UC-Denver Math 5593, Section 001   Syllabus
Linear Programming   Fall 2025

Instructor: Steffen Borgwardt	Class Hours: **TuTh 11:00am – 12:15pm**
Email: steffen.borgwardt@ucdenver.edu URL: https://clas.ucdenver.edu/steffen-borgwardt/ Office: SCB 4313	Class Room: **SCB 4017** Office Hours: TuTh 12:30pm – 1:45pm, and walk-in

Prerequisites: Graduate standing in Applied Mathematics or permission of the instructor. This course assumes the equivalent of a course in linear algebra (e.g., MATH 3191).

First Day of Classes: Tuesday, Aug. 19. Details of the syllabus will be discussed in the first class meeting.

Course Credits: 3

Catalog Description: A linear program is an optimization problem that seeks to minimize or maximize a linear function subject to a system of linear inequalities and equations. This course begins with examples of linear programs and variations in their representations. Basic theoretical foundations covered include polyhedra, convexity, linear inequalities and duality. Two classes of solution algorithms are given: simplex methods and interior point methods. The primary emphasis of this course is on mathematical foundations, and applications are used to illustrate the main results. Linear programs are crucial tools in many areas of data science. The course covers three pillars: modeling, theory, and algorithms.

Course Objectives and Learning Goals:
In this course, students learn to
1. identify which applications can be approached by linear programming
2. formulate practical problems as linear programming models
3. use software to write and solve linear programs
4. understand the main solution methods for linear programs – this includes the algebra needed to perform the computations (part of the simplex method chapter)
5. understand the geometric representation of the feasible solutions for linear programs
6. analytically derive and exploit their knowledge of (4) and (5) to gain deeper insight into properties of the underlying practical problems
7. interpret the solutions to linear programming models to make educated decisions

The course will have a significant programming component, in early homework and projects, in addition to the standard topics. Linear programs are at the core of many applications in operations research. Like all courses in optimization, this course is valuable preparation for work in industry.

Computers: Students are expected to have access to a laptop or desktop for programming work. Students are expected to have proficiency in Python. Students will be introduced to AMPL, an algebraic modeling software for mathematical programming. Student, trial, and online versions are provided on the webpage http://www.ampl.com. In addition, a full-featured time-limited version for class use during the semester will be made available by the instructor.

Proof requirement: Many lectures and most homework assignments will include proofs. Students should review the necessary skills and proof techniques independently.

Textbooks
Linear Programming: Foundations and Extensions by Robert J. Vanderbei, 5th edition, Springer, 2020. Available for free online through Auraria Library (start-my-research / skyline)

AMPL: A Modeling Language for Mathematical Programming by Robert Fourer, David M. Gay, and Brian W. Kerninghan, 2nd edition, 2003 https://ampl.com/learn/ampl-book/ (pdf is free!)

(optional) **Hands-on Mathematical Optimization with AMPL in Python** by Krzysztof Postek, Allessandro Zocca, Joaquim Gromicho, and Jeffrey Kantor, 2024, https://ampl.com/mo-book/

(optional) **Linear and Nonlinear programming** by David G. Luenberger and Yinyu Ye, 5th edition, Springer, 2021. available for free online through Auraria Library (start-my-research / skyline)

Homework: Expect to spend about 5 hours per week on reading and homework. **Reading and homework are assigned during class**. Homework will be due in large collections during the semester as indicated in the schedule. No late homework will be accepted unless prior arrangements are made. **Homework should be submitted in a group of up two or three;** submission by yourself can be arranged if you let me know. Collaboration between students of different groups is also encouraged, but every group needs to write up their personal solution in their own style. Appropriately higher standards in terms of presentation are expected if you work in a group.

Midterm: There will be a midterm test in the form of a 20-25 minute oral exam. They are scheduled the week before. If you cannot take a test at the appointed time, contact me at least one week prior to the test date so that we can make other arrangements. There will be no class on exam day.

