California Institute of Technology
Department of Computing + Mathematical Sciences

ACM/IDS 104 Applied Linear Algebra
Fall 2023

Lectures: Tue & Thu at 10:30am-11:50am in Kerckhoff 119
Instructor: Konstantin (Kostia) Zuev
Office: Annenberg 114
Email: kostia@caltech.edu (please include “104” in the subject line)
Office Hour: Thu 2pm-3pm, or by appointment (please, send an email to schedule)
Head TA: Miguel Liu-Schiaffini (mliuschi@caltech.edu)
TAs and OHs: https://piazza.com/caltech/fall2023/acm104/staff
You are welcome to attend as many office hours as you like.

Course Description
Linear algebra is a branch of mathematics that lies at the heart of applied science and engineering. This is an intermediate linear algebra course aimed at a diverse group of students, including junior and senior majors in applied and computational mathematics, and graduate students in sciences and engineering. The main goal of the course is to give an introduction to the fundamental ideas, concepts and methods of applied linear algebra and illustrate them with important applications.

Prerequisites
• Ma 1 abc or instructor’s permission.
• Some familiarity with MATLAB, e.g. ACM 11, is desired.

Textbooks
• Comprehensive Lecture Notes (will be posted on Piazza after each lecture)
• P.J. Olver & C. Shakiban, Applied Linear Algebra (covers ~ 2/3 of the course)

Course Plan
The following is a detailed tentative outline of the topics to be covered this term.
• Linear systems, Gaussian elimination, PLU factorization
• Vector spaces, spans, bases, independence, dimension, fundamental matrix subspaces
• Inner products, norms, Cauchy-Schwarz and triangle inequalities
• Application: the k-means algorithm for clustering
• Positive definite matrices, Gram matrices, application to text classification
• Minimization of general quadratic functions, least square solutions
• Application: least squares for data fitting, interpolation, and approximation
• Orthogonality, the Gram-Schmidt process, the QR factorization, projections
• Eigenvalues, eigenvectors, eigenbases, the Gerschgorin theorem
• Application: the PageRank algorithm for ranking websites
• Diagonalization, symmetric matrices, spectral theorem, optimization principle for eigenvalues
• Application: principal component analysis
• Application: the spectral method for graph partitioning
• Singular values and vectors, singular value decomposition, condition number, pseudoinverse
• Applications of SVD to image compression, best rank-k approximation, political science (analysis of senators’ voting records), and facial recognition (eigenfaces)
Grading
Your final grade will be based on your total score. Your total score is a weighted average of Problem Sets (60%), Midterm exam (20%), and Final exam (20%). You can increase your total score by up to 5% if you participate actively in Piazza discussions in the Q&A section. Every answer submitted before TAs or instructor answer, which is later endorsed as “good answer” by TAs or instructor, gets 1% of the total score. There are no fixed thresholds for grades, but if your total score is 90% (80%, 70%, 60%), then you are guaranteed at least “A” (“B”, “C”, “D”).

Problem Sets
There will be six Problem Sets. Problems (and solutions) will be posted on Piazza. For assignment and due dates see “Important Dates” below. Late submissions will not be accepted, but the Problem Set with the lowest score will be dropped and not counted toward your total score. Submitting wrong files or files in a wrong format is considered as a late submission. Extensions may be granted for academic, personal, or medical reasons. For extensions, please email the Head TA.

Exams
There will be two exams: Midterm (based on Lectures 1-8) and Final (based on Lectures 9-17). The Head TA will provide a review session before each exam. Both exams are take-home, self-timed, and closed-book, but you can use one sheet (double-sided) of your own notes. You can use your electronic devices only for typing and for basic arithmetic operations.

Collaboration Policy
A detailed collaboration policy is given on the course website at: http://www.its.caltech.edu/~zuev/teaching/2023Fall/CollaborationACM104.pdf
In general, collaboration is encouraged everywhere except for the exams. Let’s help each other and learn together! If you get stuck with a homework problem, I encourage you to discuss it with other students (offline or online on Piazza). But remember that you will have to prepare and submit your solution by yourself. No collaboration is allowed on the exams.

