Advanced Numerical Analysis

Syllabus

§A. Key Information

Class Meetings

Tu/Th 9:30–10:50, Eckhart 202

How to contact me
- **Email:** subhadip@uchicago.edu
- **Office:** Eckhart 120B

Office Hours

See Canvas for up-to-date hours. You can also email me to set up an individual meeting.

Reader Info
- **Name:** Phil Lee
- **Email:** kyungphillee26@uchicago.edu

Textbook

No purchase required. I will post links to online notes in Canvas as appropriate.

§B. Software and Generative AI Policy

Most in-class demonstrations will be done using Mathematica (UChicago has a site license). You may submit coding work in Python or Mathematica (if you want to use something else, talk with me first).

Generative AI tools (e.g., Phoenix AI, Google Gemini, ChatGPT) are allowed in this course unless an assignment explicitly forbids them. If you use GenAI for any part of your work (brainstorming, outlining, coding, debugging, exposition), you must cite that use in a clear, specific way (any reasonable format is fine). A good citation should identify the tool, what you used it for, and what you changed or verified. I might also ask you to forego using AI tools on specific assignments, and in those cases, I'll explain why.

You are responsible for the correctness of everything you submit. In particular, AI-generated code, proofs, or explanations that are incorrect, unverifiable, or not understood by you will receive reduced (or no) credit. I may ask brief follow-up questions about submitted work (especially on labs and final projects) to confirm understanding.

§C. Learning Goals

This is an upper-level numerical analysis course. You will be most successful if you are comfortable with:

- multivariable calculus and basic linear algebra (including norms and eigenvalues at the level of a standard undergraduate course),
- rigorous proof writing (at the level of an undergraduate analysis sequence), and
- writing and running short programs in a scientific computing environment (Python or Mathematica).

You do not need prior exposure to numerical analysis, but you should expect a fast pace and frequent transitions between theory and computation.

C.1 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, 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 a clear judgment about the suitability of various methods for a given computational problem.

- To communicate mathematical ideas professionally, both orally and in scientific writing.

C.2 Topics Covered

Over the remaining five weeks of the quarter, we will cover a selected set of topics, with opportunities for further exploration through the final project. The planned topics include:

- Polynomial Interpolation and Error Bounds,

- Approximation Theory,

- Numerical Integration (Quadrature) and Error Analysis,

- Initial Value Problems for ODEs (Stability and Accuracy),

- Iterative Methods for Solving Linear Systems (Convergence),

- Nonlinear Equations and Systems (Basin of Attraction)

The exact pace and emphasis may shift based on how quickly the class moves, but the assessment structure below will remain stable.

§D. Grading

Your course *base grade* (A/B/C/D/F without plus/minus) is determined by the highest column for which all requirements are met. If you do not meet all criteria for a D, the base grade is an F. I will assign plus/minus grades based on overall proximity to the next letter grade and the consistency of performance across categories.

Category	D	C	B	A
Theory Homework	50%	60%	70%	80%
Lab Homework (3 total)	At least one completed	At least one completed	At least two completed	All three completed
Final Project (see rubric)	50%	60%	70%	80%

D.1 Theory Homework

Theory homework is assigned on Tuesdays and due the following Monday at 5 pm (with a modified deadline for the last set to avoid reading period). Problems typically ask you to justify results we use in class, prove corollaries, or establish a careful error/stability statement.

Collaboration: You may discuss ideas with classmates, but your submitted write-up must be your own. If you consulted with others, include a brief acknowledgment (names and the nature of the help). If you used GenAI, cite it as described above.

Submission: I expect typeset solutions (LaTeX preferred) in PDF format. If this creates a barrier, please contact me as soon as possible.

Scoring rubric (per problem, 0–3):

- 0/3 — Not attempted, substantially incomplete, or major logical errors.

- 1/3 — Substantial effort but significant gaps, or correct core idea with inadequate justification.

- 2/3 — Essentially correct with minor errors* or omissions; reasoning is mostly clear.

- 3/3 — Correct, complete, and clearly written; arguments are well organized.

D.2 Lab Homework

Most weeks include a lab activity focused on implementing algorithms, analyzing numerical behavior, and connecting experiments to theory. Labs are assigned on Thursday and due the following Wednesday at 5 pm.

