MATH 522, Spring 2019 Syllabus

Prof. Zachariah B. Etienne

Feb. 20, 2019 Edition

This syllabus is subject to revision, at the option of the instructor. If revised, the new syllabus will not become official until the instructor has distributed it to students over email.

Class meets MWF 10:30AM–11:20AM, ARM 120

Instructor Contact Information

- zbetienne *<at>* mix.wvu.edu
- Office hours:
  - Armstrong Hall 409C
  - Monday and Friday 11:30AM–12:30PM, or by appointment

Course Website

- `http://math.wvu.edu/~zetienne/`

Course Preqrequisites

- Good computer programming skills, in a language that supports standard (IEEE-754 standard) double-precision arithmetic. In-class examples will be given in pseudocode. Students have successfully taken this course using Matlab, Python, C, C++, and Java, just to name a few languages. Warning: Computer programming will *not* be taught in this class. You will be expected to design, write, and debug (yourself) computer codes that are up to roughly 200 lines in length.
- Strong background in undergraduate mathematics (this is a *graduate-level Math class*, after all). The below list *is not comprehensive*, but indicative of the topics with which you will need to be familiar:
  - Scientific notation/significant figures
  - Basic algebra: Solving Nonlinear Equations and Inequalities
  - Calculus I: Differentiation (chain rule, maxima/minima)
  - Calculus II: Integration (by parts & variable substitution, Taylor Series)
  - Linear Algebra: Basic matrix algebra; computing determinants; properties of determinants; eigenvalues/eigenvectors.
  - Ordinary Differential Equations (ODEs): Series solutions to ODEs, Fourier series
  - Partial Differential Equations (PDEs): Solving PDEs using the Method of Separation of Variables.
- Ability to
  - Read and understand technical writing. You will be expected to study the notes for this class and apply this knowledge to solve homework problems. Homework problems are not obvious extensions to the notes or taken from any textbook; instead they are inspired by real-world problems and build upon material in the notes.
  - Express yourself in a clear, unambiguous way.

Course Objective

- Partial differential equations (PDEs) are used to describe the dynamics of a wide variety of phenomena in many scientific and engineering contexts, though are often difficult or impossible to solve by hand. Motivated by such a wide variety of applications, this course will provide necessary training for analyzing PDEs and solving them *on the computer*, with particular focus on finite difference solutions to hyperbolic, parabolic, and ellipic PDEs. Stability and trustworthiness of the numerical solution will be a central focus, through careful error analysis.
- To this end, a number of key skills will be developed:
  - Read, write, and understand technical literature at the level of a research journal, and apply this knowledge to accomplish research objectives.
  - Write algorithms for solving PDEs numerically from instructions given and properly interpreting their output, particularly when the output does not correspond to the desired result.
  - Present results and describe findings at a professional level.

Textbook

- The lecture notes are designed to be self-contained, so no textbook is necessary. One suggested textbook is listed below, however. **Warning: For certain terms in the field of Numerical Analysis, multiple definitions might exist. The lecture notes will contain the only definition accepted in this class.**
  - **"Numerical Recipes: The Art of Scientific Computing"**, by Press, Teukolsky, Vetterling, and Flannery. Any edition except the first should be fine. Note that the Second Edition is available online for free, by clicking the "Obsolete Versions" button on the Numerical Recipes homepage: `http://numerical.recipes`

Tentative Course Outline

- Estimating the physical scale of the PDE's solution
- Classification of PDEs; Dimensional Analysis
- Parabolic equations; solving the heat equation via separation of variables
- Types of errors observed in numerical solutions
- Overview of types of errors we encounter when solving PDEs and ODEs on the computer
- Scientific notation; finite precision arithmetic
- Solving ODEs on the computer
- Lagrange polynomial interpolation
- Finite difference approximations to derivatives; relationship to interpolating polynomial.
- Lax Equivalence Theorem: Stability, Consistency, & Convergence; von Neumann Stability Analysis
- Explicit schemes for solving hyperbolic PDEs: The Method of Lines
- Implicit schemes for solving hyperbolic PDEs; solving tridiagonal matrices via the Thomas algorithm
- Solving square matrices on the computer: from Gaussian Elimination to the Jacobi & Gauss-Seidel Methods.
- Elliptic equations; solving the Poisson equation
- Barotropic hydrodynamics; method of characteristics; shocks

Attendance Policy

It is expected that students will attend class every day to take notes and receive homeworks when they are handed out. All homeworks and exams will be based on course notes. **Students who cannot make it to class will need to coordinate with a classmate to obtain copies of the course notes and homeworks.** A copy of the homework may be obtained during an office hours visit, but no notes will be provided. Arriving late to class is disruptive to the normal functioning of the course, and may result in **forfeiture of significant bonus point opportunities.**

"Assume the PRT will be down!" On exam days in particular, students should have no expectation that their normal mode of transportation will be functioning properly. Additional time will not be given for exams if a student arrives late.

