University of Puerto Rico
Río Piedras Campus
College of Natural Sciences
Department of Mathematics

Course Syllabus
Second semester academic year 2019-20

Course information

Course title: Computational Analysis II
Course code: MATE 6690
Time: Monday and Wednesday 4:00-5:20 pm
Room: NCN II-A141
Credits/hours: 3 credits/45 hours
Course prerequisites: MATE 6680 and knowledge of a high level programming language.
Course web pages: `http://online.uprrp.edu/course/view.php?id=38062` and `http://epsilon.uprrp.edu/mmarcano/cursos/Computational_AnalysisII/`

Instructor: Mariano Marcano
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Course description

This is a course in numerical methods for solving ordinary and partial differential equations. We will: study the mathematical foundations of numerical methods; analyze the methods basic theoretical properties–stability, accuracy, and computational complexity; and illustrate the methods performances by means of computational examples and counterexamples by using a high-level programming platform such as MATLAB®/Octave.

Course objectives

After completing the course students will know how to:

1. Apply linear multistep methods for solving ordinary differential equations (ODE), the initial-value problem (IVP).
2. Use Runge-Kutta or multistage methods for solving ODE-IVP.
3. Determine if a method convergences to the solution of the ODE-IVP and, if so, to obtain the order of convergence of the method.

4. Analyze the linear stability of the methods for the ODE-IVP and to determine when the method is reliable to solve stiff problems.
5. Apply the shooting and finite difference methods for solving ODE, two-point boundary value-problems (BVP).
6. Apply finite difference methods for solving partial differential equations (PDE).
7. Identify numerical dispersion and dissipation introduced by a numerical method for PDE.
8. Use flux-limiter methods to capture shock formation in the PDE solution.
9. Apply von Neumann analysis to study the stability of numerical methods for PDE.

Content outline and schedule

	Topic	Time
1.	Linear multistep methods for solving ordinary differential equations, the initial-value problem (ODE-IVP): (a) Derivation of linear multistep methods (1.5 hour); (b) Analysis of consistency, stability, and convergence of linear multistep methods (3 hours); (c) Order of convergence of linear multistep methods (1.5 hour).	6 hours
2.	Linear stability analysis and stiffness	3 hours
3.	Runge-Kutta methods	3 hours
4.	Numerical solution of ordinary differential equations, two-point boundary-value problem (ODE-BVP): (a) introduction to the ODE-BVP (1.5 hour); (b) shooting method (1.5 hour); (c) finite-difference methods and stability analysis (3 hours); (d) solving the system of difference equations (3 hours).	9 hours
5.	Exam I (tentatively: Wednesday, March 18)	1.5 hour
6.	Conservation law and the transport equations	3 hours
7.	Linear finite difference methods for partial differential equations (PDE)	3 hours
8.	Flux-limiter methods	3 hours
9.	Solving the system of difference equations for PDE	3 hours
10.	Strang splitting technique	3 hours
11.	Von Neumann stability analysis	3 hours
12.	Numerical methods for the Burgers' equation, a nonlinear equation	3 hours
13.	Exam II (tentatively: Monday, May 13)	1.5 hour.
	Total:	45 hours

Instructional strategies

- The course will be taught in the classroom and online. The content of the course and supporting materials will be available to the student through the Moodle platform. The lecture notes will be in slide presentations.
- Assignments will be uploaded to Moodle in pdf format, the students will download the files and, before the deadline, the students must upload the answers to Moodle in a single file. Grading and feedback will be available in Moodle to the student.
- A frequent asked question FAQ Moodle forum will be available to post any question the student may have and answer questions posted by classmates. One point bonus (maximum two points) will be added to the corresponding homework of any student that answers completely and correctly a question of the forum.
- As alternative methods that do not require the physical presence of the students and the teacher in the classroom, we may use: recorded lectures and video conferences.

Course politics

- Exams will be in class or take home, thus students must not have conflicts with the exam time.
- Students that, under the recommendation of OAPI, need additional time to answer the exams, will stay in the classroom for the additional time and the instructor will stay with them.
- *Alternative Teaching Methods*. Certification No. 112 (2014-2015) of the Governing Board defines a classroom course as a course in which 75% or more of the hours of instruction require the physical presence of the students and the teacher in the classroom. This means that 25% of a classroom course could be offered without requiring the physical presence of the students and the teacher in the classroom. If necessary, this course will be able to complete up to 25% of the contact hours (11.25 hours) on a non-face-to-face basis by alternative methods such as: Video-conferences, instructional modules, discussion forums and others. If so, the calendar/agenda will be modified to include the topics that will be covered by alternative methods.

