Syllabus for Introduction to Numerical Computing
Math/CS 375
Spring, 2020, University of New Mexico
Version 1, Dated January 7, 2020

Time and Place: Tuesday/Thursday, SMLC 356, 9:30am-10:45am

Course webpage: http://math.unm.edu/~schroder/2020_Spring_375/index.html

Instructor: Prof. Jacob B. Schroder, jbschroder@unm.edu

Course Credits: 3

Office Hours: SMLC 332

1. Wednesday: 12:30pm-2:00pm
2. Thursday: 2:00pm - 3:30pm
3. By request

Please note that I highly respect parents who are also students. Children are always welcome at my office hours, and I usually have a few toys from my son lying around.

Prerequisites:

1. CS 151 or CS 152 or Phys 290 or ECE 131 or comparable programming skills AND
2. Math 316 or Math 314 or Math 321 or equivalent

Text: *Numerical Mathematics and Computing* by W. Cheney and D. Kincaid, 7th Edition
(6th Edition will also work)
OR
Numerical Analysis, by T. Sauer, 3rd Edition

You will need one of these books as a reference, to buttress the in-course slides and derivations. Sauer is likely a better general reference book, but some course material will more closely follow Cheney and Kincaid.

Important Dates:

- Midterm Exam: March 26, 2019
- Spring Break: March 16-20
- **Final Exam: Tuesday, May 12, 7:30am – 9:30am** (same room, different time)

Course Description: This is an introductory numerical analysis course. We study numerical methods to solve linear and nonlinear equations, to interpolate and approximate data, and methods for numerical integration and differentiation. We will implement all algorithms in MATLAB (or Python), and begin the course with a MATLAB tutorial. Python is allowed for assignments though we will not spend time learning it in class.

This is a required course for all mathematics majors with concentration in Applied Mathematics or in Computational Mathematics.

Schedule of Topics:

- MATLAB Tutorial
  - Student's responsibility to finish at home
- Taylor series approximations, big-Oh notation, and measuring convergence rates
- Numerical Differentiation
  - Using Taylor series to derive difference formulas, measuring accuracy
- Floating-Point Representation (finite precision)

    - Integer and floating-point representation, computer arithmetic, conditioning
    - Roundoff and discretization error; relative and absolute error
- Linear Systems
    - The matrix view of systems of linear equations
    - Direct methods: Gaussian elimination, triangular, tridiagonal, Cholesky, LU, pivoting (scaled and partial), operation counts
    - Norms and condition numbers, error and residuals
    - Iterative methods (Jacobi, Gauss-Seidel)
- Solving Nonlinear Equations: root-finding, algebraic systems, ODEs
    - Algorithms: bisection, fixed-point iteration, secant method, Newton's method
    - Convergence of above algorithms
- Interpolation: approximate a function with an easy-to-evaluate interpolant
    - Polynomial interpolation: monomial basis, Newton basis, Chebyshev basis, splines, Lagrange basis
    - Measuring interpolation error, Runge phenomena
- Numerical Integration
    - Trapezoid method, Simpson's method, Newton-Cotes, Gauss quadrature
- Eigenvalues and eigenvectors
    - Power method and Google's Pagerank algorithm
- Least-Squares Methods for Overdetermined Systems
    - The Singular Value Decomposition (SVD) and QR factorization
- Randomness and Monte Carlo
    - Random and quasi-random sequences
    - Monte Carlo methods, e.g., for numerical integration
- Initial Value Problems (ordinary differential equations)
    - Forward Euler, Backward Euler, Runge Kutta methods
    - Convergence and stability
- Additional topics may be covered at the instructor's discretion depending on time and student interest

Goals:

- Introduce you to the field of numerical analysis. Broadly speaking, numerical analysis uses techniques from calculus to design analytical and numerical methods to solve applied problems, and understand the accuracy and limitations of the methods.
- Apply your skills from calculus to derive, design, implement, test, and measure numerical algorithms from the above topics list.

Learning Outcomes: You will learn how to

- Understand the effects of finite precision on numerical computing, including conditioning and error types
- Solve linear systems with Gaussian Elimination (LU, PLU factorizations) and QR factorization.
    - Write down and solve systems in MATLAB (or Python)
    - Choose the correct algorithm (LU, triangular, Cholesky, etc...) for a given matrix
    - Understand the computational complexity of various linear solve algorithms, and the impacts on accuracy of conditioning
    - Understand the difference between direct and iterative methods, and when to use iterative methods
- Understand the importance of over-determined systems, how such systems arise, and how to solve such systems using the SVD and QR

- Understand how to construct interpolants of functions and choose an appropriate interpolation basis
- Derive numerical methods (e.g., with Taylor's theorem) to approximate derivatives and integrals, solve nonlinear equations, and solve initial value problems
- Evaluate the convergence properties and the numerical accuracy, e.g., for numerical derivatives and integrals, for nonlinear solution methods, for interpolation methods, and for initial value problems.

