MATH 1101: An Introduction to Optimization

FALL, 2026 Course Syllabus

INSTRUCTOR:
Associate Professor Changxi Wang, Ph.D.
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Office Hours: Tuesday 8:15 to 11:00

LECTURES:
Tuesday 19:20-21:55, SCUPI Building S204

RECITATION:
One 45-minute Recitation per week.

TEXTBOOK:
Jeter M. Mathematical programming: an introduction to optimization[M]. CRC press, 1986.

TEACHING ASSISTANT:
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PREREQUISITE:
Linear algebra

DESCRIPTION:
This course provides a rigorous introduction to optimization, focusing on both the theory and algorithms that underline modern applications in engineering, data science, and operations research. Beginning with fundamental mathematical concepts, students will learn how to formulate optimization problems, analyze their structure, and apply theoretical tools such as duality and optimality conditions. The course also introduces key algorithmic methods, emphasizing convergence, complexity, and practical implementation.

COURSE OBJECTIVES:
By the end of this course, students will be able to:
1. Recognize and formulate optimization problems in diverse domains.
2. Understand the mathematical foundations of optimization, including convex sets, convex functions, and related function properties.
3. Apply optimality conditions (first-order, second-order, KKT) to analyze problems.
4. Use duality theory to interpret and solve optimization problems.
5. Implement and analyze basic optimization algorithms, including gradient descent, Newton's method, and interior-point methods.
6. Appreciate the applications of optimization in engineering, data science, and beyond.

LEARNING OUTCOMES FOR THIS COURSE:
1) Formulate real-world problems as mathematical optimization problems.
2) Classify problems as convex, nonconvex, linear, or nonlinear.
3) Apply convex analysis tools to study problem feasibility and structure.
4) Derive and interpret optimality conditions.
5) Use duality theory to analyze sensitivity and design algorithms.
6) Implement and analyze gradient-based and Newton-type optimization algorithms.
7) Assess trade-offs between accuracy, computational complexity, and convergence rate.

GRADE DETERMINATION:

Attendance:	10%
Quiz:	10%
Homework:	15%
Mid-term Exam	30%
Final Examination:	35%
	100%

MATERIAL COVERED: The sequence of the sections covered in this class is:

Week	Date	Content
1	Sep 1	Course overview, basic optimization formulation, LP definition, and modeling examples (manufacturing, assignment, portfolio), Global/local optima.
2	Sep 8	Topology basics, sensitivity (post-optimal) analysis, parametric programming, and model stability, Matrices, vectors.
3	Sep 15	Subspaces, bases, matrix operations, inverses, and elementary row operations, Gaussian elimination and LU decomposition, affine sets.
4	Sep 20	Convex sets, convex hulls, and cones, Hyperplanes, polytopes, extreme points.
5	Sep 22	LP standard forms, convexity of the feasible set, Finite Basis Theorem, optimality at extreme points, vertex enumeration.
6	Oct 29	Basic feasible solutions, the simplex tableau, pivoting rules, and optimality conditions.
7	Oct 13	Mid-term Exam. Location: S204/S205. Time: 19:00-21:00
8	Oct 20	Full worked examples, including unbounded and multiple-optimum cases.
9	Oct 27	Big-M/two-phase method with artificial variables and initial tableau construction.
10	Nov 3	Advanced cases: degeneracy, infeasibility, and multiple optimal solutions.
11	Nov 10	Dual problem construction, weak/strong duality, and the fundamental duality theorem.
12	Nov 17	General dual forms, symmetric duals, economic interpretation, and complementary slackness.
13	Nov 24	Convex/concave definitions, quadratic forms, definiteness, and level sets.
14	Dec 1	Epigraph, one-variable convexity, gradients, directional derivatives, Taylor's theorem, and multivariable convexity.
15	Dec 8	Optimality conditions for convex problems, quasiconvex functions, star-shaped sets.
16	Dec 15	First-order necessary conditions, nonnegative variables, and Lagrange multipliers with examples.
17	Dec 22	Inequality constraints, Kuhn-Tucker (KKT) conditions and theorems, final review.
17	Dec 25	Final Exam. Location: S204/S205. Time: 19:00-21:00