Grading

Grading will be based on the total number of points earned by a student. Points are divided as follows:

- Homework Assignments (See **Homework Policy** below): 35%
- Midterm Exams (Mon Feb 4, 2019 and Fri Mar 8, 2019 at the normal class time & location): 35%
- **Comprehensive** Final Exam (Thurs May 2, 2019 2:00PM–4:00PM, normal class location; official date/location posted here: `https://registrar.wvu.edu/calendars/final-examination-schedule`): 30%

Grading Scale

- A- to A+: 90—100%
- B- to B+: 80—89%
- C- to C+: 70—79%
- D- to D+: 60—69%
- F: Below 60%

Skills Assessment

As there are no hard prerequisites for this class, a Skills Assessment exam will be given to all students early in the semester. Taking this Assessment is a requirement; failure to do so will result in a full letter grade deduction on the overall course grade.

Homework Policy

1. **Coding and Non-Coding Assignments**
   - A total of approximately seven homework assignments will be given in this class. Each assignment will be either a **coding** or a **non-coding** assignment.
     - **Coding Assignments** consist of two documents handed in *separately*:
       * The first document contains handwritten or typewritten answers to each problem (with plots and data tables) in order (no Appendices).
       * The second document consists of a printout of all source codes written to answer each problem, again in order. Homeworks without source code *will not be accepted*.
     - In **Non-Coding Assignments**, the use of calculators or any electronic computational aides is forbidden, unless the homework problem states otherwise. When computational aides are forbidden, **all work must be shown, or points will be deducted.** Non-coding assignments must be handwritten.
2. **Guidelines for Both Coding and Non-Coding Assignments**

   (a) **Red Ink**: Red ink may not be used by the student in homework assignments, or a penalty of 15% will be assessed to the entire assignment.

   (b) **Vague or Unclear Answers**: Presentation and discussion of results is at least as important as the results themselves—often graduate students doing great work *fail to achieve career goals* because they did not make adequate effort to present the results of their work to others. Thus significant penalties will be assessed if a student's answers are vague or unclear on homeworks or exams. Tip: *Whenever possible, use the vocabulary we developed in class*!

   (c) **Plots and Data Tables**
   - Plots and data tables must have axes and all data series labeled accurately, or significant penalties will be assessed. It will never be acceptable to label the vertical axis as the y-axis, and only occasionally it will be acceptable to label the horizontal axis as the x-axis.
   - When you encounter the phrase "Plot $f(x)$ versus x", or "Plot f as a function of x", you are to plot $f(x)$ on the *vertical* axis and x on the *horizontal* axis.

   (d) **No Collaboration on Homework Assignments**
   - The objective of this class is *individual* proficiency in the subject matter. To this end, **students may not collaborate on homework assignments**; all assignments must be completed ndividually. After completing the assignment, you may compare your solutions with those of other students or against a computer algebra system (e.g., Mathematica or Maple). **However, written solutions or source code listings that are substantially the same will receive zero credit for all students involved.**

   (e) **Late Homework Policy**
   - Full solutions will be due at the start of class on the due date; handing in parts of the assignment at different times is forbidden. Students are strongly encouraged to start early, or bugs may prevent them from handing in homeworks on time, and *the standard homework late penalty will be imposed*.
   - Keeping up with course material is essential to success in this class, as a great deal of material is covered. Therefore, late assignments will be penalized as follows:
     - Up to 48 hours late: 20% score reduction
     - 48–96 hours late: 50% score reduction
     - More than 96 hours late: 75% score reduction

   (f) **Bonus Credit for Professional Presentation**
   - If all problems are handed in in order for a given homework assignment, TWO "In-Order Bonus" points will be awarded toward that homework. (No Appendices allowed.)
   - If each homework assignment *document* (i.e., coding assignments contain two documents and non-coding assignments contain one) is properly bound using a single staple, ONE "Staple Bonus" point will be awarded toward that homework.

Academic Dishonesty

The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Campus Student Code. This Code may be found linked from the Office of Student Conduct web page:

`https://studentconduct.wvu.edu/`

Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me [the instructor] before the assignment is due to discuss the matter.

Inclusivity Statement & Accommodations

"The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me [the instructor] and make appropriate arrangements with the Office of Accessibility Services (304-293-6700). For more information on West Virginia University's Diversity, Equity, and Inclusion initiatives, please see `https://diversity.wvu.edu/`."

Students requesting special accommodations are required to inform the instructor at least 48 hours in advance of a test.

Electronic Device Policy

During lectures and exams, **cellular phones** and other electronic devices (including but not limited to **calculators**, tablet computers, laptops, PDAs, MP3 players, Blackberrys) are not permitted, except with the consent of the instructor. All forbidden devices must be turned off before the beginning of the class period and placed out of sight (for example, in a backpack or handbag) until the class has concluded.

A student's first violation of this policy **during lectures** will result in a verbal warning (one verbal warning per semester), and each subsequent violation *even during the same lecture* will result in a 1% deduction in the student's overall course grade. Violations of this policy **during exams** will result in a zero grade on the exam and possible expulsion from the course.

Intellectual Property Notice

All course materials, including lectures, class notes, quizzes, exams, handouts, presentations, and other materials provided to students for this course are protected intellectual property. As such, the unauthorized purchase or sale of these materials may result in disciplinary sanctions under the Campus Student Code.