Grading: The course grade will be determined by

- Homework: 45%
- Midterm Exam: 25%
- Final Exam: 30%

The final grade for the class will be based on the summed weighted percentages above. Letter grades will be assigned as follows:

- A-, 90% or above
- B-, 80% or above
- C-, 70% or above
- D-, 60% or above
- F, below 60%

The instructor reserves the right to curve grades to offset unforeseen circumstances. Such a curve will never decrease a student's letter grade below that from the above scheme.

Absences Policy: It is expected that each student regularly attend class.

- Course follows UNM handbook D-170 https://handbook.unm.edu/d170/
- Note, the handbook says "A student with excessive absences may be dropped from a course by the instructor with a grade of W/P or W/F."
- If you need to miss more than two classes during the semester, please contact the instructor.

Homework: Homework will be posted every 1 to 2 weeks on the course webpage. Each homework will consist of a number of computer and theoretical problems. You need to hand in a written report on the due date at the start of class. All plots/figures in the report must be generated in MATLAB or Python and not hand drawn (unless otherwise specified in the homework question).

Some guidelines for your homework writeup are

- It should be legibly and neatly presented, and include all the required code, figures and tables, in the order assigned.
- Figures and tables should be well-labeled printouts.
- Any discussion and analysis should be either typed or neatly written.
- All sheets of paper must be stapled, your name written on front.

You are strongly encouraged to work in pairs (a group of two students) for the homework. Hand in a single report with both collaborators cited at the top. It is expected that both of you can explain the theory and computer codes. Groups of more than two students are not allowed.

Homework may be submitted late up to a week for 50% credit. ***Homework grading disputes must be submitted in writing within one week after the work is returned.***

Software: Use of MATLAB or numerical Python will be required to complete the course homework assignments.

Exams: There are two exams, a midterm and a final. Cheating on an exam will be handled in accordance with the dishonesty policy below. There are no makeup exams; however, I am sympathetic to a student who is unable to take a scheduled test due to a hardship. Please contact the instructor before the exam (if possible), should such a hardship occur.

Exam grading disputes must be submitted in writing within one week after the work is returned.

Credit Hour Statement: This is a three credit-hour course. Class meets for two 75-minute sessions of direct instruction per week for fifteen weeks during the Fall 2019 semester. Students are expected to complete a minimum of six hours of out-of-class work (or homework, study, assignment completion, and class preparation) each week.

Academic Integrity: Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, including dismissal, against any student who is found responsible for academic dishonesty or otherwise fails to meet the standards. Any student judged to have engaged in academic dishonesty in course work may receive a reduced or failing grade for the work in question and/or for the course.

Academic dishonesty includes, but is not limited to, dishonesty on quizzes, tests or assignments; claiming credit for work not done or done by others; and hindering the academic work of other students; misrepresenting academic or professional qualifications within or without the University; and nondisclosure or misrepresentation in filling out applications or other University records.

Accommodation Statement and Americans with Disabilities Act: In accordance with University Policy 2310 and the Americans with Disabilities Act (ADA), academic accommodations may be made for any student who notifies the instructor of the need for an accommodation. It is imperative that you take the initiative to bring such needs to the instructor's attention, as I am not legally permitted to inquire. Students who may require assistance in emergency evacuations should contact the instructor as to the most appropriate procedures to follow. Contact Accessibility Resource Center at 277-3506 or arc.unm.edu for additional information.

If you need an accommodation based on how course requirements interact with the impact of a disability, you should contact me to arrange an appointment as soon as possible. At the appointment, we can discuss the course format and requirements, anticipate the need for adjustments and explore potential accommodations. I rely on the Disability Services Office for assistance in developing strategies and verifying accommodation needs. If you have not previously contacted them I encourage you to do so.

Title IX: In an effort to meet obligations under Title IX, UNM faculty, Teaching Assistants (TAs), and Graduate Assistants (GAs) are considered "responsible employees" by the Department of Education (see page 15, http://www2.ed.gov/about/offices/list/ocr/docs/qa-201404-title-ix.pdf). This designation requires that any report of gender discrimination which includes sexual harassment, sexual misconduct and sexual violence made to a faculty member, TA, or GA must be reported to the Title IX Coordinator at the Office of Equal Opportunity (http://oeo.unm.edu). For more information on the campus policy (2000, 2740) regarding sexual misconduct, see: https://policy.unm.edu/university-policies/2000/2740.html

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Citizenship and/or Immigration Status: All students are welcome in this class regardless of citizenship, residency, or immigration status. Your professor will respect your privacy if you choose to disclose your status. As for all students in the class, family emergency-related absences are normally excused with reasonable notice to the professor, as noted in the attendance guidelines above. UNM as an institution has made a core commitment to the success of all our students, including members of our undocumented community. The Administration's welcome is found on our website: http://undocumented.unm.edu/

Disclaimer: I reserve the right to make reasonable and necessary changes to the policies outlined in this syllabus. Whenever possible, the class will be notified in advance of such changes. An up-to-date copy of the syllabus can always be found on the course website. It is your responsibility to know and understand the policies discussed therein and to be up-to-date. If in doubt, please ask questions.