Available and required learning resources

To take advantage of the course material and other resources in Moodle the student needs a personal computer with fast internet access, a PDF viewer, an internet browser, a word processor (LaTeX is free and suitable for writing mathematical expressions), and the high level programming platform MATLAB®/Octave. Octave is free and can be downloaded from `http://www.gnu.org/software/octave/download.html`.

Course evaluation

Evaluation of student understanding of the class material will be made by means of homework assignments and in-class exams. The grade will be computed as follows:

Homeworks	40%
Exam I	30%
Exam II	30%
	100%

Assignments will be posted in Moodle at least one week before the deadline.

Grading system

Letter system (A, B, C, D or F).

Law 51: Rights of Students with Disabilities

Students with access to Vocational Rehabilitation Services should contact the professor at the beginning of the semester in order to plan any special arrangements and equipment necessary in accordance with the recommendations of the Office of Services to Students with disabilities (OSEI) in the Office of the Dean of Students. In addition, any students with special needs or who require any type of assistance or special arrangements should contact the professor.

Academic Integrity

The University of Puerto Rico promotes the highest standards of academic and scientific integrity. Article 6.2 of the UPR Students General Bylaws (Board of Trustees Certification 13, 2009- 2010) states that academic dishonesty includes, but is not limited to: fraudulent actions; obtaining grades or academic degrees by false or fraudulent simulations; copying the whole or part of the academic work of another person; plagiarizing totally or partially the work of another person; copying all or part of another person answers to the questions of an oral or written exam by taking or getting someone else to take the exam on his/her behalf; as well as enabling and facilitating another person to perform the aforementioned behavior. Any of these behavior will be subject to disciplinary action in accordance with the disciplinary procedure laid down in the UPR Students General Bylaws.

To ensure the integrity and security of user data, any hybrid and remote course must be offered through the institutional learning management platform, which uses secure connection and authentication protocols. The system authenticates the user's identity using the username and password assigned in their institutional account. The user is responsible for keeping secure, protecting, and not sharing his password with other people.

Normativeness on discrimination by sex and gender in sexual violence form

The University of Puerto Rico prohibits discrimination based on sex, sexual orientation, and gender identity in any of its forms, including that of sexual harassment. According to the Institutional Policy Against Sexual Harassment at the University of Puerto Rico, Certification Num. 130, 2014-2015 from the Board of Governors, any student subjected to acts constituting sexual harassment, must come to the Office of the Student Ombudsperson, the Office of the Dean of Students, and/or the Coordinator of the Office of Compliance with Title IX for an orientation and/or a formal complaint.

Textbook: Alfio Quarteroni, Riccardo Sacco, and Fausto Saleri. *Numerical Mathematics (Texts in Applied Mathematics , Vol. 37)* Second Edition, 2007. ISBN 978-3-540-49809-4

Bibliography

1. Kendall E. Atkinson, *An Introduction to Numerical Analysis*, Second Edition, John Wiley & Sons, 1989.

2. Eugene Isaacson and Herbert B. Keller, *Analysis of Numerical Methods*, Dover Publications, Inc., New York, 1994.

3. Herbert B. Keller, *Numerical Methods for Two-Point Boundary-Value Problems*, Dover Publications, Inc., New York, 1992.

4. J.D. Lambert, *Numerical Methods for Ordinary Differential Systems: The Initial Value Problem*, John Wiley & Son, 1991.

5. R. LeVeque, *Numerical methods for conservation laws*, Birkhauser Verlag, 1992.

6. James M. Ortega, *Numerical Analysis: A Second Course*, SIAM. Philadelphia, 1990.

7. Robert D. Richtmyer and K. W. Morton, *Difference Methods for Initial-Value Problems*, 2nd edition, Krieger Publishing Company, 1995.

8. J.C. Strikwerda, *Finite Difference Schemes and Partial Differential Equations*, Chapman and Hall, 1989.

9. J. Stoer and R. Bulirsch, *Introduction to Numerical Analysis (Texts in Applied Mathematics, No 12)*, Second edition, Springer, NY, 1997.

Electronic references

1. M. Marcano, *Introduction to* MATLAB, preprint, 2007, `http://epsilon.uprrp.edu/mmarcano/cursos/Computational_Analysis/Presentations/MatlabIntroduction.pdf`.

2. LN Trefethen, *The definition of numerical analysis*, Essay, 1992, https://people.maths.ox.ac.uk/trefethen/publication/PDF/1992_55.pdf