MATH 327: NUMERICAL ANALYSIS

SPRING 2022 **INSTRUCTOR: SUBHADIP CHOWDHURY**

KEY INFORMATION

Class meetings:

MWF 2:00 – 2:50 PM, Taylor 209

Office Hours

See Moodle for Up-to-date hours.
I will adjust these based on your feedback.

You can also stop by any time my door is open, or email me to set up an individual meeting.

How to contact me

Email: schowdhury@wooster.edu
Phone: 330-263-2473
Office: Taylor 307
Be sure to read my email responses policy.

Textbook

None required, but any edition of Burden & Faires' *Numerical Analysis* is a good reference.

Additional standard college policies are listed in a separate document called Academic Policies, Procedures & Support Services.

LEARNING GOALS

CATALOG DESCRIPTION

This course covers error analysis, interpolation theory, solution of nonlinear equations and systems of linear and nonlinear equations, numerical differentiation and integration, and solution of ordinary differential equations. While theoretical results are discussed, there is also an emphasis on implementing algorithms and analyzing computed results.

Prerequisites:

- Calculus II – MATH 112 (or MATH 120+125),
- Linear Algebra – MATH 211
- Imperative problem Solving – CSCI 110 or equivalent coding experience
- Also helpful, but no required – Differential Equations, Math 221

COURSE OBJECTIVES

The overarching goal of the course is to understand and appropriately apply approximate solution methods to various types of computational problems arising in natural science and engineering settings.

- To understand classes of mathematical problems for which finding analytic, exact solutions is impossible or impractical.
- To comprehend the theory underlying approximate solution algorithms for these problems, along with categorizing and quantifying types of error associated with each method.
- To implement, via scientific computing software (e.g. Python, MATLAB, Mathematica) approximate solution methods in a clear and efficient manner.
- To understand the limitations, advantages, and disadvantages of each method (often in terms of simplicity, speed, accuracy, and stability), leading to clear judgment about the suitability of various methods for a given computational problem.
- To communicate mathematical ideas professionally, both orally and in scientific writing.

Topics Covered

The standard undergraduate textbook in the field (Burden & Faires' *Numerical Analysis*) has sufficient material for a two-semester sequence. This one-semester course will survey a broad range of content, leaving opportunities for more in-depth study via Senior Independent Study, etc. Topics of discussion will include interpolation, solution of linear systems, solution of nonlinear equations and systems, numerical differentiation and integration, and solution of initial-value and boundary-value ODE problems.

Grading

To determine your course **base grade** (the letter A/B/C/D/F without plus/minus modifications), use the following table. To earn a grade, you must complete all the requirements in the column for that grade; your base grade is the **highest grade level for which all the requirements have been met or exceeded.**

Category	D	C	B	A
Lab Reports	50%	60%	70%	80%
Homework and Tests	50%	60%	70%	80%
Final Project (see Rubric)	50%	60%	70%	80%

If you do not meet all of the criteria for a D, your grade will be an F.

I will set +/- grades based on how close you are to the next higher (or lower) letter grade. For example, if you meet all criteria for an A except for one Homework, that may be an A-. If you are instead missing something bigger, like one Lab Report, that may be a B+. I will communicate details of this on Moodle towards the end of the semester.

Software Usage

There will be two types of assignments that will be using scientific computing software in this course. Most in-class demonstration and group work will be done using **Mathematica** (Wooster has a site license, See here). For lab reports, you will be occasionally required to write programs from algorithms. You are welcome to choose any programming language of your choice, but the most prevalent for this purpose are **Octave** (free, open source alternative to MATLAB) or **Python** (free, open-source). However, note that I would be unable to unable to help with coding in any other languages except these three.

Each student should enter the class with at least an intermediate level of proficiency in an appropriate programming language, as the content is sufficiently challenging for those without simultaneously learning to code. Furthermore, a 300-level course carries expectations of readiness to work independently and collaboratively without continual one-on-one assistance.

Lab Reports

Most weeks will include a lab activity, which will involve algorithm implementation, error analysis, and sometimes also theoretical derivations. For each lab, you will need to submit typeset solutions (using LaTeX, etc.) and an electronic copy of your code. Grading criteria will include the following:

- Accuracy and thoroughness of answers (including thoughtful discussion of *why*, not just *what*)
- Professionalism in the written document (academic tone, insightful well-labeled graphs, etc.)
- Clarity & efficiency in coding (readability, documentation, no irrelevant code, etc.)

Students may pair up for labs and submit one assignment with both students' names but may not work with the same partner more than once during the semester. **No other copying of code is permitted.**

FINAL PROJECT

For the final project, you will be asked to learn about a numerical analysis topic not covered in class, code it up & apply it to one or more examples, then give a 10–15-minute oral presentation about the methodology and its usage, with slides/visuals. Presentations will take place during the last week of classes.

Alternatively, you could apply a computational method (including those covered in class) to an applied science problem from another course or from your research. In this case, you would write an appropriate code to solve the problem and give a presentation on the application problem and methodology used to solve it. Talk to Dr. Chowdhury if considering this option.