Final Project: There is no final exam. There will be a final project starting in the second half of classes. **The final project should be worked on in a group of two or three;** project work by yourself can be arranged if you let me know. Project deliverables include a set of slides, a presentation in class, as well as well-commented software code (if part of the topic). If you work in a group, project scope will be appropriately larger. The project also includes the preparation of a github account and small wiki (or similar) to host the deliverables.

Grading: **45% Homework, 25% mid-term test, 30% final project.** There are a total of 100 points. Final grades will be assigned using the following scale: 89-100 A; 78-88.5 B; 67-78.5 C; 50-66.5 D; less than 56 F. A plus or minus will be assigned for borderline cases (roughly one-third of the grade range). The final project 30-point score breaks up to: 10 points for project work and material, 10 points for quality of slides, and 10 for quality of presentation in class.

Each of the 3 homework collections is worth 16.5 points, and the total maximum score for homework is 45 (so less than 3 times 16.5). This allows you to achieve full homework score even if some problems are not fully correct. Homework, midterm, and the project will be graded depending on correctness and quality of presentation. A neat writeup is expected (handwritten or typed) for full score. It is always expected that you show your work in detail. The best homework solutions may be distributed as a solution key to the rest of the class.

Week	Dates	Topics
		Unit 1: Foundations of Linear Programming & Models and Applications
1	8/19 8/21	Class Organization and Foundations of Linear Programming Foundations of Linear Programming
2	8/26 8/28	Foundations of Linear Programming Foundations of Linear Programming
3	9/2 9/4	Foundations of Linear Programming Linear Models
4	9/9 9/11	Linear Models Linear Models
5	9/16 9/18	Linear Models Linear Models (HW Collection 1)
6.1	9/23	Linear Models
		Unit 2: Theory & Foundations
6.2	9/25	Convex Analysis and Polyhedral Theory
7	9/30 10/2	Convex Analysis and Polyhedral Theory Convex Analysis and Polyhedral Theory
8	10/7 10/9	Convex Analysis and Polyhedral Theory Convex Analysis and Polyhedral Theory
9	10/14 10/16	Duality Theory Duality Theory (HW Collection 2)
		Unit 3: Methods & Algorithms
10	10/21 10/23	Simplex Methods Simplex Methods
11	10/28 10/30	**Midterm (Oral exams)** Simplex Methods
12	11/4 11/6	Simplex Methods Simplex Methods
13	11/11 11/13	Parametric Sensitivity Parametric Sensitivity (HW Collection 3)
14	11/18 11/20	Interior-Point Methods Interior-Point Methods
15	12/2 12/4 Finals Week	In-Class Presentations of Final Projects In-Class Presentations of Final Projects In-Class Presentations of Final Projects

University, college, and department policies

Academic Calendar

For university deadlines and procedures (such as the last day to withdraw from a course), please see the Academic Calendar. https://www.ucdenver.edu/student/calendars/academic/

Academic Support

Instructor office hours or other appointments are the best way to get additional help. I'm happy to help with questions not answered during class, additional explanation, or homework assistance.

Other sources of support are

- The Math and Stat Support office is located in the Learning Commons Building Room 1225 and regularly offers CU Denver students free drop-in assistance. Hours of operation, zoom links for virtual options, and other forms of support for mathematics and statistics courses are available on the Math and Stat Support webpage.

  https://clas.ucdenver.edu/mathematical-and-statistical-sciences/math-and-stat-support

- The Learning Resources Center (LRC) provides individual and group tutoring, Supplemental Instruction (SI), study skills workshops, and ESL support.

  https://www.ucdenver.edu/learning-resources-center

- The College of Liberal Arts and Sciences has a summary of campus academic support and school/college advising offices.

  https://clas.ucdenver.edu/faculty-staff/content/clas-academic-policies-deadlines

Recording of Class Meetings

Class meetings held on or streamed over a video conferencing platform (such as Zoom, Microsoft Teams, etc) may be recorded and posted for all members of the class. Student participation and interaction may be included in the recording. If you have any concerns about this, please contact the instructor.

