Math 4401 Numerical Methods Section 001 (4 cr)

Meeting Time: Spring 2013 TTh 2:00–3:40 in Sci 3650
Instructor: Barry McQuarrie
Office: Science 1380 University Minnesota, Morris
Office Hours:
Email: mcquarrb@morris.umn.edu (preferred communication) Phone: (320) 589–6302 (I do not use voicemail)
Course moodle site: https://moodle2.umn.edu/course/view.php?id=15177
(the site is accessible from your UMM portal page or the Student One Stop.)

Course Prerequisites: Math 1101, Math 1102, Math 2401, Math 2111

To succeed in this course you will need to have mastered basic calculus (Calculus I and Calculus II), differential equations, and certain topics in linear algebra (notably Gaussian elimination and eigensystems). You should have a good background in *Mathematica*.

Learning Objectives

Upon completion of this course a student should be able to:

- Demonstrate understanding of the numerical techniques we have studied in class.
- Communicate the results of a numerical method effectively.
- Be able to investigate numerical techniques which we have not studied in class, and then communicate this understanding.
- Know the strengths and limitations of the numerical techniques we have studied.
- Exhibit competence with the use of technology in the study of numerical analysis.

Beyond the curriculum, you should also expect to

- develop skill at presenting solutions to problems,
- think beyond technique, and understand the problems studied in some depth,
- develop confidence in your problem solving skills,
- see the benefit of computers to aid calculation, but also see the *absolute necessity* of understanding the theory completely before using a computer.

Time Commitment

University policy says "one credit is defined as equivalent to an average of three hours of learning effort per week (over a full semester) necessary for an average student to achieve an average grade in the course". Our course is a four-credit course, meeting approximately three hours per week: 4 credits times 3 hours/week/credit - 3 hours/week in lecture = 9 hours/week outside class. Thus, you are expected to spend 9 hours per week working outside of class, reading the textbook and working problems.

Please make the most of my office hours! The content of the course can be difficult at times and I expect to see you all in my office at some time or other. To get the most out of the course you should

- do homework every day,

- allot time to think about what it is we are doing,
- discuss the techniques we are studying and their implementation with your classmates,
- discuss any difficulties with me during office hours.

Textbook

The required textbook is Numerical Analysis, 2nd Edition by Timothy Sauer (0-3217-8367-0)–the bookstore will have the latest edition, and the course calendar is based on the 2nd Edition.

Programming Expectations. The textbook contains programs for all the algorithms in MATLAB (http://www.mathworks.com/products/matlab/), but we will be using *Mathematica*.

You will have to do a certain amount of simple programming in the course, mainly using looping structures like Do or While, and you will no doubt use the Module structure as you write your code. These capabilities exist in *Mathematica*, and I can help you with coding in *Mathematica*. Your peers in the course are also an excellent resource if you have a question about the course.

Mathematica. *Mathematica* has many useful features to someone interested in numerical analysis. Many of *Mathematica*'s internal routines use numerical methods, but of course in this class we are more interested in how the method works than simply implementing it. *Mathematica* can be used to help you with the arithmetic manipulations you need to do, but your solutions should also contain legible, hand written discussions about what it is you are doing.

I have quite a few *Mathematica* notebooks on my web page from the various courses I have taught over the years. These may serve as a useful guide. On the course moodle site I will be placing *Mathematica* notebooks for you to download and experiment with, especially any notebooks I use during lectures. As well, there is an abundance of *Mathematica* assistance available on the web, and you should use those resources as you see fit.

As the focus of this course is understanding numerical methods rather than simply implementing them, you should use *Mathematica* essentially as a simple CAS to help you do arithmetic, take derivatives or integrals where necessary, and plot graphs. You will also need to do simple programming with *Mathematica* (branch structures, looping, modules).

If you have any questions about what my expectations are at any time during the course, make sure you ask me.

Course Components

Assignments. There will be a selection of homework questions assigned throughout the semester. Since an important aspect of the course is the communication of ideas, you should concentrate on first solving the problem, and then communicating the solution in a manner understandable to others. You may work together on assignments, but each student turns in their own assignment, and any group work should involve proper collaboration and not simply copying of another student's work.

Midterm Exam and Final Exam. These exams will have questions similar to the assignment questions and be a take home exam. You will not be allowed to work in groups or discuss the test with your peers.

The exams will be handed out during class, and handed in to me in my office (Sci 1380). While you are working on a take home exam there will be no lectures scheduled. The final exam will be due at the end of the scheduled exam time for the course.

