MATH762: Numerical PDE II

Course Info

[↑] (./courses/MATH762/#md-page-menu)
This graduate course presents selected topics within the broad area of numerical solution of partial differential equations (PDEs).

Course goals: students will acquire proficiency in the formulation of numerical schemes for solving PDEs using finite difference,
finite volume, finite element, boundary element, and spectral methods. A broad overview of each approach will be discussed. Depending on class interest, specific methods will be studied in detail. Application areas are also dependent on class and instructor interest and are
chosen from domains such as fluid dynamics, rheology, elasticity, plasticity.

Title	**MATH762: Numerical PDE II**
Times	MWF 11:15AM-12:05PM, Phillips 301
Office hours	Mo 3:30-5:00PM, and by email (mailto:mitran@unc.edu) appointment, Chapman 451
Instructor	Sorin Mitran (mailto:mitran@unc.edu)

Honor Code:

- Unless explicitly stated otherwise, all work is individual. You may discuss various approaches to homework problems with students, instructors, but must draft your answers by yourself. In joint projects, each student will clearly identify which portions of the work they contributed.
- All exams are closed book

Grading

Required work

- Homework projects - 5 assignments x 20 = 80 points
- Final project defense = 20 points

Mapping of point scores to letter grades

Grade	Points	Grade	Points	Grade	Points	Grade	Points
H+ *cum laude*	101-118	H-	86-90	P-	71-75	L-	56-60
H+	96-100	P+	81-85	L+	66-70	L--	50-55
H	91-95	P	76-80	L	61-65	F	0-49

Course policies

- This is a graduate-level course. Students are expected to undertake independent work to deepen their understanding of course material
- Students are free to establish their own schedule; there is no need to inform instructor of absences. Course attendance is highly recommended to gain insight into course topics
- Late homework is not accepted.
- Homework is to be submitted in the form of a paper for publication in SIAM typeset format
- Computer code should be submitted in commented, correct, ready-to-run form, and directly reflect theory and conclusions from the homework submission. Code is to be submitted in the form of a supplement to a SIAM paper
- Homework assignments are organized around mini-projects inspired by the real-world practice of scientific computation.

Examination

The final examination consists of presentation of a selected project chosen from the homeworks. The format is a presentation within a SIAM minisymposium session.

Course materials

[↑] (./courses/MATH762/#md-page-menu)

Bibliography

There is no single course text. Topics are drawn from the following sources

- Course lecture notes, S. Mitran, link (http://mitran-lab.amath.unc.edu/courses/MATH762/bibliography/MitranNumericalPDENotes.pdf)
- *Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-Dependent Problems*, R. LeVeque link (http://epubs.siam.org/doi/book/10.1137/1.9780898717839)
- *Finite Volume Methods for Hyperbolic Problems* by R. R. LeVeque, link (http://www.cambridge.org/catalogue/catalogue.asp?isbn=0521009243)
- *Spectral Methods in Fluid Dynamics*, by C. Canuto, Y. Hussaini, A. Quarteroni, T. Zhang, link (http://link.springer.com/book/10.1007%2F978-3-642-84108-8)
- *The Finite Element Method: Its Basis and Fundamentals*, by O. Zienkiewicz, R. Taylor, J. Zhu
- *Discontinuous Galerkin Methods*, by B. Cockburn, G. Karniadakis, C.-W. Shu link (http://link.springer.com/book/10.1007%2F978-3-642-59721-3)

Class notes

Week	Monday	Wednesday	Friday
1		1/11 Overview of numerical methods for PDEs	1/13 Finite difference method analysis review
2	1/16 (MLK day, no class)	1/18 Finite volume method for nonlinear scalar PDEs	1/20

Homework

Nr.	Issue Date	Due Date	Topic	Problems	Solutions
1	1/20	2/10	Finite Volume Methods	Homework1.tm (http://mitran-lab.amath.unc.edu/courses/MATH762/homework/Homework1.tm) Homework1.pdf (http://mitran-lab.amath.unc.edu/courses/MATH762/homework/Homework1.pdf)	Homework1Solution.tm (http://mitran-lab.amath.unc.edu/courses/MATH762/homework/Homework1Solution.tm) Homework1Solution.pdf (http://mitran-lab.amath.unc.edu/courses/MATH762/homework/Homework1Solution.pdf)

Course topics

- Finite difference methods and analysis:
  - Convergence, consistency, stability
  - Modified equations
  - Fourier analysis of finite difference methods
- Finite volume methods:
  - Godunov methods and Riemann problems
  - Essentially non-oscillatory schemes
  - Central schemes
  - Adaptive mesh refinement
- Spectral methods:
  - Operator eigenfunction expansions
  - Collocation methods
  - Riesz theorem
  - Convergence analysis
- Finite element methods
  - Grid generation
  - Finite element spaces
  - System matrix assembly
  - Variational formulations
- Algorithms for parallel computations

SciComp@UNC Linux environment

Scientific computation is typically carried out in a Un*x environment (e.g. OS/X, various Linux versions). This course uses a customized Linux environment named SciComp@UNC available to students as a virtual machine. Download Virtual Box (https://www.virtualbox.org/wiki/Downloads/) and the SciComp@UNC (http://scicomp.web.unc.edu

/scicompunc-virtual-machine/) virtual machine image.

Various open source tools for carrying out and documenting practical scientific computation will be successively introduced:

- SageMath (http://www.sagemath.org/)
- TeXmacs (http://www.texmacs.org)
- LyX (https://www.lyx.org/)
- SciPy (https://www.scipy.org/)
- Maxima (http://maxima.sourceforge.net/)
- Octave (https://www.gnu.org/software/octave/)
- Gnu compilers (Fortran,C,Go) (https://gcc.gnu.org/)
- Julia (http://julialang.org/)
- Paraview (http://www.paraview.org/)
- OpenDX (http://www.opendx.org/)
- Gnuplot (http://www.gnuplot.info/)
- BEARCLAW (http://mitran-lab.amath.unc.edu:8084/redmine/projects/bearclaw/wiki)

The course will also use a few commercial tools, freely available to students while connected to the campus network (either directly or remotely through the UNC VPN (http://help.unc.edu/help/vpn-installation-and-clients/) server):

- Mathematica (http://reference.wolfram.com/language/?source=nav)
- Totalview (http://docs.roguewave.com/totalview/2016.06/html/index.html#page/User_Guides%2Ftotalviewug-title.html%23)

Course material repository

Course materials (lecture notes, workbooks, homework, examination examples) are stored in a repository that is accessed through the subversion utility, available on all major operating systems. The URL of the material is http://mitran-lab.amath.unc.edu/courses/MATH762 (http://mitran-lab.amath.unc.edu/courses/MATH762)

The above address is needed for an initial checkout using commands such as:

- mkdir ~/courses
- cd ~/courses
- svn co svn://mitran-lab.amath.unc.edu/courses/MATH762/

In the SciComp@UNC virtual machine the initial checkout has already been performed.

Update the course materials before each lecture by:

- cd ~/courses/MATH762
- svn update

Links to course materials will also be posted to this site, but the most up-to-date version is that from the subversion repository, so carry out the svn update procedure prior to each lecture.