Diversity Statement

It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture, etc. I would like to create a learning environment for my students that supports a diversity of thoughts, perspectives and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc). To help accomplish this:

- If you have a name and/or set of pronouns that differ from those that appear in your official records, please let me know!

- If you feel like your performance in the class is being impacted by your experiences outside of class, please don't hesitate to come and talk with me. I want to be a resource for you. Remember that you can also submit anonymous feedback (which will lead to me making a general announcement to the class, if necessary to address your concerns). If you prefer to speak with someone outside of the course, the Office of Diversity, Equity and Inclusion, is an excellent resource.

- I (like many people) am still in the process of learning about diverse perspectives and identities. If something was said in class (by anyone) that made you feel uncomfortable, including by me, please talk to me about it. (Again, anonymous feedback is always an option).

Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious or other cultural events, please let me know so that we can make arrangements for you.

Health and Wellness

As a student, you may experience a range of challenges that can interfere with learning, such as strained relationships, traumas, increased anxiety, substance use, feeling down, difficulty concentrating, and/or lack of motivation. These mental health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. If you or someone you know is struggling, you can find supportive campus and community resources at the Health Center at Auraria or the CU Denver Counseling Center. On weekends, holidays or after-hours you can contact the 24/7 Mental Health Crisis and Victim Assistance Line at 303-615-9911.

The University of Colorado Denver is committed the health and well-being of all students. We recognize that diminished mental health, including significant stress, mood changes, excessive worry, or problems with eating and/or sleeping can interfere with optimal academic performance. The source of such symptoms can be quite varied, and include experiences of trauma (such as sexual and relationship violence, stalking, discrimination, crimes, and accidents), responses to course work, family worries, loss, personal struggle, or crisis. If you or someone you know is struggling, you can find supportive campus and community resources at

https://www.ucdenver.edu/counseling-center

or by calling the CU Denver Counseling Center (303-315-7270) or the Health Center at Auraria (303-615-9999). On weekends, holidays or after-hours you can contact the 24/7 Mental Health Crisis and Victim Assistance Line at 303-615-9911.

Disability Accommodation and Access

The University of Colorado Denver is committed to ensuring the full participation of all students in its programs, including students with disabilities. If you have a disability or think you have a disability and need accommodations to succeed in this course, I encourage you to contact Disability Resources and Services (DRS) and/or speak with me as soon as you can. DRS is located in Student Commons Building Suite 2116, and can be reached at disabilityresources@ucdenver.edu and online at https://www.ucdenver.edu/offices/disability-resources-and-services. I am committed to providing equal access as required by federal law, and I am interested in developing strategies for your success in this course.

Nondiscrimination and Sexual Misconduct

The University of Colorado Denver is committed to maintaining a positive learning, working and living environment. University policy and Title IX prohibit discrimination on the basis of race, color, national origin, sex, age, disability, pregnancy, creed, religion, sexual orientation, veteran status, gender identity, gender expression, political philosophy or political affiliation in admission and access to, and treatment and employment in, its educational programs and activities. University policy prohibits sexual misconduct, including harassment, domestic and dating violence, sexual assault, stalking, or related retaliation. If you have experienced any sort of sexual misconduct or discrimination, please visit the Office of Equity web site at https://www.ucdenver.edu/offices/equity to understand the resources available to you or contact the Office of Equity/Title IX Coordinator at equity@ucdenver.edu.

Please note that I am a Responsible Employee, which means that if I witness or receive information regarding possible prohibited protected characteristic discrimination or harassment, any form of sexual misconduct, and/or related retaliation, I am required to promptly report the information to the Office of Equity or their designee.

Religious Holiday Accommodation

Faculty in the University of Colorado system provide reasonable accommodations to students who must be absent from classes because of religious holidays. If you will miss class or graded assignments in order to observe religious holidays, you must contact me with all course conflicts by the end of the first week of classes.

