University of Washington

AMATH 581

Scientific Computing

Autumn 2022

Instructor: Jeremy Upsal (jupsal@uw.edu) (he/him/his)

Lectures: MWF 8:30-9:20 am, Location BAG 154 (plus additional Q&A sessions posted on Canvas, as needed). Monday & Wednesday lectures will be streamed live on Panopto and recorded for students to watch later. You can find the recordings on Canvas when they happen.

Office Hours: TBD

TAs: Erin Stafford (she/her), Michele Martino (he/him/his), and Saba Heravi (she/her)

TA Office Hours: TBD

Course Description: Survey of numerical techniques for differential equations. Emphasis is on implementation of numerical schemes for application problems. For ordinary differential equations, initial value problems and second order boundary value problems are covered. Methods for partial differential equations include finite differences, finite elements and spectral methods. Requires use of a scientific programming language (e.g., MATLAB or Python). Prerequisites: Solid background in ODEs and familiarity with PDEs and MATLAB and/or python. AMATH 301 or the sequence AMATH 351-352-353. Or instructor permission.

Course notes/textbook: We will be using lecture notes created for this course by Professor Nathan Kutz, which you can find on Canvas. You can also access the published version of these notes, *Data-driven modeling & scientific computation* (especially Part 2) by Nathan Kutz, either by purchasing or accessing via UW libraries. I will regularly post which sections of the notes/book correspond to what we are covering in lecture.

Content Learning Goals: By the end of this course, students will have worked towards mastering the following skills.

Skill 1: Programming Fundamentals (MATLAB or python)

- Basics of arithmetic
- Matrices/vectors
- Loops/conditions/plotting
- Error handling

Skill 2: Initial Value Problems: Forward Integration

- Forward Euler
- Runge-Kutta methods
- Numerical errors
- Built-in integrators (e.g., ODE45 in MATLAB)

Skill 3: Initial Value Problems: Implicit Integration and Stability

- Backward Euler
- Stability
- Integral (Multi-Step) methods
- Predictor-corrector methods
- Implicit built-in integrators (e.g., ODE15s in MATLAB)

Skill 4: Boundary Value Problems - Shooting and relaxation (direct)

- Root finding
- Shooting method
- Direct method
- Computational implementation of BVP

Skill 5: Finite difference derivative operators for PDEs

- First-derivative differences
- Second-derivative differences

- The Laplacian operator
- Boundary conditions

Skill 6: Finite difference - solving linear problems

- Gaussian elimination
- LU factorization
- Iterative methods
- Computational complexity

Skill 7: Finite difference - PDE solutions and stability

- Stability for parabolic PDEs
- Stability for hyperbolic PDEs
- The method of lines
- Finite difference schemes

Skill 8: Spectral methods for PDEs

- The Fast Fourier Transform
- Other similar (or simplified) transforms
- Chebyshev polynomials
- Spectral integration through MATLAB or python.

Skill 9: Finite elements introduction

- Simplexes in 1D & 2D
- Complexes in 1D & 2D
- Interpolation (linear) in 2D
- Using built-in PDE solving tools

Cognitive Learning Goals: By the end of this course, students will learn to:

1. solve mathematical problems using computation and software;
2. understand limitations of scientific computing algorithms; and
3. demonstrate and articulate scientific work in a clear way.

Affective Learning Goals: By the end of this course, students will learn to:

1. increase their comfort level in asking and answering questions in class;
2. increase their confidence in using and discussing mathematics;
3. increase their interest in mathematics and its applications;
4. see themselves as a contributor in the field of scientific computing; and
5. continue to grow their "mathematical maturity" which is, in part, the understanding of and recognition of the interconnected nature of mathematics.

Web Page: `https://canvas.uw.edu/courses/1577398`. Check the canvas course page regularly. Lectures, homework assignments, course announcements, and grades will be posted there.

Communication: The main source of communication for this course will be Canvas.

