Course Information

Optimization is a major part of the toolbox of the applied mathematician, and more broadly, of researchers in quantitative sciences including economics, data science, machine learning, and quantitative social sciences. The course will cover some theory (duality, minimax problems, convexity) and algorithms (descent algorithms in the nonlinear case, simplex and interior point methods in the linear case). The course will put emphasis on numerical implementation.

Course Overview and Goals

Upon Completion of this Course, students will be able to:

Nonlinear optimization

· convex function and conjugacy

· Steepest descent, line search, convergence

· Other descent methods: Newton, Coordinate descent

· Conjugate gradient, proximal gradient methods
  
  ● Constrained nonlinear optimization: primal methods, barrier methods, dual methods

Linear optimization

· basics of duality, minimax theorems, complementary slackness, notions of integrality

· practical implementation on a solver

· dynamic programming and backward induction
· shortest path problem and optimal assignment problem
· network flows, optimality and equilibrium
· various applications to economics, finance and data science

Course Requirements

Prerequisites
Linear algebra, Calculus 3

Class Participation
This grade will be based on your performance during class time, ability to respond to required readings, critically engage with relevant concepts, and productively participate in group work. Your attendance at every class session is expected, and absences and tardiness will negatively affect your grade.

Assignment 1
Mid-term examination (at home)

Assignment 2
Numerical project (at home)

Assignment 3
Final exam (in class)

Grading of Assignments
The grade for this course will be determined according to the following formula:

<table>
<thead>
<tr>
<th>Assignments/Activities</th>
<th>% of Final Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class participation</td>
<td>[10%]</td>
</tr>
<tr>
<td>Mid-term paper</td>
<td>[30%]</td>
</tr>
<tr>
<td>Numerical project</td>
<td>[20%]</td>
</tr>
<tr>
<td>Assignments/Activities</td>
<td>% of Final Grade</td>
</tr>
<tr>
<td>------------------------</td>
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</tr>
<tr>
<td>Final exam</td>
<td>[30%]</td>
</tr>
</tbody>
</table>

**Letter Grades**

Letter grades for the entire course will be assigned as follows:

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Points</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16-20</td>
<td>Outstanding</td>
</tr>
<tr>
<td>A-</td>
<td>15</td>
<td>Excellent</td>
</tr>
<tr>
<td>B+</td>
<td>14</td>
<td>Very Good</td>
</tr>
<tr>
<td>B</td>
<td>13</td>
<td>Good</td>
</tr>
<tr>
<td>B-</td>
<td>12</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>C+</td>
<td>11</td>
<td>Above Average</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>Average</td>
</tr>
<tr>
<td>C-</td>
<td>9</td>
<td>Below Average</td>
</tr>
<tr>
<td>D+</td>
<td>8</td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>D</td>
<td>7</td>
<td>Low Pass</td>
</tr>
<tr>
<td>D-</td>
<td>6</td>
<td>Low Pass</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>Fail</td>
</tr>
</tbody>
</table>
Part 1. Nonlinear optimization

Section I. Generalities (2 lectures)
- Minimization of a convex function
- Convex conjugacy

Section II. Descent methods (4 lectures)
- Steepest descent, line search
- Global convergence, speed of convergence
- Newton descent
- Coordinate descent

Section III. More advanced methods (3 lectures, time permitting)
- Conjugate gradient methods
- Proximal gradient methods
- Quasi-Newton methods

Section IV. Constrained nonlinear optimization (3 lectures)
- Primal methods
- Barrier methods
- Dual methods

Part 2. Linear optimization (12 lectures)

Section V: Basic theory (4 lectures)
- Overview and main concepts of linear programming
- Duality and complementary slackness
- Computation in a solver. Application: optimal diet, based on Stigler’s original diet data (1945)

- Game theory: Zero-sum games

**Section VI: Dynamic programming (2 lectures)**

- Dynamic programming as a linear programming problem


**Section VII. Matching models (2 lectures)**

- Monge-Kantorovich duality in the discrete case

- Stable matchings. Application: dating platforms based on Dutch marriage data

**Part IV: Network flow problems (4 lectures)**

- Network flows, mass balance, path, cycles

- Min-cost flow duality

- Trade equilibrium

- Shortest path problem and the Bellman-Ford algorithm. Application: shortest path in a subway network based on the structure of NYC subway

**Course Materials**

**Required Textbooks & Materials**

- All readings will be put in a online.