Student Code of Conduct

As members of the University community, students are expected to uphold university standards, which include abiding by state civil and criminal laws and all University policies and standards of conduct. These standards are outlined in the student code of conduct, which can be found at https://www.ucdenver.edu/student/wellness/student-conduct

Academic Honesty

Students are expected to know, understand, and comply with the ethical standards of the university. A university's reputation is built on a standing tradition of excellence and scholastic integrity. As members of the University of Colorado Denver academic community, faculty and students accept the responsibility to maintain the highest standards of intellectual honesty and ethical conduct.

Academic dishonesty is defined as a student's use of unauthorized assistance with intent to deceive an instructor or other such person who may be assigned to evaluate the student's work in meeting course and degree requirements.

This course assumes your knowledge of the policies and definitions. University policies allow the instructor to decide how to respond to an ethics violation, whether by lowering the assignment grade, lowering the course grade, and/or filing charges against the student with the campus Office of Student Conduct. For more information regarding the Office of Student Conduct policies and procedures, please refer to https://www.ucdenver.edu/student/wellness/student-conduct/academic-integrity. Violating the academic honor code can lead to expulsion from the University.

Examples of academic dishonesty include, but are not limited to, the following:

Plagiarism.   Plagiarism is the use of another person's distinctive words or ideas without acknowledgment. Examples include:

1. Word-for-word copying of another person's ideas or words;
2. The mosaic (the interspersing of one's own words here and there while, in essence, copying another's work);
3. The paraphrase (the rewriting of another's work, yet still using their fundamental idea or theory);
4. Fabrication of references (inventing or counterfeiting sources);
5. Submission of another's work as one's own;
6. Neglecting quotation marks on material that is otherwise acknowledged.

Acknowledgment is not necessary when the material used is common knowledge.

Cheating.   Cheating involves the possession, communication, or use of information, materials, notes, study aids or other devices not authorized by the instructor in an academic exercise, or communication with another person during such an exercise. Examples include:

1. Copying from another's paper or receiving unauthorized assistance from another during an academic exercise or in the submission of academic material;
2. Using a calculator when its use has been disallowed;
3. Collaborating with another student or students during an academic exercise without the consent of the instructor.

Note on use of Generative AI.   Generative AI tools such as ChatGPT may not be used on exams, tests, or quizzes that do not permit the use of outside resources. The instructor will provide guidelines on whether such tools can be used for assignments and projects.

Fabrication and Falsification.   Fabrication involves inventing or counterfeiting information, i.e., creating results not obtained in a study or laboratory experiment. Falsification, on the other hand, involves the deliberate alteration of results to suit one's needs in an experiment or other academic exercise.

Multiple Submissions.   This is the submission of academic work for which academic credit has already been earned, when such submission is made without instructor authorization.

Misuse of Academic Materials.   The misuse of academic materials includes, but is not limited to, the following:

1. Stealing or destroying library or reference materials or computer programs;
2. Stealing or destroying another student's notes or materials, or having such materials in one's possession without the owner's permission;
3. Receiving assistance in locating or using sources of information in an assignment when such assistance has been forbidden by the instructor;
4. Illegitimate possession, disposition, or use of examinations or answer keys to examinations;
5. Unauthorized alteration, forgery, or falsification;
6. Unauthorized sale or purchase of examinations, papers, or assignments.

Complicity in Academic Dishonesty.   Complicity involves knowingly contributing to another's acts of academic dishonesty. Examples include:

1. Knowingly aiding another in any act of academic dishonesty;
2. Allowing another to copy from one's paper for an assignment or exam;
3. Distributing test questions or information about the materials to be tested before the scheduled exercise;
4. Taking an exam or test for someone else;
5. Signing another's name on attendance roster or on an academic exercise.

Incomplete Policy

When a student has special circumstances that make it impossible to complete course assignments, faculty members may choose to award an incomplete grade. All incomplete courses are assigned a grade of Incomplete (I). Incomplete grades are not awarded for poor academic performance or as a way of extending assignment deadlines. Faculty are not required to award an Incomplete.