Important Dates (All times are Pacific Times)

<table>
<thead>
<tr>
<th>Event</th>
<th>Available</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Set 1</td>
<td>1pm Tue, Oct 03</td>
<td>9pm Tue, Oct 10</td>
</tr>
<tr>
<td>Problem Set 2</td>
<td>1pm Tue, Oct 10</td>
<td>9pm Tue, Oct 17</td>
</tr>
<tr>
<td>Problem Set 3</td>
<td>1pm Tue, Oct 17</td>
<td>9pm Tue, Oct 24</td>
</tr>
<tr>
<td>Head TA Review</td>
<td>10:30am Tue, Oct 24</td>
<td></td>
</tr>
<tr>
<td>Midterm Exam</td>
<td>1pm Tue, Oct 24</td>
<td>9pm Tue, Oct 31</td>
</tr>
<tr>
<td>Problem Set 4</td>
<td>1pm Tue, Oct 31</td>
<td>9pm Tue, Nov 07</td>
</tr>
<tr>
<td>Problem Set 5</td>
<td>1pm Tue, Nov 07</td>
<td>9pm Tue, Nov 14</td>
</tr>
<tr>
<td>Problem Set 6</td>
<td>1pm Tue, Nov 14</td>
<td>9pm Tue, Nov 21</td>
</tr>
<tr>
<td>Head TA Review</td>
<td>10:30am Thu, Nov 30</td>
<td></td>
</tr>
<tr>
<td>Final Exam</td>
<td>1pm Thu, Nov 30</td>
<td>9pm Thu, Dec 07</td>
</tr>
</tbody>
</table>

Websites
- Course website:
  http://www.its.caltech.edu/~zuev/teaching/2023Fall/ACM104.htm
- Lecture notes, problem sets, exams, solutions, announcements, and class discussions will be managed via Piazza, which is designed such that you can get a quick help from your classmates, TA(s), and instructor. Instead of emailing questions to the teaching staff, I encourage you to post your questions on Piazza because
  - You will get the answers faster
  - Your classmates may also benefit from seeing the answers to your questions.
- Here is the Piazza page:
  http://www.piazza.com/caltech/fall2023/acm104/home

1 If you are interested in being a TA next year, try to be active on Piazza and help other students by answering their questions.
• Problem sets and exams will be graded via Gradescope.
  o If you are a registered student, you will be enrolled on Gradescope by the end of the 1st week of classes, and you will receive a notification from Gradescope about your enrollment.
    ➢ Please make sure that the email that you use on Gradescope is your official Caltech email.
  o If you are a registered student, but have not been enrolled on Gradescope by the end of the 1st week of classes, please email the Head TA as soon as possible and ask to enroll you to Gradescope. Your absence on Gradescope means that, according to my records, you are not registered.
  o If you want just to audit the course, it is fine, you will have access to Piazza and all course materials there (please email me and I will enroll you on Piazza), but you will not have access to Gradescope and your submissions will not be graded. If you audit the course this year, you should not register for the course in the future.

To submit your solution via Gradescope, you need to create a single PDF (not images) that contains the whole solution (for example, by scanning your solution), and then upload it to Gradescope. Here are some useful links:
  o Scanning on a mobile device: https://help.gradescope.com/article/0chl25eed3
  o Submitting an assignment: https://help.gradescope.com/article/cccbbppziu9

Should you have any questions regarding Gradescope, please ask on Piazza: we will have many experts there.

**Suggested Study Process**

To get the most out of ACM 104, here is my suggestion on the study process:

- Attend Lectures, focus on understanding the big picture of what is going on.
- Review Lecture Notes (ideally on the same day they are released), make sure that everything is clear.
- If something is not clear, ask on Piazza, and help your classmates by answering their questions.
- After each Lecture, very briefly summarize my notes in Your Own Notes, extract the essence.
- Start working on each Problem Set on the same day it is released (or as soon as possible after that).
- Aim at finishing each Problem Set and Exam at least 1 day before they are due.
- If you get stuck with a problem, ask for hints on Piazza (unless it is an exam problem, and then you are screwed ;-))

**Keep in Mind**

My goal is to help you understand and learn the material. Understanding is a creative and time- and effort-consuming process. If you don’t understand something, please talk to me. If you are struggling with balancing the workload please talk to me. If you have any concerns, please talk to me. Keep in mind that I am here to help.

**Honor Code**

“No member of the Caltech community shall take unfair advantage of any other member of the Caltech community.”