Optimization Theory and Methods
Course Information

Instructor: David Castañón, Photonics Building, 8 St. Mary's st., Room 434 dac@bu.edu
Office hours: T 1-2 pm, or by appointment through e-mail.

We will use Piazza for interactive questions that will be answered quickly by our graduate student teacher or me, for getting answers to well-formulated questions. The best way to reach me is via e-mail; if needed we can arrange a meeting time outside regular office hours.

Lectures: Tuesday and Thursday, 3:30-5:15pm, PHO 210.

Recitation: Friday, 4:30-6:15, PHO 117.

Graduate Student Teacher: Xiaofeng Lin , xfl@bu.edu.
GST Office hours: Fridays, 1:00 - 2:30 PM, PHO 442.

Description: This course is an introduction to optimization problems and algorithms emphasizing problem formulation, basic methodologies and the underlying mathematical structures. We will cover the classical theory as well as the state of the art. The major topics we will cover are:

1. Theory and algorithms for linear programming.
2. Introduction to combinatorial problems and methods for handling intractable problems.
3. Introduction to nonlinear programming.
4. Introduction to network optimization.

Optimization techniques have many applications in science and engineering. To name a few:

- Machine learning and Artificial Intelligence (AI) with a myriad of domain-specific applications.
- Optimal routing in communication networks.
- Power flow and economic dispatch in electric power networks.
- Transmission scheduling and resource allocation in wireless/sensor networks.
- Production planning and scheduling in manufacturing systems.
- Fleet management (airlines, logistics).
- Air traffic flow management by airlines.

- Optimal resource allocation in manufacturing and communication systems.
- Optimal portfolio selection in finance.
- Analysis and optimization of fluxes in metabolic networks.
- Protein docking.

Prerequisites: Working knowledge of Linear Algebra and some degree of mathematical maturity.

Sectioning: This is a combined class open to Ph.D., M.S., and seniors. The class can be taken under two course numbers: 524 and 674 (ECE and SE). 524 is **only** for undergraduates and M.S. students. 674 is **only** for Ph.D. students. Make sure you are in the right section, depending on your status. While lectures are common, homeworks and exams will be different and grading will be relative to your section, so this is important.

Course Websites: The course material will be posted on Blackboard: `https://learn.bu.edu/`.

We will use Piazza as a discussion board. You have been registered as users in Piazza and you should have received an invitation to join. The system is highly catered to getting you help quickly and efficiently from both the course staff and your fellow classmates. Rather than emailing questions, I encourage you to post your questions on Piazza so other students can benefit from the answers.

Piazza site: `https://piazza.com/bu/fall2024/ecse524674/home`.

Textbook: There is a required textbook for the course:

[BT] D. Bertsimas and J.N. Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific, 1997. It covers all the material we will cover except nonlinear programming. It is available at the BU bookstore, Amazon, and other vendors.

For the nonlinear programming part of the course we will use the lecture notes and

[Ber] D.P. Bertsekas, *Nonlinear Programming*, 3rd Edition, Athena Scientific, 2016.

You don't have to buy this book for the course; you may want to, since it will be the textbook for the more advanced optimization course SE 724/EC 724.

Other books on these topics are:

[PS] C.H. Papadimitriou and K. Steiglitz, *Combinatorial Optimization: Algorithms and Complexity*, Prentice-Hall, 1982.

[Lue] D.G. Luenberger, *Introduction to Linear and Nonlinear Programming, (2nd Ed.)*, Addison-Wesley, 1984.

[BSS] M.S. Bazaraa, H.D. Sherali, and C.M. Shetty, *Nonlinear Programming: Theory and Algorithms (2nd Ed.)*, Wiley, 1993.

[Mur] K.G. Murty, *Linear Programming*, Wiley, 1983.

Grading:

1. 20% Homework (based on the best $n-1$ out of the n assignments).
2. 80% from 3 exams, equally weighted.
3. Class participation is an important tiebreaker.

Homework submission: All homework submissions should be done as scanned pdf files in Gradescope. Homework can be turned in one day late, with a 25% penalty in grading.

All problem solutions will be available 24 hours after HW is due. Once solutions are available, no late HWs will be accepted by Gradescope.

HW grading: We will grade some problems selectively on your Homeworks and comment on them. We expect that you will look over the homework solutions and correct your other problems. Correcting your HW is an important pedagogical exercise that will help you learn the material.

Rules of Conduct: You *may* collaborate in study groups on the solution of homeworks. You *must*, however, write up solutions on your own. If you do collaborate you *should* acknowledge your collaborators in the write-up for each problem. Also, if you used other material in obtaining a solution (e.g., other books, papers, on-line material, or even ChatGPT) you *should* reference your source. Using material from prior terms or ChatGPT is strongly *discouraged*. ChatGPT, for instance, is not great for mathematical problems of the types you will be asked to solve. Without solving problems on your own, you may not internalize the material and this will be reflected in the exams. The due day on homeworks is *strict*. A detailed description of the BU Academic Conduct Code is at: `https://www.bu.edu/academics/policies/academic-conduct-code/`.

All lecture notes, homeworks, solutions, exams, and in general any material associated with this class is **copyrighted material**. Do not post it to any on-line forum, web site, or any other repository.

Exam Policies:

You will be allowed to bring a set of four pages of notes for the exam. Usually, looking anything up takes much valuable time needed to do the problem, so use references very sparingly if you expect to finish. It is far better to attempt every problem and get partial credit than to leave problems blank and get 0 credit because you ran out of time looking stuff up in your notes.

Optimization Solver: Throughout the semester you can use solvers of your choice. Some choices include Matlab and gurobi (`http://www.gurobi.com/`), a commercial and very powerful Linear Programming (LP), Quadratic Programming (QP), and Integer Programming (IP) solver. You can install gurobi on your machine: there is both a free academic license and a free version for online courses which can be used anywhere but has some problem size limitations. The manual of gurobi is available at `http://www.gurobi.com/documentation/`; look for the Quick Start Guide. You can use the “Interactive Shell” for simple problems but also gradually familiarize yourselves with the callable library – the method of choice for anything but toy problems.

Syllabus (tentative)

1. Introduction and linear programming (LP) formulations.
2. More LP Formulations; Linear Algebra review; Polyhedra and convex sets.
3. Geometry of LP I.
4. Geometry of LP II.
5. Simplex method I.
6. Simplex method II.
7. Simplex method III.
8. LP Duality I.
9. LP Duality II.
10. LP Duality III.
11. Sensitivity analysis.
12. Parametric LP and a case study.
13. Quiz 1.
14. Large Scale Optimization I.
15. Large Scale Optimization II and Nonlinear Programming (NLP) I.
16. NLP II.
17. NLP III.
18. Interior-point methods I.
19. Interior-point methods II.
20. Networks I.
21. Networks II.
22. Integer Programming (IP) I.
23. IP II.
24. A Case Study on the fleet assignment problem.
25. Final Exam (during Final Exam period)