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.)

Submission format: Submit a single well-organized Python or Mathematica notebook (`.ipynb` or `.nb`) file as appropriate.

Teams: You may work in teams of up to three, but you must submit individually and clearly indicate (briefly) what you personally contributed. If you used GenAI for code, include your own explanation of the algorithm and what you verified.

Completeness and revision: If a lab is not complete, I will return it with feedback and you will have one opportunity to resubmit for credit.

Tokens and Late Work

You have two "tokens" for the quarter. Each token extends one homework deadline by 24 hours with no explanation needed. To use a token, simply email me before the deadline. Beyond that, late homework will not be accepted, unless you have an approved extension.

D.3 Final Project

For the final project, you will be asked to learn a numerical analysis topic not covered in class (or substantially extend one we covered), develop the relevant mathematics, and support your claims with computational evidence. You will produce:

- an expository paper (typically 6–10 pages),

- reproducible computational evidence in a notebook (`.ipynb` or `.nb`), and

- a 10–15-minute presentation with slides.

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 the methodology used to solve it. Talk to me first if you are considering the second option.

A complete project includes at least one theorem with a complete proof and a clear discussion of numerical analysis issues (error, stability, convergence, conditioning) appropriate to your topic. You may use GenAI for coding if you cite it, but the mathematical narrative and validation must be yours.

The project rubric (100 points total) is summarized below; full details will be posted on Canvas/Gradescope.

- Mathematical content and rigor (60 points)

  - Problem formulation, scope, and goals (10)

  - Methodology described at an advanced level (10)

  - Theorem + complete proof (22)

  - Numerical analysis: error/stability/convergence/conditioning (18)

- Expository paper quality (15 points)

---

*A minor error is one that still allows you to demonstrate your relative understanding of the problem as intended.

- Organization and narrative (6)
- Mathematical correctness, notation discipline, citations (6)
- Figures/tables and interpretation (3)
- Computational evidence via notebook(s) (10 points)
  - Verification/experimental design (6)
  - Reproducibility and notebook quality (4)
- Presentation (slides) (15 points)
  - Structure, timing, and narrative (5)
  - Mathematical communication (5)
  - Visual communication (5)

§E. Other Policies

E.1 Attendance and Engagement

In this class, **showing up is necessary but not sufficient**: true engagement means being present, prepared, and actively participating in your own learning and the learning of your peers. Your best chance to discuss new material, ask questions, and avoid confusion is during class – so, don't miss class!

Being Present

Please show up to class **on time** and ready to engage. **Attendance will be taken.** If you need to miss class for any reason, email me as soon as possible and make a plan to catch up. In particular, you should:

- Read through the class notes posted to Canvas;
- Review the corresponding content using a textbook or other resources;
- Try the relevant homework problems *before* seeking additional help from me with the material from that day.

Please do not miss class without contacting me. I don't care whether you think it's a good 'excuse' or not. Just send me an email or reply to mine! This isn't about enforcing perfect attendance; it's about keeping an open line of communication so I can support you effectively. Lack of communication about absences may affect your final grade.

Engaging Actively

We'll be learning together, and the participation of every student – whether in whole-class, small-group, or individual settings – creates the best learning environment for everyone. As a college student and future professional, full engagement is not optional; it's expected.

You can demonstrate your engagement in a number of ways:

- Giving constructive feedback during in-class discussions.
- Asking relevant questions in class, during office hours, or through email.
- Participating in collaborative group work when applicable.
- Creating an inclusive and welcoming class environment for peers.

Consistent effort is the baseline, not the bonus. So, please show up, speak up, and support each other.

E.2 Respecting Each Other

We are not all coming to this class with the same privileges, resources, time, and knowledge. It's really important to keep this in mind when working with each other on homework assignments and during class meetings. **It is our strong belief that as a community, mathematicians and scientists need to do a much better job of making our disciplines more accessible to**

people of all races, genders (including gender non-conforming folks), sexual identities, and class backgrounds. While this is a priority for us in the classroom, we do not claim to know how to best honor this commitment, but we are eager to listen, adapt, and learn. So **we are very open to feedback from students when it comes to making the course more accessible and inclusive to all identities.**

It's also important to think about how to respect one another when working together in groups. It's not equally easy for all of us to speak up in a large group, and the voices of historically underrepresented/marginalized students are most easily drowned out in group work. So please keep this in mind when working together. Here are some concrete examples of positive collaborative behavior:

- Making sure everyone who wants it has the opportunity to speak frequently. This can mean checking in with each other to make sure everyone is following along and contributing when they have an idea.

