E19 Numerical Methods for Engineering Applications

Fall 2023

CRN 17992

last modified November 29, 2023

Instructor	Emad Masroor emasroo1@swarthmore.edu	
Lectures	TR 8:30 — 9:45	222 Singer Hall
Labs	W 1:15 — 4:00	222 Singer Hall
Office hours	T 10:00 — 11:30 & by appt.	112 Singer Hall
Wizard sessions	M 7:00 PM — 9:000 PM	222 Singer Hall
Wizards	Hojune Kim hkim8@swarthmore.edu Jacob Sherman jsherma2@swarthmore.edu	
Graders	Paige Poteet ppoteet1@swarthmore.edu Jiuning (Tony) Ren jren1@swarthmore.edu	
Textbook	*Numerical Methods in Engineering with Python 3* by Jaan Kiusalaas	
Prerequisite	MATH 025	
Lab	You must be concurrently enrolled in E19 Lab (CRN 18553)	
Website	moodle.swarthmore.edu	
Final Exam	None — final project	

Course description This course aims to teach you how to transform a set of equations on a page into a working computer program using Python. As a student of engineering, science or mathematics, you can already appreciate the way that mathematical equations lie at the foundation of our understanding of the world. While some of these equations can be solved 'by hand', in engineering you are much more likely to encounter equations that would take too long to solve 'manually'. This course will introduce you to some well-known methods of solving equations using a computer, and take you 'under the hood' of the 'black box' methods often used in practice. The goal is to make you an informed and scientifically-aware user of numerical methods, and to develop an appreciation for the power of numerics as well as its limitations.

Course evaluation Your grade in this course will be made up of the following four components.

Homework	20%
Lab	25%
Tests	40%
Final project	15 %

The assignment of letter grades will be at the discretion of the Instructor, but will generally adhere to the following schematic: A- 90+, B- 80+, C- 70+, D- 60+, NC <60.

Textbook The assigned textbook for this course is *Numerical Methods in Engineering with Python 3* by Jaan Kiusalaas. The book is available for free as an online resource through the College Library, and can be accessed here. Physical copies are available in the bookstore.

Lectures Lectures will be held for 75 minutes on Tuesdays and Thursdays at 8:30 AM. During lecture, the instructor will introduce the numerical techniques you will learn that week, go over the mathematics behind them, and provide examples of their applications in engineering. Students are expected to take notes. There will also be interactive demonstrations using Python. During a demonstration, you may use the built-in computers in the classroom or your personal laptop computers to follow along.

Labs Labs will be held on Wednesdays at 1:15 PM for 2 hours and 45 minutes. Labs will be assigned once every two weeks and will 'run' for two weeks, except for 'Lab 0' which will only run for a single week. The weeks during which a lab will be assigned are mandatory, and the intervening weeks will be optional class time during which the Instructor will be available in the classroom and students are welcome to work on their lab from the previous week. Typically, the lab assigned on the Wednesday of week n will be due at midnight on Tuesday of week $n+2$. Attending lab during the intervening week, $n+1$, will be optional. The week-by-week schedule lists the required lab meetings.

Labs will be conducted in groups, typically consisting of two students. The Instructor reserves the right to form these groups at his discretion, and it is expected that the groups will persist during the course of the semester. It is expected that the members of a group will contribute equally to the assignment.

During mandatory lab meetings, the Instructor will introduce a set of programming tasks which will involve using the numerical methods you will learn over the course of the semester. There may also be a significant narrative component to each lab assignment. You are encouraged to bring your own laptop computers or use the built-in computers in the classroom to begin working on the lab during the scheduled class time, and the Instructor will walk around the room to help each group

Homework Homework will be assigned each week, and will typically be due by midnight on the Monday following the week in which it was assigned. You can generally expect HW n to cover the material from week n, and to be due in week $n+1$.

Tests There will be six tests over the course of the semester, in lieu of midterms. These tests will be held on Thursdays during the first half of class time (typically for 20 to 25 minutes), and will typically be closed-book, closed-notes and closed-computer. The tests will be *incremental* rather than cumulative, and will only test the material from a few weeks prior to each test. Typically, test n will cover the material from week $2n-1$ and week $2n$ and will be held on week $2n+1$; for example, test 1 will cover weeks 1 and 2 and will be held on the Thursday of week 3; test 2 will cover weeks 3 and 4 and will be held on the Thursday of week 5, etc. There is one exception to this rule, which is week 11, the week of Thanksgiving; this test will be held on Tuesday 11/21.

Final Project This class will culminate in an end-of-semester final project in lieu of a final exam. In this project, students will have the opportunity to apply the numerical methods learned in this class to an engineering or scientific problem of interest to them. Details about the final project will be released later in the semester.