Grading will be based on the quality of the mathematical content (that the numerical analysis concepts are substantial & correctly applied) and of the presentation (organization, clarity, plots & visuals, usage of time, etc.). More details including a rubric will be posted to Moodle.

POLICIES

ATTENDANCE AND ABSENCES

Attendance is *crucial* to success in this class. Your best chance to discuss new material, ask questions, and avoid confusion is during class. So, don't miss class! You are responsible for all material and announcements from class, even in case of absence. Much of this information will be available on Moodle. Please check in with me and with your classmates when you are back.

That said, life happens. We get the flu. Relatives need your help. When this happens, do what you need to do. I trust that you are an adult and will make the best choices that you can. I appreciate it if you can notify me in advance of an absence, if possible.

If you think you will miss *more than one class in a row*, you should contact me beforehand to let me know, and meet me afterwards to discuss how you can catch up and move forward in the course. If you miss *an entire week*, I will send out an academic alert. If you miss *more than two weeks* of classes, you should contact the Dean Jen Bowen and/or Amber Larson, Director of the Academic Resource Center. They can help you consider options for completing or dropping the course.

OTHER POLICIES

Special Accommodations

The Academic Resource Center, which is in APEX (Gault library) offers a variety of academic support services such as time management and class preparation, ELL peer tutoring, coordinating accommodations for students with diagnosed disabilities, etc. Please see the Academic Policies, Procedures & Support Services document for further details or go to the ARC website.

Email Responses

I do my best to reply to emails promptly and helpfully. However, I receive a lot of email. To help both you and me, here are some specific expectations about emails:

- If you email me between 8:00 am and 6:00 pm on a *weekday*, I'll reply to you on the *same* day.
- If you email me in the evening or overnight (after 6:00 pm), I will reply to you the *next weekday*.
- **If your email asks a question that is answered in the Syllabus or on Moodle** (such as in an announcement or an assignment sheet), I may reply by directing you to read the appropriate document.
    - If you've read the relevant document and still have questions about it, please make this clear in your email, by describing what you've already read, and which specific part of it you have a question about.
- Often, it's much easier to discuss questions in person. I may ask you to meet with me in my office (at a time that works for both of us) rather than answering directly in an email.
- On homework, please include photos, PDFs, or links if possible.

Syllabus Changes

The instructor reserves the right to make changes to this syllabus, if needed. Any changes will be announced to the class in a timely manner.

HOW TO GET HELP

MY OFFICE HOURS

Please come see me during my office hours if you have questions or just want to discuss something from class. These will be most effective if you have spent some time formulating your questions beforehand - often you will answer your own questions during that process! You can also contact me via Email or MS Teams with your questions. See the email response section above for my 'business hours'!

See Moodle for office hour times and further instructions.

TEACHING ASSISTANT OFFICE HOURS

Maxwell Hosler (class of '22) is your TA for this course. He will not be present during classes but will hold weekly office hours outside the classroom. You can ask him for help with lab reports and for going over **past** homeworks.

See Moodle for his office hour times and further announcement from him.

TENTATIVE SCHEDULE

Week	Monday	Wednesday	Friday
1 (Jan 17 - 21)	MLK Day	Overview + Polynomial Interpolation	Interpolant in Lagrange Basis
2 (Jan 24 - 28)	Interpolation Error Bounds	Interpolation Error Bounds ctd. + Runge's phenomenon	**Lab 1 (Runge's phenomenon and Chebyshev Nodes)**
3 (Jan 31 - Feb 4)	Spline Interpolation	Spline Lab	Elimination algorithms
4 (Feb 7 - 11)	Computational Effort, Pivoting Strategies	**Lab 2 (Elimination algorithms)**	Vector and Matrix Norms
5 (Feb 14 - 18)	Norms contd.	Iterative methods for Linear Systems	**Lab 3 (Jacobi and Gauss-Seidel)**
6 (Feb 21 - 25)	Discrete Least Square Approximation	Continuous Least Square Approximation	Least square approx. contd.
7 (Feb 28 - Mar 4)	Intro to Nonlinear Eqns + Bracketing Algorithms	Fixed Point Iteration (Newton's Method)	**Lab 4 (Root Finding)**
8 (Mar 7 - 11)	Comparing Convergence	Order of Convergence contd.	Take-home Midterm
11 (Mar 28 - Apr 1)	Quasi-Newton methods	**Lab 5 (Newton for Systems)**	Numerical Differentiation
12 (Apr 4 - Apr 8)	Numerical Differentiation contd.	Rounding Error Instability	Interpolatory Quadrature Rules
13 (Apr 11 - Apr 15)	Quadrature Contd.	Newton–Cotes quadrature	**Lab 6 (Numerical Integration)**
14 (Apr 18-22)	ODEs, IVPs and the Existence and Uniqueness theorem	One-step Methods	Runge-Kutta contd.
15 (Apr 25 - 29)	**Lab 7 (IVP)**	Multistep Methods	I. S. Symposium (no class)
16 (May 2 - 6)	Review, Catch-up	Final Project	Final Project