MATH/CS 715 Methods of Computational Mathematics II - University of Wisconsin-Madison

Spring 2022 Syllabus

Basic information:
Credits: 3
Instructor: Saverio Spagnolie
Lecture times/locations: TR 9:30am-10:45am, Van Vleck B309
Office hours: Wednesday 4-5pm, `https://uwmadison.zoom.us/j/97644222832`, or by appointment
Email: spagnolie@math.wisc.edu
Preferred contact: PIAZZA
Piazza page (assignments, discussions): `https://piazza.com/class/kt4odtaet3v70z`
Canvas page (grades): `https://canvas.wisc.edu/courses/292690`

Course description:
The goal of this course is to provide a graduate-level introduction to numerical linear algebra and the numerical solution of elliptic partial differential equations. Topics in numerical linear algebra to be covered include matrix decomposition theorems, conditioning and stability in the numerical solution of linear systems, and iterative methods. With these tools in hand, we will proceed to discuss the finite element method, continuous and discontinuous Galerkin methods, multigrid methods, and error estimates. We will also cover boundary element and boundary integral techniques for the numerical solution of PDEs recast into integral form. Coding up and exploring different numerical methods will play a substantial role in the course.

Course learning outcomes:
By the end of this course students will be able to solve large linear systems of equations efficiently and accurately, and will have a better appreciation for which methods are most appropriate depending on the situation. They will be able to compute solutions to elliptic partial differential equations in complex domains using multiple methods. Moreover, students will be able to show analytically the expected convergence rate of these different methods, whether in the number of iterations or the spatial discretization size, and they will have substantial practice testing the output of numerical simulations to ensure that the expected rate is recovered.

Textbook:
For numerical linear algebra we will work through most of the following, I suggest that you acquire it:
Trefethen & Bau, Numerical Linear Algebra (SIAM)

For the finite element method a short, accessible, and affordable option which I suggest you acquire is:
Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method (Dover)

As supplementary texts consider the following (they will be on reserve in the library):
Braess, Finite Elements (Cambridge Univ Press)
Brenner & Scott, The Mathematical Theory of Finite Element Methods (Springer)

The library above is the AMP Library, Van Vleck B224.

Coding:
To best learn the subject one must not only learn the mathematical theory, but also get practice in algorithm implementation and testing on the computer. We will use Python version 3.9 for this course; for the sake of course coherence, students will too! I am will assume that all enrolled students have some prior coding experience, but they need not have used Python before.

Requisites:
Students are strongly encouraged to have programming skills (e.g. CS 200), undergraduate numerical analysis (e.g. MATH/CS 514 or CS 412), analysis (MATH 521), partial differential equations (MATH 322), and linear algebra (e.g. MATH 341 or equivalent).

Students should not have much trouble completing the preliminary (ungraded) take-home exam handed out at the beginning of the semester.

Homework:
There will be 5 homework sets during the semester, due at the beginning of class. Late homework will not be accepted. Homework will be checked for both accuracy and clarity, and will not be accepted unless stapled. Students are allowed (and encouraged) to work with others, but must write up (including writing code) and turn in assignments individually. You must indicate on your homework sets who you worked with.

Course Project:
Students will select and then complete a project, due late in the semester.

Grading:
The final course grade will be determined by scores on homework (80%) and on a final project (20%). A final letter grade can be secured with the following scores: A ($> 93\%$), AB ($88\% - 92\%$), B ($83\% - 87\%$), BC ($78\% - 82\%$), C ($70\% - 77\%$), D ($60\% - 69\%$), F ($< 60\%$). It is possible that these bars will be lowered at the end of the semester but they will not be raised (e.g. students are guaranteed at least a B if they have an 83%).

How to succeed in this course:
The obvious things: do everything that is asked, do the assigned reading, show up to class on time with any phones/electronics turned all the way off. Less obvious: work with each other on homework sets. Meet early and often to put in a lot of time on these sets.

Respect / Honor code:
By enrolling in this course you have tacitly entered into an unwritten contract with the instructor for mutual respect. Your instructor will show you respect and earn his own by working hard to deliver a well organized and thought out learning experience for you, with the goal of making you better thinkers and workers for all your future endeavors, mathematical and otherwise. In turn, you will earn your respect and show it in return by working hard, and working honestly. (Anyone caught cheating will be subject to a failing grade in the course and also further administrative action at the university level. I really do not enjoy spending my time on such matters but I always carry this out in the service of fairness to all students.)

