Math 340, Spring 2024

Programming in Mathematics

Schedule Number: 14687

Instructor: Dr. Bo-Wen Shen

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(Last Updated: 2024/01/15)

COURSE INFORMATION

Class Days: MW	Dr. Bo-Wen Shen:
Class Times: 9:00-9:50	Office Hours Times (and by appointment): 3:00-4:00 pm MW
Class Location: HH221	Office Hours Location: GMCS 569 or Zoom

Course Overview

Course Descriptions:

Introduction to programming in mathematics. Modeling, problem solving, visualization. This course covers essential programming foundations and numerical methods, including:

Programming Foundations in Python:

- Syntax, Data types, and Control Structures
- Graphical Representation and Visualization using Matplotlib
- Array and Matrix Computing with Numpy
- Symbolic Mathematics with SymPy
- Computer Algebra with Numpy and SymPy

Numerical Methods and Concepts:

- Error Analysis
- Sequences and Series and Their Representation Using Numerical Arrays
- Numerical Differentiation and Finite Difference Methods
- Difference Equations and Matrix Methods
- Interpolation and Splines
- Numerical Integration Techniques
- Root Findings

Upon successful completion, students will possess a strong foundation in Python programming and numerical methods, enabling them to apply computational techniques to solve diverse mathematical, scientific, and engineering problems.

Optional Concepts (Depending on Available Time):

- Various functionalities of the SciPy package for advanced numerical computing
- Object-oriented programming principles to Python
- Exposure to parallel computing using MPI4PY
- ParaView for data visualization
- Principal Component Analysis (PCA) for dimensionality reduction

Student Learning Outcomes:

- **Outcome 1 for Programming Foundations in Python:**

  - Develop a solid understanding of Python programming, including syntax, data types, and control structures.

  - Explore graphical representation and visualization techniques using Matplotlib.

  - Acquire practical skills in numerical computing with Numpy.

  - Apply symbolic mathematics through SymPy for problem-solving.

  - Gain proficiency in computer algebra using both Numpy and SymPy.

  Course Activity: Lectures & Lab Exercises

  Assessment Strategy: Homework; midterm exams, and final exam

- **Outcome 2 for Numerical Methods and Concepts:**

  - Conduct error analysis and estimate errors in numerical computations.

  - Investigate sequences and series, representing them using numerical arrays.

  - Implement numerical differentiation and finite difference methods for solving differential equations.

  - Solve difference equations and matrix problems, emphasizing applications in boundary value problems.

  - Understand interpolation and splines for approximating functions.

  - Apply numerical integration techniques, including adaptive methods and least square regression.

  - Explore root-finding methods and understand their rate of convergence.

  Course Activity: : Lectures & Lab Exercises
  Assessment Strategy: Homework; midterm exams, and final exam

Relation to Other Courses:

Students may further take advanced courses such as partial differential equations (PDEs, Math531), nonlinear dynamics (e.g., Math538, Math638), applied Fourier analysis (Math668), computational PDEs (e.g., Math693A,B).

Enrollment Information

MATH 151 and MATH 245 with a grade of C (2.0) or better in each course. Proof of completion of prerequisite(s) required: Copy of transcript. Not open to students with credit in Mathematics 242. Students with special requests may take this course subject to approval by the instructor of the course.

Course Materials (optional)

- Langtangen, H. P., 2016: *A Primer on Scientific Programming with Python.* Springer-Verlag Berlin Heidelberg. 914pp.
- Burden, R., D. Faires, and A. M. Burden, 2014: Numerical Analysis. Cengage Learning. ISBN 978-1-305-25366-7.
- Gerald P. O and C. F Wheatley, Applied Numerical Analysis. Pearson Education, 2004, ISBN 8131717402, 609 pp.

Course Structure and Conduct

Style of the Course: (1) Lectures/Discussions with, Jupyter notebook files, power point slides and pdf materials; (2) practices on personal computers.

Course Assessment and Grading Policy

Homework	23%	Weekly, due at 11:00 pm Friday
In-class Assessments	2 *10%	
Mid Term Exam	25%	
Final Exam	30%	

- Attendance and discussions 2%

- Class Attendance: Students are required to attend all class meetings and discussions. Class attendance will be taken randomly.
- Make-up exams: Missed Timed Homework or exams can only be made up in the case of a University approved absence.

Course Grade

You will be guaranteed the following grades as given by your percentage score on the homework, midterm, and final project presentation and report.

A 90%	B 80%	C 70%	D 60%
A- [89%, 90%)	B+ [85%, 89%)	C+ [75%, 79%)	D+ [65%, 69%)
	B [80%, 85%)	C [70%, 75%)	D [60%, 65%)
	B- [79%, 80%)	C- [69%, 70%)	D- [59%, 60%)

Important Dates

January 17 (Wed)	First day of Classes
February 16 (Fri)	ICA-1 (In-class Assessments 1*)
March 6 (Wed)	Midterm Exam
March 29 (Fri)	ICA-2 (In-class Assessments 2*)
April 1-5	Spring recess
May 2 (Thur)	Last day of classes before final examinations
May 6 (Mon), 8:00-10:00	Final Exam
May 16 (Th)	Grades due from instructors (11 p.m. deadline)

*Please refer to Lecture#1 slides for details regarding the In-class Assessments (ICA). If you have specific questions or need additional information about any of these dates, please check with the instructor.

Students with Disabilities

If you are a student with a disability and believe you will need accommodations for this class, it is your responsibility to contact Student Disability Services at (619) 594-6473. To avoid any delay in the receipt of your accommodations, you should contact Student Disability Services as soon as possible. Please note that accommodations are not retroactive, and that accommodations based upon disability cannot be provided until you have presented your instructor with an accommodation letter from Student Disability Services. Your cooperation is appreciated.

