MATH 257
Linear Algebra with Computational Applications

Lectures, Labs, Discussions. For detailed schedule of lectures, labs, and discussions see Course Explorer https://courses.illinois.edu/schedule/2022/fall/MATH/257

- Lectures: Mondays and Wednesdays in 3039 Campus Instructional Facility
- Labs: Fridays synchronous online via Zoom. (*Please update Zoom to the latest version before the first lab*) See also the course Moodle page
- Discussion Sections: Tuesdays and Thursdays at various campus locations
- TA office hours: Mon-Thur 5-7PM, location TBA
- Instructor office hours: M 4-5PM and W 11:45AM-12:45PM CAB 233

Teaching Staff.

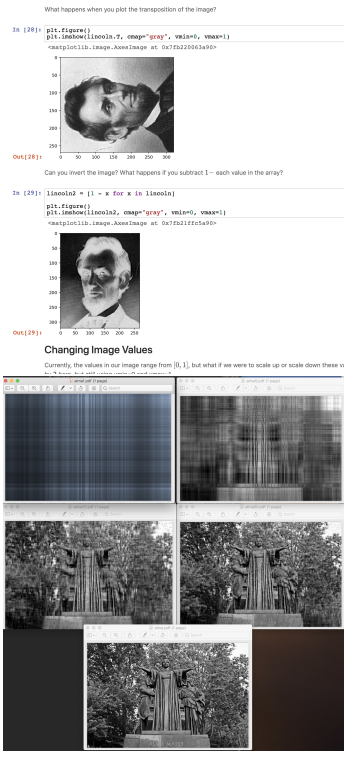
- Lecture instructor: Jer-Chin Chuang (jchuang@illinois.edu)
- Discussion and Lab TAs: see Course Information tab on Moodle

Introduction.

This is a first course in linear algebra. This covers basic definitions and algorithms of the subject needed in the higher level (engineering, science and economics) courses and more sophisticated mathematical techniques such as the Singular Value Decomposition.

In this course you learn the mathematical theory and how to implement it in Python. You will discover many of the striking modern applications of linear algebra, such as Google's PageRank algorithm, image and audio compression schemes such as JPEG and MP3, automatic face recognition and other data science and machine learning algorithms.

The course covers the same mathematical theory as MATH 415, but adds a focus on the computational and large data aspect of linear algebra through the lab sessions.



Technical equipment. Many aspects of this course will be conducted online. As such, each student will be assumed throughout the semester to have the necessary technical equipment to participate in course activities:

- a computer/laptop/tablet with a webcam and a microphone,

- a stable internet access, sufficient bandwidth and data allowance for using a webcam on Zoom.

Please contact the Student Assistance Center (helpdean@illinois.edu) immediately if you are missing any of required technology.

Other Linear Algebra courses. Be aware that course credit is not given for both MATH 257 and any of MATH 125, MATH 225, MATH 227, MATH 415, MATH 416 or ASRM 406. Any enrollment related questions should be sent to mathadvising@illinois.edu.

Three disclaimers.

- This is not a course that only teaches you how to compute stuff. Computer will always be faster. Modern applications of linear algebra require a sophisticated understanding of theory and methods of linear algebra, and learning these is the purpose of this course. Some of it might look like *abstract* linear algebra. However, through the applications we cover in the labs, you realize that this indeed is *applied* linear algebra.
- If you already know some linear algebra, this course might look easy at the beginning. Don't be fooled into thinking it will stay like that. Even the material familiar to you will be covered in more depth here. Furthermore, the exams will require a deeper understanding of the concepts you already know something about. So *it is a good idea to take this course seriously from the beginning*.
- This is only the second official large-scale offering for MATH 257. A significant part of the material for this new course is - not surprisingly - new. So if you find a typo or an error in any part of this course, please let us know by sending an email to the instructors. We appreciate your help, and are also happy to hear any further comments or suggestions. Thank you!

Learn@Illinois. This course has a page on Learn@Illinois:

https://learn.illinois.edu/course/view.php?id=69673

All material will be available there or linked from there. Please note that if you have just registered for the course, you will automatically be given access to the Learn@Illinois website within a few hours. *Only if you do not have access to the course site 48 hours after registering, then contact your instructor.*

COVID. University COVID-19 policies are in effect for the semester. Please review the relevant policies at

https://covid19.illinois.edu/guides/students/

and **be sure to be in compliance with university policies**.