- **Course Announcements:** The instructor will regularly post course announcements with information about what was done in class as well as upcoming due dates and scheduling changes. You are responsible for keeping up with the announcements.
- **Discussion Board:** This term we will be using Piazza for class discussion. The Piazza discussion board is a great place to ask questions about the course material or discuss homework problems. Homework questions should not be asked over email, they should instead be posted on Piazza. If the question gives away the solution to the problem, the question can be asked as a private question to instructors. You are encouraged to answer each other's questions, but the instructor will also regularly answer questions on the discussion board. While discussions about the homework are encouraged on the discussion board, no solutions should be posted.

- **Discord Channel:** I will also create a Discord channel for this class. This channel is to be used for more casual conversation about the class and is designed to give a more intimate space for interaction than Piazza. It also allows for voice channels and screen sharing, in case people want to use these features.
- **Email:** Email is the best way to reach me if you have any other questions or concerns, especially if they are of a personal matter. Homework questions should not be asked over email. When you send an email, please include your full name and course number.

Grading Policy: In this course, we will use a competency-based (mastery) approach. Associated with the class are 22 key skills. For a perfect grade, students would need to demonstrate competency of all of them by the end of the quarter. Your grade is determined by the number of key skills you become competent in during the course, using the following table.

Mastered skills	**GPA**
22	4.0
21	3.9
⋮	⋮
12	3.0
11	2.8
10	2.5
9	2.1
8	1.7
7 and below	0

Competency means to fully and correctly answer the questions related to the skill. This means you need to get almost a perfect score (typically above 90%, but this will be determined on a case-by-case basis). You need only to demonstrate competency in a particular skill once and you will have several attempts over several weeks to demonstrate competency in each skill. The available skill points follow.

- 9 quizzes, one for each section of the course (the 9 skills listed above).
- 5 homework assignments.
- 3 skills for the final project.
- 5 presentation (plotting and discussion) skills, demonstrated throughout homework or the final project.

Competency-based grading helps to promote *mastery* of certain topics instead of a loose partial understanding of few topics, such as through partial credit.

Quiz procedure: Quizzes evaluating competency in each key area will be held on canvas every Friday. You may take several (up to 3) quizzes throughout the day on Friday. Each quiz will be of a particular duration (30-45 min). **You must work on quizzes alone. Any student found working on a quiz with another student will receive a 0 in that skill and potentially in the entire class**. A practice quiz will be provided ahead of time once the skill is covered in lectures and the questions for it have been written. Questions included in the quiz will be randomly selected from banks of questions where each bank addresses a particular skill (listed above). Quizzes will typically consist of a small subset of 4-5 (short) questions and competency will be determined when you answer all of them correctly (or almost all). Once you demonstrated competency you don't need to demonstrate it again and will be penalized for taking the quiz again (your mastery score will be removed). Skill 1 (Programming Fundamentals) is a mandatory skill. You will have to show competency in it to get a passing grade since this skill covers the toolset that we will use throughout the course. If you really struggle with this skill (no improvement over weekly attempts), consider taking AMATH 301 first and take this course in the future. There will be no traditional exam during the final exam period (MyUW should say "no traditional final exam"), but you will have an additional opportunity to retake quizzes for topics you have not mastered.

Homework: Homework assignments will be assigned regularly, every two weeks. Typically, homework will be assigned on **Thursday** morning and due the following **Thursday** at 11:59pm Pacific Time. The assignments will be posted to Canvas and turned in via Gradescope. You will submit code (MATLAB or python) and it will be autograded. You will have **6 attempts on each homework** to get everything correct. If everything is correct the first time homework is submitted, you will receive 100% for that homework. If something is incorrect, then you may fix it and resubmit. Your best score for each homework will be your recorded grade (i.e. there is no penalty for correcting and resubmitting). **In order to receive a competency in homework, you would need to receive the full grade in that homework.**

Note that the autograder checks your answers and compares (anti-cheat) your code against the codes of others in your section, in other sections, and all past years. Also, note that 6 attempts is not very many to get everything exactly correct, so **DO NOT use the autograder as a debugger**. Make sure your code runs all the way through before submitting it. **I will not be giving extra attempts to those who submit code that does not run**.

