MA/CSC 580: Numerical Analysis I

Lecture details

Instructor:	Alen Alexanderian
Lecture time/location:	MWF 9:35–10:25, 2235 SAS Hall
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Office Hours:	1–2 Wednesday (in person) or by appointment (in person or zoom)

Preferred Method of Communication: If you need to contact me directly, please email me.

Course Description

This is a first graduate course in numerical analysis The topics covered in this course include: (1) vector and matrix norms, conditioning, errors and floating point arithmetic; (2) linear systems of equations (3) linear least-squares; (4) QR and SVD decompositions; (5) iterative methods for linear systems; (6) solution of nonlinear equations; (7) eigenvalue problems.

Time permitting, I will also discuss some special topics such as inverse problems, nonlinear optimization, or randomized linear algebra.

Prerequisites

Background in linear algebra (MA 405), elementary real analysis (MA 425 or MA 511), and some programming experience.

Materials/Textbooks

- I. C. F. Ipsen, Numerical Matrix Analysis, SIAM, 2009.
  http://catalog.lib.ncsu.edu/record/NCSU2514760

- C. T. Kelley, Iterative Methods for Linear and Nonlinear Equations, SIAM, 1995.
  http://catalog.lib.ncsu.edu/record/NCSU2512957

These books are available (freely) online for NCSU users through NCSU library.

Other recommended (optional) literature

- David S. Watkins, Fundamentals of Matrix Computations, 3rd Edition. 2002.

- Lloyd N. Trefethen, David Bau, Numerical Linear Algebra 1st Edition. 1997.

- Kendall E. Atkinson, An Introduction to Numerical Analysis, second edition, Wiley, 1989.

- David Kincaid and Ward Cheney, Numerical Analysis, Brooks/Cole, 1996.

- James M. Ortega. Numerical analysis: A Second Course, volume 3 of Classics in Applied Mathematics. SIAM, second edition, 1990.

- Peter Deuflhard, Andreas Hohmann: Numerical Analysis in Modern Scientific Computing. An Introduction, 2nd edition, Springer, 2003.

- Alfio Quarteroni, Riccardo Sacco, Fausto Saleri: Numerical Mathematics, 2nd edition, Springer, 2007.

- Cleve Moler: Numerical Computing with Matlab, SIAM, 2007.

- Desmond J. Higham and Nicholas J. Higham, Matlab Guide: Second Edition, SIAM, 2005
  http://catalog.lib.ncsu.edu/record/NCSU3108706

Learning Objectives/Outcomes Upon the completion of this course the students should be able to

- understand concepts of conditioning of a problem and its significance;

- understand types of errors in computations and basics of floating point arithmetic;

- use direct and iterative methods for solving linear systems of equations;

- use methods for solving over- and under-determined linear least-squares problems;

- understand the theory and applications matrix factorizations (LU, QR, SVD)

- understand methods for solving nonlinear systems of equations (fixed point iteration, and Newton's method);

- become familiar with theory and methods for eigenvalue problems (power method and variants, Rayleigh quotient iteration, QR algorithm, Lancsoz).

Course Structure: We will be meeting in person. The course will be structured so that there is a lot of student interaction. In this class we will share ideas and learn from each other. It will be important for each of you to "try" on new ideas and to make conjectures even if you are not sure that you are correct.

Email: I will send all emails to your official ncsu.edu email address.

Course Schedule:

topic	weeks
Preliminaries	1-1.5 weeks
Errors and floating point arithmetic	0.5 week
Direct methods for linear systems	2–3 weeks
Linear least squares	2–3 weeks
Stationary iterative methods for linear systems	2 weeks
Krylov iterative methods (CG / GMRES)	2–3 weeks
Nonlinear equations	1–2 weeks
Eigenvalue problems	1–2 weeks

Grading:
The grading will be assigned on a 10-point scale: **A: $90 - 100$, B: $80 - 89$, C: $70 - 79$, D: $60 - 69$, F: $\leq$ 60.** The cutoffs for the $+$/- grades are determined at the end of the semester. Your final grade in this course will be determined by marks earned on about six homework assignments involving a mix of theory and computational experiments (45%) a midterm (20%) and a final exam (35%).

