ISE 417: Nonlinear Optimization, Spring 2017

Course Information:

Lectures:	Tuesdays and Thursdays, 2:35pm-3:50pm, Mohler 375
Office Hours:	Thursdays, 1:30pm-2:30pm, Mohler 475

Instructor Information:

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Description: One of our fundamental goals as engineers is to optimize, whether it be designs, systems, processes, or decisions. This, along with the fact that so many phenomena behave in a nonlinear manner, brings us to the desire to solve *nonlinear optimization* problems (NLPs). The purpose of this course is to introduce the basic theoretical principles underlying nonlinear optimization problems and the numerical methods that are available to solve them. We begin with fundamental (sub)gradient methods and Newton's method for unconstrained optimization, which represent the core of numerous nonlinear optimization algorithms. We then develop an understanding of optimality conditions and duality in the presence of nonlinear functions, ending by discussing modern numerical methods for nonlinear constrained optimization.

Course Objectives: The objectives of this course are for students to do the following:

- Understand how nonlinear functions can be used to model complex optimization problems.
- Understand how to characterize types of solutions of NLPs.
- Understand and be able to use common methodology for the numerical solution of NLPs.
- Understand the central role of (sub)gradient methods in the numerical solution of NLPs.
- Understand the central role of Newton's method in the numerical solution of NLPs.
- Understand the central role of constraint qualifications in characterizing constrained NLP solutions.
- Be familiar with various software packages available for solving NLPs.
- Be able to apply course concepts in practice to solve NLPs.

Prerequisite Topics: Mathematical Logic, Multivariable Calculus, Linear Algebra, and Real Analysis. Please see the *Mathematical Background* document provided on Course Site.

Office Hours: Please come to office hours if you have any questions about the course. I am also available through e-mail (always), on Google Talk (often), and on Skype (sometimes). If I do not respond to an e-mail within 24 hours, then please assume that I have not received it and send a follow-up e-mail. If I do not respond on Google Talk or Skype, then I am either busy or you are contacting me too late in the day, in which case you can try again the next day (during work hours) or send an e-mail instead. I am also willing to meet at other times, but in such cases please e-mail me in advance to set up a mutually convenient time.

Course Site: Lecture notes will be posted on Course Site prior to each lecture. Homework assignments, solutions, announcements, and other important material will also be posted on Course Site. Important information, corrections, and updates about the course may also be sent by e-mail (via Course Site).

Textbook: The primary textbook for the course is:

- J. Nocedal and S. J. Wright, *Numerical Optimization*, Second Edition, Springer Series in Operations Research, Springer, New York, NY, USA, 2006.

Reading the textbook is not required, but it is recommended. You are not responsible for textbook material that is not covered in lecture. Course material also will be derived from the following recommended textbooks:

- M. S. Bazaraa, H. D. Sherali, and C. M. Shetty, *Nonlinear Programming: Theory and Algorithms*, John Wiley & Sons, Hoboken, NJ, USA, 2006.
- D. P. Bertsekas, *Nonlinear Programming*, Second Edition, Athena Scientific, Belmont, MA, USA, 1999.
- D. P. Bertsekas, *Convex Optimization Theory*, Athena Scientific, Nashua, NH, USA, 2009.
- R. L. Burden and J. D. Faires, *Numerical Analysis*, Seventh Edition, Brooks/Cole, Pacific Grove, CA, USA, 2001.
- J. E. Dennis, Jr. and R. B. Schnabel, *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*, Classics in Applied Mathematics, SIAM, Philadelphia, PA, USA, 1996.
- R. Fletcher, *Practical Methods of Optimization*, Second Edition, John Wiley & Sons, Chichester, West Sussex, England, 1987.
- A. Ruszczyński, *Nonlinear Optimization*, Princeton University Press, Princeton, NJ, USA, 2006.