Setup. This course consists of two hours per week of lecture, one hour per week of computing lab, and one hour per of week of active learning (paper-based) discussion sections.

Discussion section. Discussion sections are held on Tuesdays and Thursdays with the detailed schedule available at Course Explorer:

https://courses.illinois.edu/schedule/2022/fall/MATH/257

Only attend the discussion section you are signed up for. No credit is given otherwise.

During the discussion sections, TAs will distribute worksheets to be completed collaboratively in small groups. At the end of the period, each group will submit one worksheet. Complete solutions to the worksheet will be posted afterwards on Learn@Illinois.

Attendance will be taken. You will be given a password at the beginning of each discussion section and you will have *15 minutes* to mark yourself present on Learn@Illinois. Note that it is not enough to just be present. You have to be actively working with your group, and the worksheet submitted by your group must show that your group put in the necessary effort. If this is not the case, we will not consider you present and you will not receive points for participation. All students in a group receive the same amount of participation credit on the worksheet. The maximum score for each week is two points (one for attendance and one for participation).

Computational Lab. Labs are held synchronously online on Zoom on Fridays. The times are available on Course Explorer, but please see the Labs document under the Course Information tab on Moodle for details including Zoom Meeting IDs and passwords. *Please only attend the lab sections you are signed up for. No credit is given otherwise.*

In the labs you will use computational tools in Python to solve linear algebra problems in real world applications in science and engineering. You will be working in small groups on a Python worksheet together. Though the first lab session is a Python tutorial, **students are assumed to have prior experience in Python or be able to familiarize themselves quickly to Python.** Students without the requisite programming background have struggled to complete the course.

Attendance will be taken. You will be given a password at the beginning of each lab and you will have *5 minutes* to mark yourself present on Learn@Illinois. Note that it is not enough to just be present. You have to be actively working with your group on the project. If this is not the case, we will not consider you present.

Textbook. We will post extensive lecture notes for all lectures and practice problems online. For many students these notes are enough. If you still want to buy/download a book, here are some options (several of them free!) in no particular order.:

- Philip N. Klein, *Coding the Matrix: Linear Algebra through Applications to Computer Science*, first edition, Newtonian Press
- Feryal Alayont, Steven Schlicker, *Linear Algebra and Applications:An Inquiry-Based Approach*, scholarworks.gvsu.edu/books/21/
- David Cherney, Tom Denton,Rohit Thomas, Andrew Waldron, *Linear Algebra*, www.math.ucdavis.edu/∼linear/

- Stephen Boyd and Lieven Vandenberghe, *Introduction to Applied Linear Algebra - Vectors, Matrices, and Least Squares*, https://web.stanford.edu/ boyd/vmls/
- Gilbert Strang, *Linear Algebra and its Applications*, fourth edition, Cengage.

You are not required to buy any of these textbooks. Please note the coverage and order of topics for these resources may differ from our course.

Lectures and Slides. Lectures are twice weekly on Mondays and Wednesdays. *You are expected to read the lecture notes and/or watch the lecture videos before attending the in-person lectures.* The in-person lecture times will focus on reviewing the concepts introduced in the lecture notes and providing further examples.

Lecture notes are on Learn@Illinois. An interactive version with fill-in boxes is also available.

Videos. We will post module videos on the Learn@Illinois page of this course. An interactive version of the slides with fill-in boxes is also available. If you would like to use this feature, print out the fill-in slides and fill them out on your own or while watching the videos. Video errata may be found at the video link on the Moodle page under the appropriate week's tab.

There are many other great (free) videos about linear algebra. Here are some we recommend as an addition (not a substitute) for the lecture videos.

- *Essence of Linear Algebra* by 3Blue1Brown, on Youtube, highly recommended
- MIT lectures by Gilbert Strang, MIT Open Courseware
- *Coding the Matrix* videos by Philip Klein, on Youtube

Online homework. Each module comes with two sets of homework. All are open-notes and you may collaborate with other students:

The Moodle module quizzes each consists of two to three conceptual questions. You only have one attempt for each quiz. *Be sure to spend some time thinking over the material in the module before attempting the quiz. Since these are conceptual questions, precision is important so read the lecture notes and the questions carefully.*

The PrairieLearn homework comes in two forms: lab and non-lab. The non-lab homework associated with each module provides opportunity to practice the computations and algorithms covered in the module. In this homework you will have to do the computation we did in the video by yourself. The lab homework is based on the most recent Friday Python lab activity. See below for more information on PrairieLearn. This course is listed in PrairieLearn as follows:

MATH 257: Linear Algebra with Computational Applications, MATH 257 - Fall 2022

Either of the above two types of assessments in the first two weeks of the semester will not count towards the final grade due to changing enrollments during that period.

