Description of Course

This course covers more advanced topics in linear algebra beyond traditional undergraduate courses, focusing on topics useful for data science applications, e.g., common matrix factorizations and low-rank approximation. Time permitting, additional topics may be covered at the discretion of the instructor, for example kernel methods, graph theory, optimization, compressed sensing, clustering, and frames. The theory will be complemented with illustrative applications. Note the catalog does not completely specify the contents of any course. For specific content I plan to cover this term, see tentative schedule below.

Course Prerequisites or Co-requisites

MATH 313 Linear Algebra. Previous exposure to multivariate calculus (at the level of MATH 223) and basic statistical concepts (at the level of DATA 363) helpful but not required.

Instructor and Contact Information

Kevin K. Lin
Email: lin1@arizona.edu
Phone: 520-626-6626
Office: Math 606

Office Hours. Office hours will be hybrid. For times, see instructor home page. I am also available to meet individually, online or in person, by appointment. Zoom link(s) for office hours will be shared separately.

Course Webpage: https://www.math.arizona.edu/~klin/412

Course Brightspace site: https://d2l.arizona.edu/d2l/home/1653261

I will announce Gradescope workflow on Brightspace.

Most course information, e.g., the course calendar, syllabus, and any course notes, will be available on both the public web page and our Brightspace site.

Course Format and Teaching Methods

This class is scheduled to be taught in the in-person modality. Selected lectures may be recorded and/or streamed at the discretion of the instructor.

Course Objectives

During this course students will:

- Work effectively with a variety of matrix representations and decompositions.

- Understand a variety of matrix types and their connections to statistical ideas.

- Effectively use numerical linear algebra techniques to solve questions in statistics, especially setting with moderate to high dimensional data.
- Be prepared for the use of linear algebra in statistical machine learning.

Expected Learning Outcomes
Students will

- Understand the basic concepts for the types of matrices commonly used in statistical analysis
- Effectively select a suitable approach to represent matrices to solve statistical questions.
- Create scripts and use numerical linear algebra libraries to solve statistical questions.
- Use statistical software to perform formal estimation inferential procedures – hypothesis testing and confidence intervals – for a wide array of models.
- Describe appropriate procedures and communicate the results of analysis to non-experts.

Makeup Policy for Students Who Register Late
Students who register after the first class meeting are expected to make up some or all of the missed work. Specific assignments and deadlines are to be arranged with the instructor on a case by case basis.

Course Communications
Course-wide announcements will be made in class and distributed electronically by email and Brightspace. It is the student's responsibility to keep informed of any announcements, syllabus adjustments or policy changes. The best way to reach me is by email. I will do my best to respond within 1 business day.

Class Meetings
The class will meet in person at the time and place stated above.

- If you feel sick, or if you need to isolate or quarantine, stay home. Seek medical care as needed.
- Notify your instructor(s) if you will be missing a course meeting or an assignment deadline.
- Non-attendance for any reason does **not** guarantee an automatic extension of due date or rescheduling of examinations/assessments.
    - Please communicate and coordinate any request directly with your instructor.
    - If you must miss the equivalent of more than one week of class, please contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing.

Staying current: It is expected that you will keep up with the course material by

- attending lectures
- reading the textbook according to the course calendar
- completing all assignments.

Additionally, I may post short notes covering additional examples and background material. These will be announced in class, by email, and on Brightspace. You are responsible for learning this material on your own time by the assigned date.

Class Recordings: At the discretion of the instructor, some lectures *may* be recorded. These recordings will be shared with students in the class upon request. If you do not wish your name to be used in class, please inform the instructor ASAP.

For lecture recordings, which are used at the discretion of the instructor, students must access content in Brightspace only. Students may not modify content or re-use content for any purpose other than personal educational reasons. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner inconsistent with UArizona values and educational policies (Code of Academic Integrity and the Student Code of Conduct) are also subject to civil action.