To be eligible for an Incomplete grade, students MUST:

- Have participated in the class for a significant proportion of the term.
- Have successfully completed a significant proportion of the course assignments.
- Have special circumstances (verification may be required) that preclude the student from attending class and/or completing graded assignments.
- Make arrangements to complete missing assignments with the original instructor by a mutually agreed upon date but within one calendar year. Note that it is not the instructor's responsibility to teach the student missed material.
- Both the instructor and student should complete and sign a Course Completion Agreement found at

  https://clas.ucdenver.edu/faculty-staff/content/incomplete-grade-policy

- The instructor gives a copy of the signed Course Completion Agreement to the department.

Incompletes cannot:

- require a student to repeat the entire course,
- repeat or replace existing grades,
- allow the student an indeterminate period of time to complete a course, or
- allow the student to repeat the course with a different instructor.

Student Grievances

Students who have concerns about the course or instructor should first contact the instructor to discuss the issue. If the issue is not resolved, the student should next contact the Associate Chair of the Department of Mathematical and Statistical Sciences (currently Stephen Hartke <stephen.hartke@ucdenver.edu>). If not satisfied, the student should then appeal to the appropriate Associate Dean of the student's home school or college (for CLAS, this is the Associate Dean for Student Success). No step in this process should be skipped.

UCD Access (Student Portal)
Registrar Forms
Registration Information
All deadlines are 11:59 PM MT unless otherwise indicated.

Main Session	Date	Important Notes
First day to apply for Fall Graduation via UCDAccess	April 1, 2025	
Registration begins for Fall Semester via UCDAccess	April 1-16, 2025	Check UCDAccess for your specific registration date and time assignment. For best course selection, register as soon as possible after your registration time assignment.
Open enrollment begins for Fall Semester via UCDAccess	April 17, 2025	
First day of Fall semester classes	August 18, 2025	
Last day to waitlist Fall classes using UCDAccess	August 24, 2025	
Last day to drop a Fall class without a $100 drop charge	August 25, 2025	All waitlists will be eliminated today.
First day instructor approval may be required to add some Fall classes	August 25, 2025	If unable to enroll in UCDAccess because "Instructor Consent is Required", obtain instructor approval on a Schedule Adjustment Form.
Labor Day Holiday	September 1, 2025	No classes. Campus closed.
Census Day	September 3, 2025	Deadline time is 5:00 PM MT.
Last Day to add Fall classes in UCDAccess	September 3, 2025	Deadline time is 5:00 PM MT.
Last day to add Fall classes with instructor consent on the Schedule Adjustment form	September 3, 2025	If unable to enroll in UCDAccess because "Instructor Consent is Required", obtain instructor approval on a Schedule Adjustment Form. Deadline time is 5:00 PM MT.
Full tuition will be charged for additional Fall classes added after this date	September 3, 2025	College Opportunity Fund will not apply nor will hours be deducted from eligible lifetime hours after this date. Deadline time is 5:00 PM MT.
Last day to drop Fall classes with a financial adjustment	September 3, 2025	Deadline time is 5:00 PM MT.
Fall classes dropped after this date will appear on your transcript with a grade of 'W'	September 3, 2025	Deadline time is 5:00 PM MT.
Last day to request or cancel Grade Forgiveness for Fall Semester	September 3, 2025	Refer to the Grade Forgiveness form for restrictions. Deadline time is 5:00 PM MT.
Last day to apply for Fall graduation via UCDAccess	September 3, 2025	Deadline time is 5:00 PM MT. After this, contact your advisor.
Last day to request No Credit or Pass/Fail grade for a Fall class	October 26, 2025	Graduate degree students can exercise the P+/P/F option for undergraduate courses only. Graduate students should consult their school or college regarding the P+/P/F option. A grade of P+/P/S will not be acceptable for graduate credit to satisfy any graduate education requirement.
Last day to withdraw from a Fall class via UCDAccess	October 26, 2025	
First day to withdraw from a Fall class with a Late Withdraw Petition form	October 27, 2025	
Registration begins for Spring Semester via UCDAccess	Nov. 3, 2025 - Nov. 18, 2025	Check UCDAccess for your specific registration date and time assignment. For best course selection, register as soon as possible after your registration time assignment.
Open enrollment begins for Spring Semester via UCDAccess	November 19, 2025	
Fall Break	November 24 - 30, 2025	No classes. Campus open.
Thanksgiving Day	November 27, 2025	No classes. Campus closed.
Last day to withdraw from a Fall class with a Late Withdrawal Petition form	December 3, 2025	
Finals Week	December 8 - 13, 2025	
End of Fall semester - Commencement	December 13, 2025	
Final Fall Semester grades available on UCDAccess and transcripts (tentative)	December 18, 2025	
Winter Break	Dec. 25, 2025 - Jan. 1, 2026	No classes. Campus closed.
Fall degrees posted on UCDAccess and transcripts (tentative)	January 13, 2026	This is the date degrees will be recorded on the transcript; diplomas begin mailing approximately February 1st.

