AE 470

Computational Methods in Aerospace Engineering

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University of Illinois at Urbana-Champaign

courses.ae.uiuc.edu/AE470

Notes written by Philippe Geubelle, Eric Loth and Sang Lee

Class schedule: Mon. Wed. Fri. 9:00am to 9:50am in 103 Transportation

Instructor:

Sang Lee
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Office Hours:

Teaching Assistant:

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322 Talbot Lab
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Office hours:

Course notes and class participation

- **Course notes**
  - Available at Illini Bookstore
  - Cover theoretical part of the course
  - Make sure to bring the notes in class
  - Application problems to be solved in class on the blackboard
  - Please send typos/suggestions (in class, by email, etc.) to help us improve the notes

- **Class participation**
  - Notes contain some question marks/blanks to be filled in in class via class input
  - Sample problems to be solved primarily by students
  - Class participation essential but informal and does not affect grades in any way (i.e, don't hesitate to make suggestions/guesses)
  - Since notes do not contain applications, class attendance is highly recommended

- **Note: email and web site are the preferred means of communication for the course. Make sure to empty your inbox regularly.**

Recommended textbooks

- **Heath, M. T. "*Scientific Computing: An Introductory Survey*" McGraw-Hill. 1st or 2nd ed.**

- **Cook, R. D., Malkus, D. S. and Plesha, M. E. "*Concepts and Applications of Finite Element Analysis*" Wiley & Sons. 4th ed.**

- Moin, P. "*Fundamentals of Engineering Numerical Analysis*" Cambridge University Press

- Ferziger, J. "Numerical Methods for Engineering Applications" Wiley-Interscience 2nd Ed.

- Anderson, D.A., Tannehill, J.C. and Pletcher, R.H. "*Computational Fluid Mechanics and Heat Transfer*" Hemisphere Publishing Company. 2nd ed.

- Palm, W. J. *Introduction to Matlab 7 for Engineers*. McGraw-Hill

- Scilling, R. J. and Harris, S. L. *Applied Numerical Methods for Engineers using Matlab and C*. Brooks/Cole

Assignments

- **“conventional” (pencil and paper) homework assignments**
  - These will involve direct applications of concepts discussed in class
  - You are **strongly** encouraged to solve these problems, as some are likely to appear in the midterm and final exams.
  - The solution will be provided after 1-2 weeks

- **programming assignments**
  - Essential part of the course: they **will** be graded
  - Must be written **individually**
  - To be written in Matlab* and uploaded for TA to test.
  - Make sure to include your name at the beginning of **every** file and **many** comments
  - We will sometimes build upon codes from previous assignments, so don’t give up!

- **graphic software**
  - A short introduction to Matlab will be posted on the web site.

*If you have no Matlab experience and would like to use another programming language, please see me

Exams

- **Midterm**
  - 50 minutes - Closed notes/books - 2-page equation sheet
  - Covers the first three chapters
  - Will be related to HW assignments (may involve a programming problem)

- **Final**
  - 3 hours - Closed notes/books
  - Covers the last two chapters (finite difference and finite element methods)
  - Will be related to HW assignments (may involve a programming problem)

- **Grades**
  - Conventional homeworks: 15%
  - Programming assignments: 30%
  - Midterm: 25%
  - Final exam: 30%

- **Grade sheet on course web site**
  - Send 4-digit code (between ‘0000’ and ‘9999’) to patel3@illinois.edu

Course Content

1. **Introduction**
1.1 Motivation for computational analysis
1.2 Steps for PDE simulations
1.3 Programming guidelines

2. **Introduction to computational analysis**
2.1 Computational errors
2.2 Interpolation and polynomial approximation
2.3 Integration
2.4 Root finding
2.5 Solution of ODE

3. **Numerical solution of linear systems**
3.1 Matrix characteristics
3.2 Direct vs. iterative methods
3.3 Direct methods
- 3.3.1 Gauss elimination
- 3.3.2 LU decomposition
- 3.3.3 Pivoting and other special matrix operations
- 3.3.4 Accuracy and condition number

3.4 Iterative methods
- 3.4.1 Splitting (residue) methods
- 3.4.2 Jacobi method
- 3.4.3 Gauss-Seidel method
- 3.4.4 Relaxation methods

Course Content (cont.)

4. **Finite difference method (FDM)**
4.1 Classification of PDE
4.2 PDE Initial and boundary conditions
4.3 Taylor series for finite-difference operators
4.4 Finite difference of ODE's
4.5 Finite difference for boundary conditions
4.6 Finite difference of elliptic PDE's
4.7 Finite difference of parabolic PDE's
4.8 Finite difference of hyperbolic PDE's

5. **Finite element method (FEM)**
5.1 Reminder: energy formulation (PVM, PMPE)
5.2 Rayleigh-Ritz method
5.3 FEA of 1-D Poisson problem
5.4 FEA of 2-D truss structures
5.5 FEA of 2-D Poisson problem
5.6 Additional topics on the FEM
- 5.6.1 Node numbering and storage requirements
- 5.6.2 Error control and mesh design
- 5.6.3 FEA of 2-D structural problems