Academic Honesty

The University adheres to a strict policy regarding cheating and plagiarism. These activities will not be tolerated in this class. Become familiar with the policy (http://www.sa.sdsu.edu/srr/conduct1.html). Any cheating or plagiarism will result in failing this class and a disciplinary review by Student Affairs.

Examples of Plagiarism include but are not limited to:

- Using sources verbatim or paraphrasing without giving proper attribution (this can include phrases, sentences, paragraphs and/or pages of work)
- Copying and pasting work from an online or offline source directly and calling it your own
- Using information you find from an online or offline source without giving the author credit
- Replacing words or phrases from another source and inserting your own words or phrases
- Submitting a piece of work you did for one class to another class

If you have questions on what is plagiarism, please consult the policy (http://www.sa.sdsu.edu/srr/conduct1.html) and this helpful guide from the Library:(http://infodome.sdsu.edu/infolit/exploratorium/Standard_5/plagiarism.pdf)

At the end of the course, students will be ranked from first to last for each category (i.e. worst to be.st). The number of participation points allocated will then be based on each student's overall relative ranking score.

Interacting with me

I'll try to respond within 24-48 hours to emails sent me (sdsu.math340.shen@gmail.com). For quick questions, the turnaround time may be much shorter. (If Canvas is not working or for non-course-related communications, write to me using my work email address: bshen@sdsu.edu.)

Please feel free to call me in my office at (619) 594-5962. My message phone works most of the time, but email is to be preferred. My regular office hours are MW 3:00-4:00 pm Pacific Time.

Getting Help

Students are encouraged to make use of The Math and Science Learning Center (MSLC) for free STEM tutoring, located in the Love Library, Room 328. For a full list of courses tutored, please visit the MSLC website: https://mslc.sdsu.edu/.

The MSLC is supported by your student success fee. We strongly encourage you to use this wonderful, **free resource**. Here is how it works! Some students believe that they shouldn't need to ask for help, but research has shown that **the average grade for students who attend tutoring is higher** than those who don't seek such support.

TA Office Hours for select courses will also be held in the MSLC. Please check https://mslc.sdsu.edu/ for the hours for your course.

The Math & Stats Learning Center (MSLC) offers drop-in tutoring services at the following times:

On Campus in Love Library 328:

M-Th 10am-5pm

F 10am-2pm

Virtual for Chemistry only via https://mslc.sdsu.edu/:

*Please see https://mslc.sdsu.edu/ta-office-hours/ for specific TA Office Hours

Course Outline

Schedule	Topics	Remarks
Week 1-3	**Introduction to Python Programming** • Overview • IPython, Jupyter, and Google Colab • Demos for General Programming (Curses, Signal Handling, TCP/IP Client & Server, Game, etc.) • Python Shell • Basic syntax and data types • Control structures: Conditional Statements and Loops • Advanced Data Structures • Functions and Modules	
Week 3	**Graphical Representation and Visualization** • matplotlib package for general plots • seaborn package for statistics plots	
Week 3-4	**Numerical Python (Numpy) Package for Arrays and Vectors** • In-place arithmetic • Array indexing and array slicing • Vectorization for efficient computations	
Week 4-5	**Error Estimates**	

	• Triangle inequality • Taylor's remainder theorem • Integral inequality • Relative error • Truncation error • Floating-point numbers represented in machines • Round off error	
Week 5-6	**Sequences, Series, and Special Functions** • Fibonacci sequence • 3n+1 sequence • Prime numbers and the fundamental theorem of arithmetic • Bessel Function	
Week 7	**Numerical Differentiation and Finite Difference Methods** • Euler method and finite difference method • General divided differences • General solutions of finite difference equation • Discretization of $y' = \lambda y$ and Fibonacci sequence • Discretization of the Logistic differential equation for the Logistic map	
Week 8	**Symbolic Mathematics in Python (SymPy) for Computational Algebra** • Numeric Types • Symbolic Differentiation and Integration • Ordinary Differential Equations (ODEs) • Matrix Data Arrangement: Row-major and Column-major • Linear systems of algebraic equations • Eigenvalues and Eigenvectors • Ill-conditions and conditional number	
Week 9	**Difference Equations and Matrix Methods** • Boundary value problem (BVP) • Sparse matrices • Derivatives using Chebyshev polynomials	
Week 10-11	**Interpolation and Splines** • Interpolation techniques • Runge phenomena • Lagrange interpolation polynomials • Clustered meshes (non-uniform grids) • Linear splines • Cubic splines	
Week 11-12	**Numerical Integration** • Numerical quadrature • Trapezoid method • Simpson's method • Adaptive quadrature	
Week 13 (A)	**Root Finding** • Root finding methods (Newton's method, Secant method) • Rate of convergence	One of Options (A)-(C) will be selected for discussions
Week 13 (B)	**Principle Component Analysis (PCA)** • Basis vectors and basis functions (e.g., Bessel Functions) • Eigenvalues and eigenvectors • Dimensionality reduction	
Week 13 (C)	**SpiPy Package**	

	• Interpolation • Optimization • Integration • Fast Fourier Transform • Signal Processing	
Week 14	**Advanced Topics** • Object Oriented Programming with Python • Parallel Computing (e.g., MPI4PY, threading module, etc) • ParaView	Optional(*)
Week 15	**Final Review** • Review of key topics and problem-solving session.	

*Optional: these lectures will be presented subject to time availability.