Workspace/help sessions. We reserved the room 1060 Lincoln Hall (1LH) Mondays to Thursdays 5-7pm. See the Office Hours tab on Moodle for details. At least one TA will be present during this time to answer your (non-Python related) questions.

You don't have to come to the room only if you already have a question. You can just go there and work—either alone or with your fellow students. We will highly recommend that you form study groups and make use of this room! The room will be open during the first week, but the TAs will start being there in Week 2.

For Python-related questions, undergraduate course assistants (CAs) will hold online office hours via Zoom throughout the week starting Week 2. See the Moodle course page for details.

Weekly assignment schedule. Regular weekly assignments due dates are as follows:

- ⌛ Moodle Quizzes (covering modules from current week), due Thursdays 11:59PM (except on weeks with midterms, due following Monday 11:59PM instead)
- ⌛ PrairieLearn (non-lab) Homework (covering modules from previous week), due Tuesdays 11:59PM at 100% (see below)
- ⌛ PrairieLearn lab Homework (covering lab from previous week), due Thursdays 11:59PM.

For example, the Moodle quizzes for Week 1 are due on Thursday 08/25 (Thursday of Week 1). PrairieLearn Week 1 non-lab homework is due (at 100%) on Tuesday 08/30 (Tuesday of Week 2).

Netiquette. Since this course has a substantial online component, please be respectful of your fellow classmates and teaching staff in all online communications. Fostering a helpful learning environment requires everyone's cooperation. Remember that forum posts are visible to all students and staff in the course (over 700 people). So please double-check your posts before submitting them.

PrairieLearn. We will use PrairieLearn for homework. See the Quick links at the top of the course Moodle page.

(Non-lab) Homework (at 100%) will be due on Tuesdays at 11:59PM. The first homework is due on Tuesday 08/30 of Week 2. The PraireLearn homework will lean towards computations, while the Moodle quizzes and the worksheets in the discussion section will focus more on conceptual problems.

How points are given on PrairieLearn. PrairieLearn places emphasis on mastery. The idea is to keep doing questions until you master the underlying concept or method. Once you do, you should be able to answer these questions very quickly.

The way this works in PrairieLearn is that each question has a value, a point total, and a point maximum. If you answer a question correctly, two things happen:

- ▶ The point total increases by the value, until you reach the point maximum.
- ▶ The value increases.

If you answer a question incorrectly, one thing happens:

- ▶ The value goes back to what it was originally.

This system rewards repeated correct answers, which tend to demonstrate mastery. There is no penalty (other than resetting the value) for answering a question incorrectly, so don't be afraid to submit an answer. Similarly, don't be afraid to keep doing

a question after you reach the point maximum - your point total with never go down!

Credit. There is no need to "submit" your homework. The system will record whatever your score is at that time. However, you'll note the following line at the top of your screen:

Available credit: 110% until 11:59PM, Fri, 08/26

What this means is that if you reach 100% prior to 11:59PM on that Friday - i.e., complete the homework early - you will receive an extra 10% bonus. You will see this reflected in your score (the instant you reach 100%, it will jump to 110%).

If you click on the "?" just to the right of the line about available credit, you'll see all the dates associated with this homework. In particular, it says:

- you can receive 100% until 11:59PM, Tuesday, 08/30,
- you can receive 80% until 11:59PM, Tuesday, 09/06.

Note that your score will never go down. For example, if you achieve 90% by 11:59PM on Tuesday, 08/30, you won't be able to increase your score after that time, but you won't be penalized for not reaching 100% - your score will remain 90% forever. On the other hand, if you achieve only 70% by 11:59PM on Tuesday, 08/30, you will be able to increase your score after that time (to a maximum of 80%).

Please note that your overall PrairieLearn score is capped at 100%. So even if you score 110% on every assignment, you will only receive 100% overall. The bonus is designed to help off-set homeworks where you may not have received full credit.

Lab Homework (at 110%) will be due on Thursdays at 11:59PM. The first lab homework is due on Thursday 09/01 of Week 2. Unlike the non-lab homework, the lab homework will only be offered at 110% and 80%.

Any changes to regular homework deadlines for either type will be announced on CampusWire.