- Respecting people's pronouns and other aspects of their identity.

- Making sure that everyone's ideas are acknowledged when writing up the final solution to a problem. When working in groups, solutions often evolve organically; an idea might pop into your head, and you may think it's yours and yours alone, but perhaps you only arrived there because of something else that someone already said. Pay attention to what people are saying and try to learn from one another.

We will do our best to check in with folks periodically during the quarter. If at any time in the quarter, you find yourself in a group of students for which the above behaviors aren't being practiced and people aren't feeling respected, please let me know.

§F. Helpful Resources

F.1 Office Hours

Office hours are really Student hours! They are an opportunity for you to stop by your instructor's office and ask questions. I have specifically set this time aside in order to give personalized help to individual students. Any and all questions are welcome, whether you are working on a homework question, have questions on a broader concept discussed in class, or potentially even questions beyond the scope of the course.

Typically, students' misunderstandings in mathematics are initially small, but due to the constructive nature of math, a small misunderstanding can compound as concepts are utilized together. Students who frequently attend office hours and actively engage by asking questions are able to continually resolve their small misunderstandings, resulting in sustained improvement.

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 5:00 PM on a weekday, I'll reply to you on the same day.

- If you email me in the evening or overnight (after 5:00 pm), I will reply to you the next weekday.

- If your email asks a question that is answered in the Syllabus or on Canvas (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.

F.2 Academic Accommodations

If you require any special academic accommodations, please provide me with a copy of your Accommodation Determination Letter (issued by the Student Disability Services office) as soon as possible, so we can discuss how your accommodations may be

implemented in this course. If you are in the process of obtaining accommodations, please inform me as soon as possible. More information can be found here: https://disabilities.uchicago.edu/.

F.3 Religious Accommodations

The University of Chicago is home to students of all the world's major religions and, though firmly a secular institution, values the rich diversity of spiritual expression and practice found on campus. It is therefore the policy of the University that students who miss class, assignments, or exams to observe a religious holiday must be accommodated as follows: (i) absences may not be counted as a missed class in any course in which attendance is a measure of academic performance; (ii) reasonable extensions of time must be given, without academic penalty, for missed assignments; and (iii) exams must be reasonably rescheduled without academic penalty. You must inform me in writing of your need to observe a religious holiday reasonably well in advance of the absence, preferably at the beginning of the quarter. More information can be found at the following: https://provost.uchicago.edu/handbook/clause/policy-religious-accommodation-missed-classes-assignments-and-exams.

F.4 Wellness Resources

UChicago has counseling available both 24/7 and by appointment through http://wellness.uchicago.edu. Additionally, you can access medical care, including 24/7 support from medical professionals to address your healthcare questions.

F.5 Sexual Misconduct Policy

The University of Chicago recognizes that members of the university community are responsible for ensuring that the community is free from discrimination and other forms of sexual misconduct based on sex or gender, including sexual harassment, sexual assault, stalking, domestic violence, and dating violence. Faculty are considered "Individuals with Title IX Reporting Responsibilities" of the University and are obligated to report information to the Title IX Coordinator related to sexual misconduct. If you think your rights, or the rights of someone else in the university community, have been violated, you can find information on resources and reporting at: https://cares.uchicago.edu/.

Title IX Coordinator: Bridget Collier, Associate Provost & Director (bcollier@uchicago.edu, 773-702- 5671)

§G. Recording and Deletion Policy

The Recording and Deletion Policies for the current academic year can be found in the Student Manual under Petitions, Audio & Video Recording on Campus.

- Do not record, share, or disseminate any course sessions, videos, transcripts, audio, or chats.
- Do not share links for the course with those not currently enrolled.
- Any Zoom cloud recordings will be automatically deleted 90 days after the completion of the recording.

§H. 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.