Analysis Project. The analysis project is an important part of the course, since it will require you to investigate a numerical method on your own (no group work on this project). Acquiring this skill is one of the main goals of

the course. The project should be based on one of the methods from the text which we did not study in class, or some other numerical technique that is not in the textbook but that you find interesting.

The project will consist of two components, a paper (60 marks) and oral presentation (40 marks). The Applied Project will be graded out of 100 marks.

Analysis Project Paper. Your paper should be about 10 pages long, and written with proper sectioning, numbered equations, and include an abstract and bibliography. It should be typed, using Word, LaTeX, or *Mathematica* (or other typesetting software like OpenOffice). If you have lots of complicated equations or figures to typeset, you can write those in neatly by hand. Your paper will be graded based on neatness, organization, grammar, and mathematical content. Your paper should include the following:

- The Method
  - describe in words and general pictures what the method does
  - describe (derived if possible) in math
- An Application of the Method
  - worked through by hand (entirely, or one step of the solution)
  - a more complex problem solved using a computer (include computer code)
- Conclusion
  - strengths, weaknesses of method
  - when it should be used
  - possible improvements
- References

Analysis Project Presentation. The presentations will be 30 minutes long, so you will probably have to edit what is in your paper and determine what is the best way to get your main points across. You may use overheads, the whiteboard, powerpoint, LaTeX, *Mathematica*, or webpages in your presentation. Remember, the presentation is about communicating information, not about flashy effects. Some of the best presentations I have seen used simple, neatly written overheads. Keep the following in mind as you prepare your presentation:

- Introduction.
- Description of problem (with sufficient mathematical detail that can be conveyed to audience in short time).
- Clarity and organization of material (avoid showing anything the audience doesn't have time to follow or understand).
- Enthusiasm doesn't just mean being loud. Are you keeping your audience intellectually engaged?
- Most importantly, think about what you want your fellow classmates to take away from your presentation (it probably won't be everything that is in your paper). The audience should understand the broad picture of what you have done, and if they want more detail they can read your paper or you can go out for coffee with them after to talk about it. Really, that's the goal–get them interested enough to want to learn more!

Grading

The University utilizes plus and minus grading on a 4.000 cumulative grade point scale in accordance with the following:

A	4.000	Represents achievement that is outstanding relative to the level necessary to meet course requirements
A−	3.667	
B+	3.333	
B	3.000	Represents achievement that is significantly above the level necessary to meet course requirements
B−	2.667	
C+	2.333	
C	2.000	Represents achievement that meets the course requirements in every respect
C−	1.667	
D+	1.333	
D	1.000	Represents achievement that is worthy of credit even though it fails to meet fully the course requirements
S		Represents achievement that is satisfactory, which is equivalent to a C- or better

The grade for the course will be calculated by the following formula (there is no extra credit):

Assignments (Jan 24, Feb 7, 21, Mar 7, Apr 4, 18)	55%
Midterm Exam (Due Thu Mar 14 3:40pm)	15%
Final Exam (Due Thu May 9 4:00pm).....	15%
Analysis Project (Paper Due Thu May 2 2:00pm)	15%

Your numerical grades will be converted to letter grades and finally Grade Points via the following cutoffs (grades are not rounded up):

Numerical	95.0%	90.0%	87.0%	83.0%	80.0%	77.0%	73.0%	70.0%	65.0%	60.0%	Below 60.0%
Letter	A	A−	B+	B	B−	C+	C	C−	D+	D	F
Grade Point	4.000	3.667	3.333	3.000	2.667	2.333	2.000	1.667	1.333	1.000	0.000

A Healthy Learning Environment

- **Attendance.** Attendance does not count towards your final grade, but missing class means you don't get the benefit of what we do in class, so please come to class and make sure to be in class on time. Neither I nor your fellow classmates enjoy the disruption late arrival causes. I know that situations crop up that will entail late arrival (please come even if you are late!) but try to ensure it is the exception and not the rule. Buy an alarm clock with a battery backup, as the power often goes out for a moment in Morris. If you are coming from another class and fear you may be late often, just let me know and don't stress about it. If you need to leave class early, let me know before class and slip out as unobtrusively as possible.
- **Computers/Cell Phones.** During class, cell phones and music devices should be turned off, and headphones removed from ears. If I find you are surfing the internet during class I will ask you to leave.
  http://www.policy.umn.edu/Policies/Education/Education/CLASSROOMPED.html
- **Personal Conduct In Class and Online.** Be mindful of your peers around you, and keep stray chatter in class to a minimum. In the discussion forums and email communications, please consider the tone of your writing. We must maintain a respectful, open environment if we hope to have effective forum discussions. Also, make sure to use correct grammar, spelling, and punctuation in all your electronic communications. The UMM Student Conduct Code is available at www1.umn.edu/regents/policies/academic/Student_Conduct_Code.pdf
- **Academic Dishonesty.** Cooperation is vital to your future success, which ever path you take. I encourage cooperation amongst students where ever possible, but the act of copying or other forms of cheating will not be tolerated. Academic dishonesty in any portion of the academic work for a course is grounds for awarding a grade of F or N for