Typos/Errors. If you believe there is a typo or an error in a question, or if you believe your answer was graded incorrectly, please take a screenshot and post to CampusWire. We have access to all of your submissions and can check to see what, if anything, went wrong.

CampusWire. All announcements will be posted on CampusWire at

https://campuswire.com/p/G3D3A7589

Please make sure you are signed up for CampusWire. The registration PIN is available under the Quick links at the top of the Moodle course page. When posting on CampusWire, please use the subject line wisely and post in the appropriate category. For example, if you ask something about matrix multiplication in Lecture notes 5, write "Lecture notes 5 - Matrix multiplication" and not just "Question about matrices". In addition, please post to the entire class whenever this is appropriate. No question will ever be held against you.

Because of the large number of students (700+) and the limited number of teaching staff, please help us facilitate response times by observing the following:

- Please post all content questions and those of general interest regarding course material or organization to CampusWire rather than via email. Multiple course staff monitor CampusWire, and this allows all students to benefit from both the question and our reply.
- For questions about the scoring of your assignment (quizzes, labs, exams, etc.) please post on CampusWire using the option "Post to instructors and TAs" when posting.
- For *private questions* regarding special cases of course policy (e.g. DRES, absence from an exam, etc.) please use email and copy the relevant teaching staff (e.g. TA, lab TA, or course instructor). *Please clearly indicating your lecture/discussion/lab sections in the email subject.* We aim to have response times for emails generally in one or two business days.

Syllabus Quiz. Because of the online format for this course, familiarity with course policies will be essential. All students will be required to complete by **11:59PM Friday of Week 3 (September 9)** a syllabus quiz on Learn@Illinois. This quiz covers basic course policies. It is open-notes and unlimited attempts are allowed.

Exams. There will be three midterm exams, each about 50 minutes long, and a three hour final exam. Students register with CBTF for an exam slot during the below specified **tentative** windows. Details regarding administration of the final exam will be announced later in the semester.

- **Midterm 1: Week 4, 09/13-09/15**
- **Midterm 2: Week 8, 10/11-10/13**
- **Midterm 3: Week 11, 11/01-11/03**
- **Final: TBA.**

Students are responsible to ensure they are properly registered with CBTF and sit for their exam at their registered time. There will be no make-up exams. Instead, if you miss an exam and have a valid excuse, we will mark the exam as 'excused'. (see "Grading" below for details) **Valid excuses must be documented** and must be reported to your instructor immediately (no later than the same day as your CBTF midterm registration). *There are no Friday Python labs on the weeks with midterms.*

CBTF. This course uses the College of Engineering Computer-Based Testing Facility service CBTF Online for its exams:

https://cbtf.engr.illinois.edu

The policies of the CBTF are the policies of this course, and academic integrity infractions related to the CBTF are infractions in this course.

If you have accommodations identified by the Division of Rehabilitation-Education Services (DRES) for exams, please upload your Letter of Accommodations (LOA) to the CBTF site: https://cbtf.illinois.edu/students/dres before you make your first exam reservation (at least five business days prior).

If you have any issue during an exam, please inform the proctor or relevant CBTF staff immediately. Work with the proctor to resolve the issue at the time before logging off. *If you do not inform a proctor of a problem during the test, then you forfeit all rights to redress.*

Review all instructions on the CBTF website before your first exam:

https://cbtf.engr.illinois.edu/cbtf-online/index.html

Cheating. No books, notes, cheat sheets or electronic devices are allowed during the exams except a non-graphing scientific calculator. We take cheating very seriously! A more detailed description of the University policy on cheating and plagiarism may be found in the following link:

http://www.las.illinois.edu/students/integrity/

Grading. The course grade will be a weighted average of the following assessments:

- 2% syllabus quiz
- 5% discussion section attendance/completion (the two lowest weekly combined scores will be dropped)
- 5% lab attendance & completion (the two lowest scores of each will be dropped and the two categories weighted 33%+67% respectively)
- 8% PrairieLearn (non-lab) homework (the two lowest scores will be dropped)
- 5% PrairieLearn lab homework (the two lowest scores will dropped)
- 2% Moodle module quizzes (the six lowest scores will be dropped)
- 17% each Midterm exam (total 51%)
- 22% final exam

In addition: If your final exam score is higher than one of your midterm scores, then we will replace your lowest midterm score by your final exam score.

If you miss one midterm (**and have a valid excuse**), we will use the average of the two other midterms and the final exam as the score for the midterm you missed. We then apply the above calculation (including the potential replacement of your lowest midterm score).