STUDENT SUPPORT

CARE Team is there for you
Call 303-352-3579 if you
or a classmate needs extra help
Submit a concern at
http://www.ucdenver.edu/care

Call 911 in case of emergency
Auraria Campus Police: 303-556-5000

CAREER COUNSELING at LYNXCONNECT
ucdenver.edu/careercenter - Tivoli 339
303-315-7315 - CareerCenter@ucdenver.edu

COUNSELING CENTER
ucdenver.edu/counselingcenter - Tivoli 454 (4th floor)
303-315-7270 (*Emergency After-Hours: 303-615-9911*)

DISABILITY RESOURCES & SERVICES
ucdenver.edu/offices/disability-resources-and-services
 Student Commons 2116
303-315-3510 - disabilityresources@ucdenver.edu

OFFICE OF EQUITY
ucdenver.edu/equity - Lawrence Street Center 12th floor
303-315-2567 – equity@ucdenver.edu

PHOENIX CENTER AT AURARIA
24/7 Free and Confidential Helpline: 303-556-2255
Info on interpersonal violence, referrals, options, & next steps
www.thepca.org - Tivoli 227 - 303-315-7250 - info@thepca.org

FREE TUTORING
Contact these services for academic assistance throughout the semester

LEARNING RESOURCES CENTER
ucdenver.edu/lrc – Learning Commons Suite 1231
303-315-3531 - LRC@ucdenver.edu

MATH AND STAT SUPPORT
Learning Commons Room 1225
clas.ucdenver.edu/mathematical-and-statistical-sciences/math-and-stat-support

WRITING CENTER
writingcenter.ucdenver.edu - Learning Commons First Floor

UNDERGRADUATE ACADEMIC ADVISING
ucdenver.edu/undergradadvising

Graduate students: contact your graduate program directly for advising information

ARCHITECTURE AND PLANNING (CAP) ADVISING
CU Building 2000
303-315-1000 - cap@ucdenver.edu

ARTS AND MEDIA (CAM) ADVISING
Arts Building 177
303-315-7400 - camadvising@ucdenver.edu

BUSINESS SCHOOL ADVISING
15th and Lawrence Street, 4th floor
303-315-8110 – undergrad.advising@ucdenver.edu

CENTER FOR UNDERGRADUATE EXPLORATION & ADVISING (CUE&A)
Student Commons 1113
303-315-1940 - cuea@ucdenver.edu

EDUCATION & HUMAN DEVELOPMENT (SEHD) ADVISING
Lawrence Street Center 701
303-315-6300 - education@ucdenver.edu

ENGINEERING, DESIGN & COMPUTING (CEDC) ADVISING
North Classroom 3034
303-315-7170 - engineering@ucdenver.edu

LIBERAL ARTS AND SCIENCES (CLAS) ADVISING
North Classroom 1030
303-315-7100 – clas_advising@ucdenver.edu

PUBLIC AFFAIRS (SPA) ADVISING
Lawrence Street Center 525
303-315-2228 – spa.advising@ucdenver.edu

Plan Ahead! Review Important Dates & Deadlines
at http://ucdenver.edu/academiccalendar