Absence and Class Participation Policy

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. If you anticipate being absent, are unexpectedly absent, or are unable to participate in class activities, please contact me as soon as possible. Students who miss the first two class meetings, and do not contact me within 24 hours of the second class meeting, may be administratively dropped. To request a disability-related accommodation to this attendance policy, please contact the Disability Resource Center at (520) 621-3268 or drc-info@email.arizona.edu. If you are experiencing unexpected barriers to your success in your courses, the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office is located in the Robert L. Nugent Building, room 100, or call 520-621-7057.

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: https://catalog.arizona.edu/policy/class-attendance-and-participation

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable; see http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See https://deanofstudents.arizona.edu/absences

It is the student's responsibility to notify the instructor in advance of an absence related to religious observation or an activity for which a Dean's excuse has been granted, and to arrange for how any missed work will be handled. It is also the student's responsibility to keep informed of any announcements, syllabus adjustments or policy changes made during scheduled classes.

Required Texts or Readings

Our textbook this term is Linear Algebra, Data Science, and Machine Learning by Jeff Calder and Peter J. Olver. It is a new text, and is available for now only electronically (free for UA students via the link above). The text Applied Linear Algebra by Peter J. Olver and Cheri Shakiban is a useful reference for reviewing material covered in earlier courses. I may supplement these with other references and/or notes as needed.

Required Materials

Equipment and software requirements: For this class you will need daily access to a device with reliable internet signal that can:

- Access Brightspace

- Join Zoom meetings (for, e.g., office hours)

- Watch videos posted on Brightspace (if any)

- Access Gradescope

- Scan and upload written work: If you hand-write your assignments, it is strongly recommended that you use a free scanning app such as Adobe Scan to scan documents. You may, if you wish, either typeset your homework or use a tablet. Raw images that are illegible are not accepted.

- View PDF documents

- A software environment that supports numerical linear algebra operations, e.g., MATLAB, R / RStudio, Python, Julia, etc. I will say more about this in class.

   You are strongly encouraged to use Python for this course. There are many different Python distributions; I use Anaconda, which packages Python together with additional libraries you need for linear algebra and data science.

Note: Enrolled students can borrow technology from the UA Library on a first come, first served basis. See https://new.library.arizona.edu/tech/borrow for details.

Assignments and Examinations: Schedule/Due Dates

Weekly homework assignments are to be turned in online, via Gradescope or Brightspace. In addition, there will be regular in-class quizzes based on the homework material.

Collaboration policy. I encourage you to work together on homework assignments. However, each student must turn in their own written solution, which may not be simply copied from another person's work (or from any other outside source). If you work with someone else on a problem or assignment, give them credit in your write-up.

Computing. Some homework assignments will involve computing, and I will do frequent demonstrations in class. As mentioned above, (see "**Equipment and software requirements**" above), you are strongly encouraged to use Python in this course. I will do my best to use Python in class demos. I can provide some limited technical support (generally not with software installation but can help with issues directly related to assignments).

Generative AI policy: Generative artificial intelligence (AI) tools, including (but not limited to) large language models (LLM) like ChatGPT, Dall-e, Bard, Bing, etc, may be used for homework assignments ***with appropriate acknowledgment and citation***. Be aware that many AI companies may collect any information you enter; do not enter confidential information as part of a prompt. ***In particular, I ask that you do not upload problem sets in their entirety into an LLM or any other online tool / service.***

LLMs may make up or hallucinate information. These tools may reflect misconceptions and biases of the data on which they were trained and the human-written prompts used to steer them. You are ultimately responsible for checking facts, finding reliable sources for, and making a careful, critical examination of any work that you submit. *If you make use of an LLM, I encourage you to rewrite the solution in your own words, and keep in mind you are not allowed electronic tools on quizzes or exams.*

If you are in doubt as to whether you are using generative AI tools appropriately in this course, I encourage you to discuss your situation with me.

Please use the following guidelines for acknowledging/citing generative AI.

Copying. Sharing and/or copying solutions from an electronic solutions manual or similar source is prohibited, and will be considered a violation of the University of Arizona Code of Academic Integrity; note that this includes consulting and/or posting a homework question to an online forum.

