Fall 2011
Department of Scientific Computing
Florida State University

ISC 4232 C: Computational Methods for Continuous Problems

Instructor	Dr. Anter El-Azab
TA	Benjamin McLaughlin
Class Time	MWF 11:15 am–12:05 noon
Room	DSL 152 (will change to DSL 468)

Contact information

Dr. Anter El-Azab

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Office hours

- Monday 1:00-2:00 pm, DSL 415
- Other times by appointment
- Students may also come to my office any time; if I am avaialable, I will help with any questions/issues

Missed classes

- While traveling, I will use remote teaching technology (e.g., Skype, EVO) to give the class on schedule. Handouts will be distributed to students before the class time.
- We will test remote teaching technology prior to its actual use to ensure that the lecture delivery goes smoothly.
- I will find a substitute instructor If I cannot offer the class myself while on travel.

Grading

– Homework assignments	30%
– Laboratory assignments	30%
– Midterm exam (part 1,2)	20%
– Final exam	20%

Exams Dates/Times

- Midterm part 1: Oct. 14 (Fri), lecture time
- Midterm part 2: Oct. 17 (Mon), lecture time
- Final Tuesday, Dec. 13, 2011 at 5:30-7:30 pm

- All exams will be held in classroom (no take home tests).
- Midterm will cover the first part of the course.
- The final will cover the second part of the course.

Homework & laboratory assignments

- Homework and Laboratory assignments will be given on alternate weeks; both will require the use of the computer lab (DSL 152).
- Homework assignments focus mostly on concepts and analytical work and can include programming work.
- Laboratory assignments will include (i) running codes and software packages, and (ii) some level of programming.
- Due dates of homework and laboratory reports will be specified when assigned.
- Please note that, together, homework and laboratory assignments weigh 60% of your total grade.

University attendance policy

Excused absences include documented illness, deaths in the family and other documented crises, call to active military duty or jury duty, religious holidays, and official University activities. These absences will be accommodated in a way that does not arbitrarily penalize students who have a valid excuse. Consideration will also be given to students whose dependent children experience serious illness.

Academic honor policy

The Florida State University Academic Honor Policy outlines the University's expectations for the integrity of students' academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process. Students are responsible for reading the Academic Honor Policy and for living up to their pledge to "... be honest and truthful and ... [to] strive for personal and institutional integrity at Florida State University." (Florida State University Academic Honor Policy, found at http://dof.fsu.edu/honorpolicy.htm.)

Americans with disabilities act

- Students with disabilities needing academic accommodation should: (1) register with and provide documentation to the Student Disability Resource Center; and (2) bring a letter to the instructor indicating the need for accommodation and what type. This should be done during the first week of class.
- This syllabus and other class materials are available in alternative format upon request.
- For more information about services available to FSU students with disabilities, contact the:

  Student Disability Resource Center
  874 Traditions Way
  108 Student Services Building
  Florida State University
  Tallahassee, FL 32306-4167
  (850) 644-9566 (voice)
  (850) 644-8504 (TDD)
  sdrc@admin.fsu.edu
  http://www.disabilitycenter.fsu.edu/

Catalogue description

ISC 4232 C: Computational Methods for Continuous Problems (4). Numerical solution of partial differential equations and implementation for case studies drawn from various science areas. Finite difference, finite element, and Fourier spectral methods will be introduced. Common software packages will be used. A laboratory component of the class will illustrate the concepts learned on a variety of application problems.

Prerequisites

- MAS 3105 Applied Linear Algebra I
- ISC 4304 Programming for Scientific Application

Course objectives (student learning)

At the end of the course, the student will be able to

- model simple sciences problems with partial differential equations;
- obtain numerical solution of partial differential equations using finite difference method;
- obtain numerical solution of partial differential equations using finite element method;
- obtain numerical solution of partial differential equations using Fourier spectral method;
- analyze the convergence of the solution of partial differential equations by comparing with analytical solutions;
- analyze the scientific phenomena modeled by the partial differential equations by varying the model parameters and studying changes in the numerical solution; and
- use a select set of software packages to perform all of the above.

List of topics

- Introduction to modeling with partial differential equations
- Classification of partial differential equations
- Analytical solution I: methods of separation of variables, integral transforms
- Finite difference methods
- Finite element methods
- Fourier spectral methods
- Applications to science problems
- Software for Finite element and Fourier spectral methods

Textbook/Reference book

– Instructor will make hand-written or PowerPoint handouts available to students.

– The material will be based on two references:

1. Advanced Engineering Mathematics, Peter O'Neil, 5^{th} (2003) or 6^{th} (2007) Edition, Thomson – Part 6. Chapters 16,17,18,19 (5^{th} Edition); chapters 17, 18, 19 (6^{th} Edition)
2. Computational Science and Engineering, Gilbert Strang, Wellesley-Cambridge Press, 2007

– Additional reference material will be announced or handed out as we proceed.

– Ref 1: the introduction part, analytical methods

– Ref 2: the computational part

Course details

- Introduction to modeling with partial differential equation (1 week)

  PDE models in science and engineering: heat conduction, particle diffusion and reaction-diffusion problems, fluid flow problems, electromagnetism, elasticity

- Classification of partial differential equations (1 week)

  Hyperbolic, parabolic and elliptic partial differential equations, canonical forms

- Analytical solution (2 weeks)
  - Part I: methods of separation of variables, series solutions
  - Part II: integral transforms
- Time discretization for numerical solution of PDEs (1 week)
  - Explicit, implicit, high order schemes

Time line is only an estimate. We should expect some deviations from what is stated here. I will try to include one or two review sessions at the end if time allows.

- Finite difference solution and applications (1 week)
  - (1D problems): 1D wave equation and transient diffusion equation
- Finite difference solution and applications (2D problems) (2 weeks)
  - Finite difference stencils, applications to potential problems
- Finite element solution and applications (1D and 2D problems) (3 weeks)
  - Motivation for using FEM and weak form of differential equations
  - Finite elements and interpolation functions
  - Numerical integration
  - Formation of global matrix and load vector, boundary conditions, solution
  - Applications, COMSOL software
- Fourier spectral method and applications (1D and 2D problems) (2 week)
  - Discrete Fourier Transform (DFT), FFT algorithm and software (FFTW)
  - Application to 2D partial differential equations

Laboratory work and software

- Introduction part: students will compute and visualize solutions of 1D and 2D problems.
- Finite Difference Method: students will code solutions for explicit and implicit Euler methods for solving 1D problems using finite difference scheme; 2D solution of potential problems
- The students will study the convergence of the numerical solution for a given set of initial and/or boundary conditions by comparing the numerical solution with the analytical solution. The students will also conduct analysis of the physical models by varying the initial conditions, boundary conditions, parameters in the PDE, forcing terms, etc. Students will prepare a brief report summarizing their work.

Laboratory work and software

- Finite Element Method
  - Students will solve 2D elliptic equations using COMSOL software package.
  - The laboratory assignment will be given in the form of mini projects involving simple problems. Three types of problems will be assigned: particle diffusion, head conduction and electrostatic field problems. The student will choose one problem, construct the governing equations, model the domain of solution with FEM, design the solution strategy (e.g., mesh type, mesh density), analyze the solution and prepare a report.
  - The mini projects will be assigned to students at the beginning of the FEM module.

Laboratory work and software

- Fourier Spectral Method
  - Students will solve 2D partial differential equations using Fourier spectral method.
  - A commonly used FFT package such as FFTW will be used for this purpose.