You are expected to attend class regularly and to make efforts to be mentally present. In particular, please

do not use any electronics (computers, phones...) unless we've decided together to actively use them in class. They distract other students and your inattention will spread like wildfire.

COVID-19 policies: Students are expected to comply with the University's current COVID rules and policies that are maintained here: `https://covidresponse.wisc.edu` (see in particular `https://covidresponse.wisc.edu/faq/`).

Students who do not comply with these rules can be asked to leave the classroom, and students who repeatedly fail to comply will be referred to the Office of Student Conduct and Community Standards. Any student who requires an exemption to current policies must contact the McBurney Office, as instructors do not have the authority to grant such exceptions.

Anyone experiencing COVID-related symptoms should test and isolate until they receive test results.

If you are unable to attend in-person class meetings for COVID-19-related reasons (e.g. if you have even mild symptoms, `https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html`) you can let me know on Piazza. I will make course notes and any code presented in class available online throughout the semester so that you can stay with us.

I will do whatever I am allowed to do to provide a safe learning environment for you.

Academic integrity: By enrolling in this course, each student assumes the responsibilities of an active participant in UW-Madison's community of scholars in which everyone's academic work and behavior are held to the highest academic integrity standards. Academic misconduct compromises the integrity of the university. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these acts are examples of academic misconduct, which can result in disciplinary action. This includes but is not limited to failure on the assignment/course, disciplinary probation, or suspension. Substantial or repeated cases of misconduct will be forwarded to the Office of Student Conduct & Community Standards for additional review. For more information, refer to `studentconduct.wiscweb.wisc.edu/academic-integrity/`.

Privacy: The privacy and security of faculty, staff and students' personal information is a top priority for UW-Madison. The university carefully evaluates and vets all campus-supported digital tools used to support teaching and learning, to help support success through learning analytics, and to enable proctoring capabilities. View the university?s full teaching and learning data transparency statement here: `https://teachlearn.provost.wisc.edu/teaching-and-learning-data-transparency-statement/`.

Accommodations for students with disabilities: The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. (See: McBurney Disability Resource Center) `http://mcburney.wisc.edu/facstaffother/faculty/syllabus.php`

Diversity and inclusion: Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals. The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background, people who as students, faculty, and staff serve Wisconsin and the world. `https://diversity.wisc.edu/`

Course Designation:
Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2021

Earned credit: Each credit is earned as follows: one hour (i.e. 50 minutes) of classroom or direct faculty/instructor instruction and a minimum of two hours of out of class student work each week over approximately 15 weeks, or an equivalent amount of engagement over a different number of weeks. This is

the status quo and represents the traditional college credit format used for decades.

Privacy of Student Records & the Use of Audio Recorded Lectures Statement: Lecture materials and recordings for this course are protected intellectual property at UW-Madison. Students in this course may use the materials and recordings for their personal use related to participation in this class. Students may also take notes solely for their personal use. If a lecture is not already recorded, you are not authorized to record my lectures without my permission unless you are considered by the university to be a qualified student with a disability requiring accommodation. [Regent Policy Document 4-1] Students may not copy or have lecture materials and recordings outside of class, including posting on internet sites or selling to commercial entities. Students are also prohibited from providing or selling their personal notes to anyone else or being paid for taking notes by any person or commercial firm without the instructor?s express written permission. Unauthorized use of these copyrighted lecture materials and recordings constitutes copyright infringement and may be addressed under the university's policies, UWS Chapters 14 and 17, governing student academic and non-academic misconduct.

Course Evaluations: Students will be provided with an opportunity to evaluate this course and your learning experience. Student participation is an integral component of this course, and your confidential feedback is important to me. I strongly encourage you to participate in the course evaluation.

Digital Course Evaluation (AEFIS): UW-Madison uses a digital course evaluation survey tool called AEFIS. For this course, you will receive an official email two weeks prior to the end of the semester, notifying you that your course evaluation is available. In the email you will receive a link to log into the course evaluation with your NetID. Evaluations are anonymous. Your participation is an integral component of this course, and your feedback is important to me. I strongly encourage you to participate in the course evaluation.

Students' Rules, Rights & Responsibilities:
`https://guide.wisc.edu/undergraduate/#rulesrightsandresponsibilitiestext`

Academic Calendar & Religious Observances: `https://secfac.wisc.edu/academic-calendar/`.