Clarity matters. Homework should be typed or written in legible, use complete sentences, and show calculations and reasoning in a clear, logical order. If you choose to scan your assignment, please use a scanning app instead of turning in raw pictures. There are several free apps you can use, e.g., Adobe Scan. If I'm unable to read your solution due to poor image quality, it will be considered incorrect.

Late homework. Homework is due at the announced day and time. Unless you have prior permission to turn in an assignment late, I will accept late homework for partial credit (20% will be deducted per day the assignment is late).

Midterm exams. There will be two in-class mid-term exams. The exams are closed book, closed notes. No electronic devices are allowed.

Your **letter grade** in the course will be based on the following:

- Homework + quizzes: 22%
- Midterms: 42% total (21% each)
- Final: 36%

If it improves your grade, I will replace the lower (in percentage) of your midterms by your final exam percentage.

Tentative midterm dates are **Friday 10/10** and **Friday 11/21**.

Final Examination or Project
The final examination will be comprehensive. It is closed book, closed notes, and no electronic devices are allowed. It will take place at the scheduled time and place (see above). The University's Exam regulations will be strictly followed. ***The final exam for this course will be on Wednesday 12/17 at 10:30am-12:30pm.***

Grading Scale and Policies
Your final course grade will be determined by a percentage of total possible points in the course. Grades will be *no lower than the following:*

A: 100-90%   B: 89-80%   C: 79-70%   D: 69-60%   E: 59-0%

At the instructor's discretion, letter grade cutoffs may be lowered. No extra credit or bonus points are offered in this course.

Incomplete (I) or Withdrawal (W):
Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, available https://catalog.arizona.edu/policy/courses-credit/grading/grading-system.

You may drop the class without a W through **September 7, 2025** using UAccess; the class will appear on your UAccess record, but will not appear on your transcript. You may withdraw with a W through **November 2, 2025** using UAccess.

Dispute of Grade Policy
In general, any questions regarding the grading of any assignment, quiz, or exam need to be cleared up within one week after the graded item has been returned.

Honors Credit
Students wishing to contract this course for Honors Credit should email me to set up an appointment to discuss the terms of the contract. Information on Honors Contracts can be found at https://www.honors.arizona.edu/honors-contracts.

Scheduled Topics/Activities
This schedule is tentative and subject to change. For up-to-date schedule, see the course calendar on the web page or Brightspace.

Week #	Topic
1	Orthogonality, orthogonal subspaces, and projections
2-3	Structure and basic properties of matrices; QR factorization
4-5	Eigenvalues and singular values
6-7	Intro to ML; Principal Components Analysis (PCA)
8-9	Linear regression and regularization
10-11	Brief introduction to optimization
12-14	Fourier transform and applications
15	Review

Subject to Change Statement
Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

Classroom Behavior Policy
To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

Safety on Campus and in the Classroom
For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): https://cirt.arizona.edu/case-emergency/overview

Also watch the video available at
https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy000000000003560

Should you need it, here are resources available to all students:

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Campus Health
http://www.health.arizona.edu/
Campus Health provides quality medical and mental health care services through virtual and in-person care.
Phone: 520-621-9202

Counseling and Psych Services (CAPS)
https://health.arizona.edu/counseling-psych-services
CAPS provides mental health care, including short-term counseling services.
Phone: 520-621-3334

The Dean of Students Office's Student Assistance Program
https://deanofstudents.arizona.edu/support/student-assistance
Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services.
Email: DOS-deanofstudents@arizona.edu
Phone: 520-621-7057

Survivor Advocacy Program
https://survivoradvocacy.arizona.edu/
The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support.
Email: survivoradvocacy@arizona.edu
Phone: 520-621-5767

Confidentiality of Student Records
See http://www.registrar.arizona.edu/ferpa for information on UA's policy on confidentiality.

University-wide Policies link
Links to the following UA policies are provided at http://catalog.arizona.edu/syllabus-policies

- Absence and Class Participation Policies
- Threatening Behavior Policy
- Accessibility and Accommodations Policy
- Code of Academic Integrity
- Nondiscrimination and Anti-Harassment Policy
- Subject to Change Statement