Exams

- Midterm exam date: Friday, October 10

- Final exam date: Monday, Dec 8, 8:30 AM–11:00 AM

Changes to syllabus: Note that the above course schedule is tentative—it is subject to change. I will let you know at least a week in advance if we need to move the date for any of our hourly exams. I will announce such changes in class and via email. Similarly, I will let you know if there are other major changes in our syllabus.

Note regarding homework The homework is weighted so heavily, because it includes the computational and theoretical exercises that are essential to understanding the course material. Also, an important part of your education at this stage is to learn how to present your results in the form of a professional-grade typeset report. Label each problem clearly, label equations as necessary, and produce high quality and easy to understand figures

(use axis labels, captions, etc.) using for example Matlab. I encourage you to typeset your homework solutions in Latex (I will provide Latex source files for the homeworks). You must show complete work to receive full credit. This means that you should provide sufficient details such that others with similar background as yourself can reproduce your results.

You may use the information posted on our Moodle site, in-class lecture notes, and recommended text book references. However, may not use any other online website or resource on your homework. In particular, you should not look up any of our homework problems on the web. Our goal is to learn by doing the problems.

Use of AI-tools Students might find generative AI tools such as ChatGPT useful for exploration when studying or thinking about homework problems. I encourage judicious use of such tools. However, while helpful at times, these tools have pitfalls: they sometimes produce incomplete, misleading, or incorrect answers. You should use AI tools only as an aid—not a replacement—for your engagement with the course materials. Always verify the output you receive and ground your work in the lecture notes, course textbooks, or other authoritative book references. Solutions submitted for grading should reflect your own thinking and effort; using AI to generate graded solutions in place of your own work is academic dishonesty.

Other acceptable uses of AI tools in this class include: (i) translating MATLAB code to Python or vice versa; (ii) refactoring existing computer codes for readability or performance; (iii) assistance with LaTeX typesetting; and (iv) looking up specific commands in MATLAB or Python (e.g., ChatGPT can explain what a command does and provide an illustrative code snippet).

If at any time you are unsure about acceptable uses of AI tools for this class, please feel free to contact me. I will be happy to provide clarification and advice.

Wellness day: Tuesday, September 16, 2025. We will not have any assignments due on September 16th or September 17th. We will also not have a test on the 16th or the 17th. The Wellness Day is a special day to give you time to focus on your health and well-being, and the University will host events to help you do just that.

S/U Grading: If you are registered for use the S/U grading option, you will need to complete the course and receive at least a C− to pass the course.

Auditing the Course: To audit the course, you must have the approval of your advisor and the Mathematics Department. To receive an AU, you must attend the majority of the sessions, and you must hand in all of the homework and take all of the tests. See:

https://policies.ncsu.edu/regulation/reg-02-20-04/

for more information concerning course audits.

Incomplete Grades: Incomplete grades will be handled on an individual basis. Note, however, that if an extended deadline is not authorized by an instructor or department, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as attempted courses on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at:

https://policies.ncsu.edu/regulation/reg-02-50-03/.

Attendance Policy/Absence Policy/Late Assignments/Make-up Work: You are expected to attend all classes on time. Late assignments and make-up work will only be allowed for excused absences. Otherwise, a late homework will incur a 5% deduction in score each day after the due date for the homework. So, for example, if you are five days late, and the homework is worth 20 points, the maximum score you can earn on the homework will be $20 - 20 \times 0.25 = 15$ points. After 10 days, I stop the deductions for the late homework; and if you submit the homework beyond that point, you can get at most 50% percent of the points in that homework. You should

contact me by email or in person before any anticipated excused absence. If you have an unanticipated excused absence (for example, a medical emergency), you should contact me within one week of returning to class.

For complete attendance and excused absence policies, please see:

https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/

Academic Integrity Statement and Academic Dishonesty: Students are required to comply with the university policy on academic integrity/honesty found in the Code of Student Conduct:

https://policies.ncsu.edu/policy/pol-11-35-01/

Violations of academic integrity will be handled in accordance with the Student Discipline Procedures (NCSU REG 11.35.02).

Digital Course Components: In this course we will use Zoom and Moodle. Please see the relevant technology requirements in

https://docs.google.com/document/d/1Bfrka-Y4qm3WouAGOnCm0YBAytykTjQjvEBErBkNDgc/edit.