the entire course. Any act of plagiarism (presenting the ideas, words, or work of someone else as your own) that is detected will result in a mark of zero on the entire assignment or test for both parties. I will make it clear during class what is appropriate collaboration for each activity, but if you still have questions about what constitutes academic dishonesty, please come and talk to me. UMM's Academic Integrity policy and procedures can be found at www.morris.umn.edu/committees/scholastic/academicintegrity/.

Academic Dishonesty FAQ: http://www.oscai.umn.edu/integrity/student/index.html

- **Late Work/Missed Exams.** Since the assignments are handed out days in advance, only under exceptional circumstances (which can be officially documented) will I accept late work. You will receive a mark of zero if an assignment is submitted late. **However, please talk with me asap (do not wait until the next class) if you missed turning something in, even if it is after the deadline.** If an assignment is partially complete but you are not granted an extension, still submit the work you have completed so you can earn some partial credit. This is far preferable to earning zero on the assignment by not submitting anything.

  If you are going to miss a test (for a documented reason), let me know in advance so we can work out alternate plans. If you unexpectedly miss an exam/quiz/etc for a documentable reason, get in touch with me asap so we can work out alternate arrangements, or schedule a make-up.

  Assignments are due in class (come to class and turn them in). Slipping assignments into my mailbox or under my office door while I am teaching your course is **severely frowned upon** unless we have agreed that you will be doing this.

- **Your Health.** As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating, and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. If you have any special needs or requirements to help you succeed in the class, come and talk to me as soon as possible, or visit the appropriate University service yourself. You can learn more about the range of services available on campus by visiting the websites:

  - The Academic Assistance Center www.morris.umn.edu/services/dsoaac/aac/
  - Student Counseling www.morris.umn.edu/services/counseling/
  - Disability Services www.morris.umn.edu/services/dsoaac/dso
  - Multi-Ethnic Student Program www.morris.umn.edu/services/msp/

Other Policies

- **Makeup Work for Legitimate Absenses.**
  http://policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html.
- **Appropriate Student Use of Class Notes and Course Materials.**
  http://policy.umn.edu/Policies/Education/Education/CLASSNOTESSTUDENTS.html.
- **Student Conduct.**
  http://www1.umn.edu/regents/policies/academic/Student_Conduct_Code.html.
- **Sexual Harassment.**
  http://www1.umn.edu/regents/policies/humanresources/SexHarassment.html.
- **Equity, Diversity, Equal Opportunity, and Affirmative Action.**
  http://www1.umn.edu/regents/policies/administrative/Equity_Diversity_EO_AA.html.
- **Academic Freedom and Responsibility**.
  http://www1.umn.edu/regents/policies/academic/Academic_Freedom.pdf.

Topics

- 0. Fundamentals
- 1.1 Bisection Method
- 1.2 Fixed Point Iteration
- 1.4 Newton's Methods
- 1.5 Root Finding Without Derivatives
- 2.1 Gaussian Elimination
- 2.2 The LU Factorization
- Norms
- 2.5 Iterative methods
- 2.7 Nonlinear systems of equations
- 3.1 Data and interpolating functions
- 3.2 Interpolation error
- 3.3 Chebyshev Interpolation
- 3.4 Cubic Splines
- 4.1 Least squares and the normal equations
- 4.2 Linear and nonlinear models
- 4.3.1 Gram-Schmidt Orthogonalization
- 5.1 Numerical Differentiation
- 5.2 Newton-Cotes formulas for numerical integration
- 5.3 Romberg Integration
- 5.4 Adaptive Quadrature
- 5.5 Gaussian Quadrature
- 9.1 Random numbers
- 9.2 Monte-Carlo simulation
- 6.1 Initial value problems
- 6.2 Analysis of IVP solvers
- 6.4 Runge-Kutta methods and applications
- 6.7 Multi-step methods
- 6.3 Systems of ordinary differential equations
- Accelerating Convergence (handout)
- Padé Approximants (handout)
- 12.1 Eigenvalues