MATH 707: Optimization
Fall 2022 Course Syllabus

NJIT Academic Integrity Code: All Students should be aware that the Department of Mathematical Sciences takes the University Code on Academic Integrity at NJIT very seriously and enforces it strictly. This means that there must not be any forms of plagiarism, i.e., copying of homework, class projects, or lab assignments, or any form of cheating in quizzes and exams. Under the University Code on Academic Integrity, students are obligated to report any such activities to the Instructor.

COURSE INFORMATION

Course Description: This graduate course covers modern topics in continuous optimization. Starting with theoretical foundations, the course develops a working knowledge of state-of-the-art algorithms, and concludes with applications in engineering and the applied sciences.

Math 707 covers three key areas:
1. Developing a rigorous treatment of convex analysis (include conditions for optimality). Convex analysis forms the mathematical underpinnings for much of modern optimization.
2. A systematic development of interior-point methods. Interior-point methods are state-of-the-art algorithms for solving (continuous) optimization problems, such as those that arise in physical applications of applied mathematics.
3. Exposure to modern applications of optimization in applied mathematics, including obstacle problems, image processing, compressed sensing of signals, stochastic gradient descent and Tikhonov regularization using norms.

Number of Credits: 3

Prerequisites: This course draws extensively on linear algebra (Math 631) and multivariable calculus (Math 213). The course makes some use of some undergraduate analysis (Math 480-481) and numerical methods (Math 613-614). Students may also seek permission from the instructor for enrollment.

Course-Section and Instructors:

Course-Section	Instructor
Math 707-001	Professor D. Shirokoff

Office Hours for All Math Instructors: Fall 2022 Office Hours and Emails

Textbook: There is no required textbook for this class. We will use resources from several resources.

1. S. Boyd, L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 1st Ed., 2004.

   This book is freely available at: https://web.stanford.edu/~boyd/cvxbook/

2. D. P. Bertsekas, *Convex Optimization Theory*, 1st Ed., Athena Scientific, 2009.

   The book website is here: www.athenasc.com/convexduality.html

   Much of the text material is available in course notes on the authors website: www.athenasc.com/Convex_Slides.pdf

University-wide Withdrawal Date: The last day to withdraw with a **M** is **Monday, November 14, 2022**. It will be strictly enforced.

POLICIES

DMS Course Policies: All DMS students must familiarize themselves with, and adhere to, the Department of Mathematical Sciences Course Policies, in addition to official university-wide policies. DMS takes these policies very seriously and enforces them strictly.

Grading Policy: The final grade in this course will be determined as follows:

Homeworks	70%
Project/Presentations	30%

Your final letter grade will be based on the following tentative curve.

A	90 - 100	**C+**	60 - 69
B+	80 - 89	**C**	50 - 59
B	70 - 79	**F**	0 - 49

Attendance Policy: Attendance at all classes will be recorded and is **mandatory**. Please make sure you read and fully understand the Math Department's Attendance Policy. This policy will be strictly enforced.

Homework policy: No late homework will be accepted. In the event a student has a legitimate reason for missing a homework deadline, the student should contact the Dean of Students office and present written verifiable proof of the reason for missing the deadline, e.g., a doctor's note, police report, court notice, etc. clearly stating the date AND time of the mitigating problem.

Discussing homework with classmates and the instructor is allowed. However, all homework are to be completed individually.

Project presentations: There will be final project presentations during the exam week:

Final Exam Period	December 16 – 22, 2022

Cellular Phones: All cellular phones and other electronic devices must be switched off during all class times.

ADDITIONAL RESOURCES

Further Assistance: For further questions, students should contact their instructor. All instructors have regular

office hours during the week. These office hours are listed on the Math Department's webpage for Instructor Office Hours and Emails.

Accommodation of Disabilities: The Office of Accessibility Resources and Services (OARS) offers long term and temporary accommodations for undergraduate, graduate and visiting students at NJIT.

If you are in need of accommodations due to a disability please contact Scott Janz, Associate Director of Disability Support Services at 973-596-5417 or via email at scott.p.janz@njit.edu. The office is located in Kupfrian Hall, Room 201. A Letter of Accommodation Eligibility from the Office of Accessibility Resources and Services office authorizing your accommodations will be required.

For further information regarding self identification, the submission of medical documentation and additional support services provided please visit the Office of Accessibility Resources and Services (OARS) website.

Important Dates (See: Fall 2022 Academic Calendar, Registrar)

Date	Day	Event
September 5, 2022	Monday	Labor Day
September 6, 2022	Tuesday	First Day of Classes
September 12, 2022	Monday	Last Day to Add/Drop Classes
November 14, 2022	Monday	Last Day to Withdraw
November 22, 2022	Tuesday	Thursday Classes Meet
November 23, 2022	Wednesday	Friday Classes Meet
November 24 to November 25, 2022	Thursday and Friday	Thanksgiving Recess - Closed
November 26, 2022	Saturday	Saturday Classes Meet
December 14, 2022	Wednesday	Last Day of Classes
December 15, 2022	Thursday	Reading Day
December 16 to December 22, 2022	Friday to Thursday	Final Exam Period

Course Outline

Week/Chapter	Topic	Number of Lectures
1	**Introduction to convex analysis:** definitions and properties of convex sets and convex functions. Caratheodory's theorem. Norms are convex functions, both finite and infinite dimensional. L2 versus L1 norms. Separating and supporting hyperplanes. Convex envelopes.	8
2	**Conditions for optimality:** Development of the KKT conditions for optimality in convex and non-convex problems from a geometric viewpoint. Discussion on when KKT conditions are sufficient.	8

	Includes both equality (Lagrange multipliers) and inequality constraints. Convex duality.	
3	**Introduction to Numerical Algorithms:** Interior point methods as a way to handle inequality constraints. Discussion of Newton's method and gradient descent as approaches for solving the interior point (penalty) equations. Examples from PDE based problems, including Stokes equations, obstacle problems, elasticity, image processing.	8
5	**Focus on Special Topics. Possible topics include:** (i) Optimal control problems/PDE constrained optimization, (ii) Stochastic gradient descent, (iii) Obstacle problems, (iv) Optimal transport, (v) Compressed sensing, (vi) Semi-definite programing, (vii) Image processing.	2