On each assignment you will have an opportunity to demonstrate mastery of 2-3 of the presentation skills. This work must be submitted as a pdf and will be graded by me and the TAs. You **do not** need to submit a pdf for every assignment, only

for those for which you want to demonstrate mastery in a presentation skill. Since you are demonstrating presentation skills with the writeup section of the homework, it needs to be typed and easy to read/follow.

Collaboration on homework is encouraged but each student **must code up and submit their own assignment**. Copying will not be tolerated. This means that you may discuss pseudocode with your classmates but you should not be sharing your code in any way, including but not limited to emailing entire/snippets of code or showing someone your code on your computer.

Late homework will not be accepted, except for in very urgent circumstances such as medical emergencies. Since you will have two weeks to complete the homework, you should start early so that you do not feel like you are rushing at the last minute, potentially turning in homework late. I will give a 10 minute buffer for each assignment to allow for internet difficulties, but any assignments turned in after that 10 minute buffer will be considered late.

Class Meetings: We will hold regular lectures on Monday and Wednesday. Fridays will be reserved for taking the quizzes. Since this is a 5-credit class, you will also be asked to watch additional lectures posted online throughout the week, on your own time. At least one of these will be a Q&A session hosted by a TA and at least one (perhaps the same or another one) will discuss common difficulties on the current homework. I will also be providing recorded lectures from the previous instructor as well as lecture notes. Using these resources instead of my lectures is completely okay if you find them to be better for you. If you choose to do this, just be careful to look out for announcements of any discrepancies between those materials and what I discuss in class.

Office Hours: Office hours (times TBD) will be held in person or via Zoom. Office hours that are held in person will be during the work day. Those that are online are during the evening. Priority will be given to online students in AMATH 581 for evening office hours. Most in-person office hours will be held in the Arts & Sciences Instructional Computing Lab (B027 in the Communications Building) but some will be held in Lewis Hall (LEW) which is **not** an ADA accessible building. If you are unable to attend office hours due to this issue please contact me immediately and we will provide appropriate accommodations.

Academic Misconduct: All students are expected to abide by the University's Student Conduct Code (see `http://www.washington.edu/cssc/for-students/student-code-of-conduct/`) including the avoidance of academic misconduct as defined in Student Governance Policy, Chapter 209 Section 7.C (`http://www.washington.edu/admin/rules/policies/SGP/SPCH209.html#7`). All homework and quizzes must be your own work. Copying or submitting work that is identical to a classmate's work or online solution, in part or in whole, is academic misconduct. At no time should another student be looking at your solution for a problem. Any instances of academic misconduct will be reported. Please contact the instructor if you are unsure whether a particular behavior is a violation of the policy. **This has been a major problem in many classes I have taught at UW. I take it very seriously so please let's not have to deal with this this year.**

Access and Accommodations: Your experience in this class is important to me. If you have already established accommodations with Disability Resources for Students (DRS), please communicate your approved accommodations to me at your earliest convenience so we can discuss your needs in this course.

If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), you are welcome to contact DRS at 206-543-8924 or uwdrs@uw.edu or disability.uw.edu. DRS offers resources and coordinates reasonable accommodations for students with disabilities and/or temporary health conditions. Reasonable accommodations are established through an interactive process between you, your instructor(s) and DRS. It is the policy and practice of the University of Washington to create inclusive and accessible learning environments consistent with federal and state law.

Religious Accommodation Policy It is important to me that our classroom be a welcoming and accommodating classroom for all. This means that if you have expected absences or hardship due to reasons of faith or conscience or for organized religious activities, I will be happy to accommodate you.

Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/). Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/).

Also, if you feel comfortable telling me about any required accommodations please let me know via email.