Expected Schedule:

Week	Dates	Topics	Notes
1	1/24, 1/26	Introduction, Convexity and Differentiability	
2	1/31, 2/02	Unconstrained Optimization Theory, Fundamental (Sub)gradient Algorithms	
3	2/07, 2/09	Newton's Method, Numerical Analysis	
4	2/14, 2/16	Line Search Methods	
5	2/21, 2/23	Trust Region Methods	
6	2/28, 3/02	Conjugate Direction Methods	
7	3/07, 3/09	Quasi-Newton Methods	
8	3/14, 3/16	(No lectures)	Spring Break
9	3/21, 3/23	(Tuesday lecture time used for exam) Constrained Optimization Theory	Midterm Exam Project Posted
10	3/28, 3/30	Constraint Qualifications, Duality Theory	
11	4/04, 4/06	Linear Optimization, Quadratic Optimization	
12	4/11, 4/13	Penalty Methods	
13	4/18, 4/20	Sequential Quadratic Optimization	
14	4/25, 4/27	Interior-Point Methods	
15	5/02, 5/04	Nonlinear Optimization Software	Project Due
16	5/09–5/13		Final Exams

Grading: Your grade will be calculated as follows.

Homework:	15%
Project:	25%
Midterm Exam:	25%
Final Exam:	25%
Participation:	10%

Homeworks: There will be regular homework assignments throughout the semester, generally assigned and due every few weeks. Each homework must be submitted electronically via Course Site. No credit will be given for any late assignment. You are free to consult with other students when working on homework, but the work you turn in must be your own. *Please cite any references you use, including fellow students.*

Project: The course project will involve implementing software and writing a report to describe your software and numerical results obtained on test problems. Much of the code will come from the accumulation of coding exercises that will be made available throughout the semester. All coding must be done in Matlab. If you are not experienced in coding and/or Matlab, then I suggest you start practicing early as you will be expected to learn these things on your own. Ask me if you have any questions. The grade for the project will be based on the quality of your report, the correctness of the code, and the comments/documentation that you provide. When in doubt, comment every line of your code.

Collaboration Policy: The sharing of ideas is educationally useful and you are encouraged to discuss assignments with other students. However, *plagiarism* of any kind is destructive, fraudulent, and unacceptable. You are *strictly* forbidden to copy another student's written work, whole or in part, and submit that work under your name. You are also *strictly* forbidden to make trivial or mechanical changes to another student's written work and submit that work under your name. Note that while electronic plagiarism is easier to perform (via copy-and-paste), it is also easier to detect. Plagiarized work will receive no credit and repeat offenses will result in more severe action. A sure way to avoid this issue is to discuss the assignments with fellow students, but then write your solutions individually and independently.

LaTeX: Homework solutions and the project report must be submitted as documents produced with LaTeX. There are no exceptions to this requirement. I am happy to provide assistance for those new to LaTeX; simply e-mail me to set up a time or come to office hours. I will also provide a template for homework solutions. It is not required that you use the provided template, but it is recommended.

Exams: The midterm will be a cumulative, closed-book, closed-notes, in-class, *written* exam. The final will be a cumulative, closed-book, closed-notes, *oral* exam.

Participation: Attendance will not be taken. However, participation will factor into your grade. If you are unable to participate in lecture, then participation entails being a presence online—via e-mail or Course Site—or in office hours. In short, if by the end of the semester we have not had any one-on-one discussions about the course and/or course material, then your participation grade will suffer.

Emergencies: Everyone is responsible for all material covered and announcements made in lecture. If you believe you will miss a long period of time in the course due to illness, a family emergency, etc., then please contact me as early as possible. Under no circumstances will credit be given for missed work unless you have discussed your absence with me in advance.

Regrade Requests: If you disagree with a grade you receive, then you may submit a regrade request. This request must be written and submitted no more than 48 hours after you receive the grade.

Recording Devices: Voice and/or video recording devices may be used only with the approval of everyone in the classroom. Please let me know in advance if you wish to use these types of devices.

Students with Disabilities: If you have a disability for which you are or may be requesting accommodations, please contact me and the Office of Academic Support Services, University Center C212 (+1 (610) 758-4152) as early as possible in the semester. You must have documentation from Academic Support Services before accommodations can be granted.

Equitable Community Principles: Lehigh University endorses The Principles of Our Equitable Community (http://www4.lehigh.edu/diversity/principles). We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.