If you miss more than one midterm and have a valid excuse for each absence, please contact your instructor.

Letter grades will be assigned according to (this is for the percentage, not for the absolute score!):

- 100.00 % - 98.00 % $\rightarrow$ A+
- 97.99 % - 93.00 % $\rightarrow$ A
- 92.99% - 90.00% $\rightarrow$ A-
- 89.99 % -87.00 % $\rightarrow$ B+
- 86.99 % - 83.00 % $\rightarrow$ B
- 82.99 % - 80.00 % $\rightarrow$ B-
- 79.99 % - 77.00 % $\rightarrow$ C+
- 76.99 % - 73.00 % $\rightarrow$ C

- 72.99 % - 70.00 % → C-
- 69.99 % - 67.00 % → D+
- 66.99 % - 55.00 % → D
- 54.99 % -0.00 % → F

Usually around 30% of the students in comparable courses get an A letter grade (including +/-) and around 70% score a B letter grade or higher. The median score is usually between 83% and 84%. We anticipate this course to have similar statistics.

We will renormalize each of the midterms and final exam such that the distribution of letter grades coincides with this historic distribution of the letter grades. No further curve will be applied at the end of the course.

In particular, there will be **no individual extra credit opportunities** after class instruction ends and closed assessments do not reopen. So make sure to work hard for every assessment!

Please check each week that your scores were entered correctly on Learn@Illinois. With so many students it can happen that your grade is entered incorrectly. If, after an assessment, you find an error in the grading, please contact course staff *immediately* via CampusWire or before or after class/discussion section or during our office hours. It can always happen that we made a mistake, so we always encourage you to see us if you think that happened. *Except for exams, rescoring requests will only be considered within a week of the assessment due date. For exams, rescoring requests will only be considered within a week of the posting of exam scores.* So don't wait!

With more than 700 students there are always many cases where students are close (sometimes even very close) to the next letter grade, and at the end of the semester make the case that they should receive higher grades. Unfortunately, in almost all cases we can not grant the request without being unfair to other students—even if we would like to!

Course Calendar

Date	Week	Lecture	Lab	Topic
08/22	1	1		Introduction to linear systems, Matrices
08/24	1	2		Echelon form of matrices, Gaussian Elimination
08/26	1		1	Python tutorial
08/29	2	3		Linear combinations, Matrix vector multiplication
08/31	2	4		Matrix multiplication, Properties of matrix multiplication
09/02	2		2	Working with vectors
09/05	3			No class (Labor Day)
09/07	3	5		Elementary matrices, Matrix inverses and computation
09/09	3		3	Matrix operations
09/12	4	6		LU decomposition, Solving linear systems using LU
09/14	4	7		Mass-spring system, Inner products
09/13-09/15	4			Midterm 1
09/19	5	8		Subspaces of $\mathbb{R}^n$, Column spaces and nullspaces
09/21	5	9		Abstract vector spaces, Linear independence
09/23	5		4	Solving systems of linear equations
09/26	6	10		Basis and dimension, The four fundamental subspaces
09/28	6	11		Orthogonal complements, Graphs
09/30	6		5	Graphs and Algebraic Graph Theory
10/03	7	12		Coordinates, Orthonormal bases
10/05	7	13		Linear transformations, Coordinate matrix
10/07	7		6	Data compression
10/10	8	14		Determinants, Cofactor expansion
10/12	8	15		Eigenvectors and Eigenvalues and their computation
10/11-10/13	8			Midterm 2
10/17	9	16		Properties of eigenvectors, Markov matrices
10/19	9	17		Diagonalization
10/21	9		7	Markov Chains
10/24	10	18		Powers of matrices, Matrix Exponential
10/26	10	19		Linear Differential Equations
10/28	10		8	Dynamical Systems
10/31	11	20		Orthogonal projection onto lines and subspaces
11/02	11	21		Least squares solutions, Linear Regression
11/01-11/03	11			Midterm 3
11/07	12	22		Gram-Schmidt process and QR decomposition
11/08	12			No class (Election Day)
11/09	12	23		Spectral Theorem
11/10	12		9	Linear Regression
11/14	13	24		SVD
11/16	13	25		Low rank approximations, Pseudo-Inverse
11/18	13		10	SVD and applications
11/21-11/25				No class (Fall break)
11/28	14	26		Principal Component Analysis
11/30	14	27		Review complex numbers, Complex linear algebra
12/02	14		11	Principal Component Analysis
12/05-12/07	15	28-29		Leeway and Review