If you need access to additional technological support, please contact the Libraries' Technology Lending Service:

https://www.lib.ncsu.edu/devices.

Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include online discussions of class topics and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

- **Moodle**: All reading materials are housed on the course page in Moodle.

- **Zoom**: Our regular office hours will be in person. However, the students can also make appointments to meet with me to ask questions about the course content in times outside the office hours. In such cases, zoom appointments are possible.

Developing a Welcoming and Inclusive Classroom Environment: Every student, every faculty member, and every staff member who comes to NC State enriches us through their varied perspectives, knowledge, and backgrounds. Our classroom is one in which every student is respected and feels heard. In an effort to affirm and respect the identities of the students in our classroom and beyond, please contact me if you wish to be referred to using a name and/or pronouns other than those listed in the student directory. Our classroom is one in which we are all partners. I want to create a community in which all students in our class can succeed. So I would welcome any additional suggestions you have for making our classroom more welcoming and supportive.

Accommodations for Disabilities: Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the Disability Resource Office at Holmes Hall, Suite 304, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation: https://policies.ncsu.edu/regulation/reg-02-20-01/

Non-Discrimination Policy: NC State prohibits discrimination, harassment, and retaliation based on a person's age (40 years or older), color, disability, genetic information, gender identity, national origin, race, religion, sex (including pregnancy), sexual orientation or veteran status. If you feel that you have been the subject of prohibited discrimination, harassment, or retaliation, you should contact the Office of Equal Opportunity at 919-513-0574.

NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at http://policies.ncsu.edu/policy/pol-04-25-05 or https://equalopportunity.ncsu.edu.

Health and Well-Being Resources: Many of us have struggled with physical and mental health issues, food insecurity, and other challenges, particularly during the last several years. As a student you may experience a range of personal issues that can impede learning, issues such as strained relationships, increased anxiety, alcohol/drug concerns, feelings of depression, difficulty concentrating and/or lack of motivation. Physical and mental health concerns, as well as stressful events, may lead to diminished academic performance and may impact your ability to participate in daily activities. It is very important that you have a support system and that you ask for help when you are struggling.

Everyone is encouraged to take care of themselves and their peers. If you need additional support, there are many resources on campus to help you:

- Wolfpack Wellness website (link)

- Counseling Center (link)

- Teletherapy (link): NC State has partnered with Mantra Health to offer free teletherapy sessions to NC State's degree-seeking students.

- Campus Health (link)

- NC State CARES Team: As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that our campus remains a healthy and safe environment for learning. Occasionally, you may come across a classmate whose personal behavior concerns or worries you, either for your classmate's well-being, for your well-being or for the well-being of others. When this is the case, I would encourage you to report the behavior to the NC State CARES team: Share a Concern

- If you or someone you know are experiencing food, housing or financial insecurity, please see the Pack Essentials Program (Pack Essentials).

- Student Ombuds Services (link): The Student Ombuds provides independent and confidential advice for conflict management, prevention, and resolution.

Additional NC State Rules and Regulations: Students are responsible for reviewing the NC State University Policies, Rules, and Regulations (PRRs) which pertain to their course rights and responsibilities, including those referenced both below and above in this syllabus:

- Equal Opportunity and Non-Discrimination Policy Statement with additional references at `https://oied.ncsu.edu/equity/policies/`

- Code of Student Conduct

Important Resources for Students:

- Mathematics Tutoring Center (open Monday through Friday from 8 a.m. to 5 p.m. in SAS 2105):

  `https://math.sciences.ncsu.edu/undergraduate/courses-faq/math-multimedia-center/`

- Introduction to Zoom for Students:

  `https://youtu.be/5LbPzzPbYEw`

- Learning with Moodle, a student's guide to using Moodle:

  `https://moodle-projects.wolfware.ncsu.edu/course/view.php?id=226`

- NC State Protect the Pack Resources for Students:

  https://www.ncsu.edu/coronavirus/reactivating-campus/resources-for-students/

  Academic Success Center (tutoring, drop-in advising, career and wellness advising):

  https://asc.dasa.ncsu.edu