution of Partial Differential Equations: Finite Difference Methods* – G. D. Smith, Oxford University Press, (1985)
- *Engineering numerical analysis* – Parviz Moin (2^{nd} edition, 2010), Cambridge University Press.
- *Introduction to Numerical Analysis* – Kendall Atkinson
- *Numerical methods for scientists and engineers* – J. Hoffman and S. Frankel, CRC Press
- *Numerical Mathematics and Computing* – W. Cheney and D. Kincaid, International Thomson Publishing Company
- *Applied Numerical Analysis* – C. Gerald and P. Wheatley, Addison-Wesley
- *Analysis of Numerical Methods* – E. Isaacson and H. B. Keller, John Wiley & Sons

Pre-requisites

- Knowledge of Engineering Mathematics
  - Basics of matrix algebra
  - Basics of ODEs and PDEs
- Familiarity with one of the programming languages FORTRAN/C/C++
- Familiarity with plotting software such as `gnuplot` and any editor such as `vi, emacs, gedit`
- Familiartiy with linux operating system
- No consent of teacher required

Grading Policy

- Assignments – 20%
  - Theoretical
  - Computational

- Quiz 1 – Theory – 15%
- Quiz 2 – Theory – 15%
- Final exam
  - Theoretical – 40%
  - Computational – 10%

- Institute norm – Attendance $\geq$ 85%