MATH 361S: Mathematical Numerical Analysis
Spring 2020 Syllabus

Instructor: Holden Lee (holee@math.duke.edu)

Office Hours: Mon. 4:30-5:30PM, Fri. 2-3PM or by appointment. Virtual office are held through Sakai using Zoom.

Class times/Location: MW 3:05-4:20, Held through Sakai using Zoom.

Website: Course website
(http://services.math.duke.edu/~holee/math361-2020/index.html)

Piazza (piazza.com/duke/spring2020/math361s)

Textbook: Uri Ascher & Chen Greif, *A First Couse in Numerical Methods* and excerpts from Cleve Moler's book *Numerical Methods in MATLAB* (free online at https://www.mathworks.com/moler/chapters.html).

Other suggested texts: T. Sauer's *Numerical Analysis* is a good, approachable introduction.

Changes for distance learning: Announced will be given on Piazza, and a list of announcements will be kept on the course website
http://services.math.duke.edu/~holee/math361-2020/index.html.
Lectures will be recorded and made available on Sakai (with Zoom), and lecture notes will be available. You are asked to watch the videos and/or read the lecture notes before class time, and are encouraged to ask questions and discuss the lecture on the Piazza page.
Class time will be devoted to discussion and to working out examples. We will experiment with the format, but the general plan is to (a) first devote some time to QA on the relevant material, (b) work out practice problems, and (c) show demos involving code.

Course synopsis: Development of numerical techniques for accurate, efficient solution of problems in science, engineering, and mathematics through the use of computers. Linear systems, nonlinear equations, optimization, interpolation, numerical integration, differential equations, error analysis.

Preqrequisites: A solid understanding of fundamental concepts from linear algebra is essential, including linearity, solving linear systems, eigenvalues and eigenvectors. A course in multi-variable calculus (e.g. Math 212) is also required. Experience with ordinary differential equations is recommended, but not necessary.

Some exposure to basic programming is required (e.g. CS 101), but no prior experience with any specific language will be assumed. The official programming language for the course is Matlab. I may also give support for Python and Julia.

Schedule: Below is a tentative schedule with expected topics. A detailed schedule and further information about the topics will be posted and updated on the course website.

- Week 1: Introduction, floating point arithmetic
- Week 2-3: Error analysis, non-linear equations (scalar)
- Week 4-5: Linear systems: direct and iterative methods
- Week 6-7: Interpolation
- Week 8: Differentiation
- Week 9: Integration (Quadrature)
- Week 10-11: ODE's
- Week 11-12: Optimization
- Week 13-14: Additional topics, wrap-up, presentations

Some possible additional topics (we may cover one or two briefly) are:

- Singular value decomposition
- Least squares approximation
- Discrete Fourier transform / FFT
- Boundary value problems, PDEs
- Numerical analysis for deep learning (automatic differentiation, quantized neural networks)

Course Logistics

Exams and Grading: Grades will be assigned based on several components:

- Midterms (40%): First midterm: closed-notes, closed-book exams in class. The second midterm will be an open-notes, open-book exam. You can use course notes, notes you have taken, and the textbook, but not other online resources or books, or discuss with others. You will have at least one full day to complete the exam.
- Final project (30%): An in-depth exploration of a topic in numerical analysis with two components: a written report and a presentation.
- Homework (30%): Assignments comprised of two parts: theoretical exercises and computational problems (which involve writing code).

- Participation will be taken into account when determining grades (maximum of 10% extra). Participation includes discussing the material, asking or answering questions in class or on the Piazza site, attending office hours and discussing the project. If you are not able to make the class time, participation will be based on questions/answers and discussion you contribute online.
- **There is no final exam for the course**.

Homework:

- Homework will be assigned (roughly) weekly and will typically be due the following Wednesday. Consult the schedule for due dates. All homework is to be submitted via Sakai. If you scan or take a picture, make sure it is legible.
- Working and studying in groups is encouraged. However, you should write your own solutions to each problem in your own words.
- **Late assignments will not be accepted**, barring exceptional circumstances as per Duke policy.
- Solutions should be complete arguments; the process by which you arrive at the solution is far more important than a correct answer. When appropriate (which is often), use complete sentences to develop your arguments. Assertions should be supported by computed data and code when it is needed.
- Make sure the work is organized and readable. Solutions should be in the same order as in the list of problems.

Computational problems:

- Some homework problems will require writing and running code. The official choice of language for this course is Matlab; most examples/solutions will also include python code. You may write your code in Matlab or python (for python, use the `numpy` package).
- Collaboration is encouraged but the code you submit should be your own, which includes not copy-pasting code from other sources. Avoid looking up code online because it is difficult to un-see it when writing your own.
- Expectations for computational problems are detailed in the *Guidelines for computational problems* document (on the webpage).

Final project: The final project is a research project exploring a topic in numerical analysis in depth and some key applications. Examples include calculation of dominant eigenvectors as used in Google's search algorithm (PageRank) or simulation of chaotic systems. Due dates and detailed expecations are given at `https://services.math.duke.edu/~holee/math361-2020/project/Project-2020.pdf`.

- The final project has two components: a written report and a presentation. The report **must be written in LaTeX** and will take the form of a scientific article, including an introduction, description of numerical methods, discussion of your results, conclusions, references, and an appendix containing your code. For the presentation, you can either (1) upload a ≈ 20 minute video presentation, or (2) write a blog post on the topic. You will be asked to watch/read and comment on the other presentations (which counts as part of your participation grade), and respond to questions on your presentation (this counts towards your presentation grade).
- A list of topics is available at `https://services.math.duke.edu/~holee/math361-2020/project/Math_361_Project_topics.pdf`. You may also choose your own topic, subject to instructor approval. A one page abstract of the topic will be due about halfway through the course.
- Due dates for the draft of the report and presentation, and for the final presentation are given in the schedule. The written report will be due during Finals week.

Ethics: Students are expected to follow the Duke Community Standard. If a student is found responsible for academic dishonesty through the Office of Student Conduct, the student will receive a score of zero for that assignment. If a student's admitted academic dishonesty is resolved directly through a faculty-student resolution agreement approved by the Office of Student Conduct, the terms of that agreement will dictate the grading response to the assignment at issue.