Policy on deadlines Starting with week 2,

- In general, late assignments will not be graded, and any requests for an extension in the deadline must be requested by the student and agreed to by the instructor **before** the deadline.
- You may ask for (and automatically receive) a one-week extension on homework **and** lab assignments, no questions asked, once each during the semester. Please indicate in your email that you are using your 'one free extension' when you do so. Your 'free extension' applies once to homework assignments and once to lab assignments.
- In extenuating circumstances, the Instructor may agree to grant a case-by-case extension in the deadline for a particular homework or lab assignment upon request by a student. This request should be sent by email **at least 24 hours before the deadline**, and should indicate the reason for the extension and its duration. Grant of an extension is not guaranteed.

Collaboration Policy

- Homework should be completed individually.
- Lab assignments should be completed in assigned groups.
- You are allowed to *discuss* assignments with your classmates, but are not permitted to *copy* code or text from each other.
- If you substantially discuss your solution, or solution strategy, to a homework or lab assignment, with others, you are expected to disclose this at the beginning of the document in the form of a 'credit statement'. For example, you could write 'I discussed this assignment with J. Doe'.
- Suspicious similarities between students' work, without attribution of credit, will be investigated.

Policy on Artificial Intelligence and Computer Assistance With the widespread availability of Large Language Models (LLMs), such as OpenAI's ChatGPT, Google's Bard, or Microsoft's Bing AI, this semester you will have unprecedented access to a new, powerful piece of technology that has the potential to drastically change the way we obtain information. LLMs are more advanced forms of other information-assembly tools that have been around for a few decades, such as search engines and online fora.

Please note that:

- As a byproduct of taking this course, you will learn to use Python to carry out numerical calculations, write algorithms, and present your results in text or graphical form. However, this is not a Python class, and it is OK to ask a computer for help with Python syntax. For example, you could ask: "How do I write a function with two input arguments in Python?".
- You are not permitted to use Large Language Models to write any part of the code that you will turn in for the class, whether homework or lab assignments. Similarly, you may not re-use code that you find on an online resource or forum.
- You are encouraged to use AI tools creatively to aid in your understanding. For example, you might a LLM: "What is the difference between LU Decomposition and Singular Value Decomposition, and how are the two used?".
- Consulting an AI tool or online resource during a 'closed-book' test will be treated as academic misconduct.

Week	Date	Topic	
1: Introduction	T 9/5	Introduction	
	W 9/6*	Lab 0: Python 'clinic'	
	R 9/7	Types of errors. 'Ill-conditioned' problems	
2: Root Finding	T 9/12	Solving $f(x) = 0$ with a computer	M 9/11: HW 1 due
	W 9/13*	Lab 1	T 9/12: Lab 0 due
	R 9/14	Iterative root-finding techniques	
3: Linear Systems	T 9/19	Introducing $\mathbf{Ax} = \mathbf{b}$	M 9/18: HW 2 due
	W 9/20		No lab due
	R 9/21	Gaussian Elimination & LU Decomposition	R 9/21: Test 1
4: Linear Systems	T 9/26	Iterative methods	M 9/25: HW 3 due
	W 9/27*	Lab 2	T 9/26: Lab 1 due
	R 9/28	Iterative methods & banded matrices	
5: Curve Fitting Interpolation	T 10/3	Polynomial Interpolation	M 10/2: HW 4 due
	W 10/4		No lab due
	R 10/5	Curve fitting	R 10/5: Test 2
6: Optimization	T 10/10	Single-variable unconstrained optimization	T 10/10: HW 5 due
	W 10/11*	Lab 3	T 10/10: Lab 2 due
	R 10/12	Optimizing with constraints	
		Fall Break	
7: Optimization	T 10/24	Multivariable optimization	T 10/24: HW 6 due
	W 10/25		No lab due
	R 10/26	Optimizing with constraints	R 10/26: Test 3
8: Numerical diff. & integration	T 10/31	Finite Difference approximations	T 10/31: HW 7 due
	W 11/1*	Lab 4	T 10/31: Lab 3 due
	R 11/2	Integration or 'quadrature'	
9: Integrators	T 11/7	Euler & Runge-Kutta methods	T 11/7: HW 8 due
	W 11/8		No lab due
	R 11/9	Stability & Stiffness	R 11/9: Test 4
10: Diff. Eqs. in time	T 11/14	Initial Value Problems	T 11/14: HW 9 due
	W 11/15*	Lab 5; Final Project Announced	T 11/14: Lab 4 due
	R 11/16	Equations of motion	
11: Diff. Eqs. in space	T 11/21	Discrete spatial derivatives	T 11/21: HW 10 due
	W 11/22		No lab due
	R 11/23	No class — Thanksgiving Break	**T 11/21: Test 5**
12: Diff. Eqs. in space & time	T 11/28	1-D convection & diffusion	M 11/27: Proposal due
	W 11/29*	Lab 6; Project proposal 'presentation'	T 11/28: HW 11 due
	R 11/30	Burgers' Equation	W 11/29: Lab 5 due
13: Final Project	T 12/5	Time to work on project	T 12/5: HW 12 due
	W 12/6		No lab due
	R 12/7	Test & Guest Lecture	R 12/7: Test 6
14: Final Project	T 12/12	Final Presentations	M 12/11: Project due
	W 12/13*	Additional final presentations	

* indicates required lab meetings