**Optional Textbooks & Materials**


**Software:**
• Python / Numpy
• Gurobi

Resources

• **Access your course materials:** NYU Classes (nyu.edu/its/classes)
• **Databases, journal articles, and more:** Bobst Library (library.nyu.edu)
• **Assistance with strengthening your writing:** NYU Writing Center (nyu.mywconline.com)
• **Obtain 24/7 technology assistance:** IT Help Desk (nyu.edu/it/servicedesk)

Course Policies

Attendance and Tardiness

• Study abroad at Global Academic Centers is an academically intensive and immersive experience in which students from a wide range of backgrounds exchange ideas in discussion-based seminars. Learning in such an environment depends on the active participation of all students. And since classes typically meet once or twice a week, even a single absence can cause a student to miss a significant portion of a course. To ensure the integrity of this academic experience, class attendance at the centers is mandatory, and unexcused absences will be penalized with a two percent deduction from the student’s final course grade for every week’s worth of classes missed. Students are responsible for making up any work missed due to absence. Repeated absences in a course may result in harsher penalties including failure.

• Unexcused absences affect students’ grades: unexcused absences will be penalized with a 2% deduction from the students’ final course grade.

• Absences are excused only for illness, religious observance, and emergencies.

**Illness:** For a single absence, students may be required to provide a doctor’s note, at the discretion of the Associate Director of Academics. In the case of two consecutive absences, students must provide a doctor’s note. Exams, quizzes, and presentations will not be made up without a doctor’s note.

**Religious Observance:** Students observing a religious holiday during regularly scheduled class time are entitled to miss class without any penalty to their grade. This is for the holiday only and does not include the days of travel that may come before and/or after the holiday. Students must notify their instructor and the Academic Office in writing via email one week in advance before being absent for this purpose. If exams, quizzes,
and presentations are scheduled on a holiday a student will observe, the Associate Director, in coordination with the instructor, will reschedule them.

**Please note:** if you are unable to attend class, you are required to email your professors directly to notify them.

**Late Assignment**

Late submission or work will be accepted only with justifiable reasons of health or family emergency.

**Academic Honesty/Plagiarism**

*At NYU, a commitment to excellence, fairness, honesty, and respect within and outside the classroom is essential to maintaining the integrity of our community.*

**Plagiarism:** presenting others’ work without adequate acknowledgement of its source, as though it were one’s own. *Plagiarism is a form of fraud. We all stand on the shoulders of others, and we must give credit to the creators of the works that we incorporate into products that we call our own.* Some examples of plagiarism:

- a sequence of words incorporated without quotation marks
- an unacknowledged passage paraphrased from another’s work
- the use of ideas, sound recordings, computer data or images created by others as though it were one’s own
- submitting evaluations of group members’ work for an assigned group project which misrepresent the work that was performed by another group member
- altering or forging academic documents, including but not limited to admissions materials, academic records, grade reports, add/drop forms, course registration forms, etc.

*For further information, students are encouraged to check www.nyu.edu/about/policies-guidelines-compliance/policies-and-guidelines/academic-integrity-for-students-at-nyu.html*

**Disability Disclosure Statement**

Academic accommodations are available for students with disabilities. Please contact the Moses Center for Students with Disabilities (212-998-4980 or mosescsd@nyu.edu) for further information. Students who are requesting academic accommodations are advised to reach out to the Moses Center as early as possible in the semester for assistance.