**RUTGERS**
Rutgers Business School
Newark and New Brunswick

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| **Operations Research**<br>**Course Number: 26:711:652**<br>**Course Title: Nonlinear Optimization** |

## COURSE DESCRIPTION

The aim of this course is to convey a solid understanding of the theoretical and practical fundamentals of nonlinear optimization. I will not attempt to rigorously prove every result discussed in the class. In some cases I will refer you to the textbook for proofs, and just give an interpretation of the results in class, or just sketch the key ideas in proofs you can find in the textbook of reference material. In other cases and where I think they will be illuminating, I will give full proofs in class. Throughout the semester, we will review and introduce some basic concepts from real and convex analysis as they are needed. The planned topics are as follows:

1. Unconstrained optimization
   a. Elements of convex analysis
      i. Convex sets
      ii. Convex functions
   b. Local optimality conditions for differentiable unconstrained problems
   c. Line search algorithms
   d. Gradient and related methods
   e. Algorithm rates of convergence
   f. Newton methods
   g. Conjugate gradient / quasi-Newton methods

2. Optimality conditions for constrained optimization problems
   a. More elements of convex analysis
      i. Projection and separation
      ii. Cones, polars, and duals
      iii. Recession, feasible direction, tangent, and normal cones
   b. Simple abstract optimality conditions for functions and sets
   c. Constraint qualifications, metric regularity, and separation
   d. Lagrange necessary condition, Lagrangians

3. Langrangian duality for nonlinear optimization

4. Constrained optimization methods
   a. Gradient projection methods
   b. Reduced gradient / feasible direction methods

   c. Penalty methods
   d. Newton / SQP methods
   e. Barrier methods
   f. Augmented Lagrangian methods

## COURSE MATERIALS

- Required textbook: *Nonlinear Optimization* by Andrzej Ruszczyński, Princeton University Press, 2006
- Optional supplementary textbook: *Nonlinear Programming*, Second Edition, by Dimitri Bertsekas, Athena Scientific, 1999
- Occasionally, supplementary course notes will be distributed in class and made available online.

## LEARNING GOALS AND OBJECTIVES

Students completing the course should understand the fundamentals of optimization of nonlinear functions, possibly subject to nonlinear constraints. This includes optimality conditions, algorithms, duality, and some related elementary aspects of convex analysis.

## PREREQUISITES AND EXPECTED BACKGROUND

The course does not assume prior background in optimization. However, it does assume knowledge of elementary linear algebra, real analysis, and multivariable calculus. Some resources you may find helpful in reviewing this material include

- *Principles of Mathematical Analysis* by Walter Rudin, McGraw-Hill, 1953/1976.
- *Linear Algebra and Its Applications* by Gilbert Strang, Harcourth Brace Jovanovich, 1988.

## ACADEMIC INTEGRITY

*I do* NOT *tolerate cheating*. Students are responsible for understanding the RU Academic Integrity Policy
http://academicintegrity.rutgers.edu/

I will strongly enforce this Policy and pursue *all* violations. On all examinations and assignments, students must sign the RU Honor Pledge, which states, "On my honor, I have neither received nor given any unauthorized assistance on this examination or assignment." I will screen all written assignments through *SafeAssign* or *Turnitin*, plagiarism detection services that compare the work against a large database of past work. Don't let cheating destroy your hard-earned opportunity to learn. See business.rutgers.edu/ai for more details.

## ATTENDANCE AND CLASS CANCELLATION POLICIES

As this is a graduate class, I do not plan to take formal attendance.

Severe weather and other cancellations:

- My general policy is to hold class whenever the campus is open and class is scheduled, regardless of the weather or religious observances.
- Your primary source of information for whether the campus is open is the [Rutgers New Brunswick operating status page](). I will base the class on whether the New Brunswick campus is open because I will be physically present there and the majority of students have registered for that location.
- You may also check the course website at [()](), where I will try to post cancellation information if possible.
- If it is impossible or unsafe for me to attend class and I cannot find a substitute lecturer, I will make every effort to send an e-mail announcement (to your e-mail address officially registered with Rutgers) and post an announcement on (). This eventuality is highly unlikely if the campus is open (I have only cancelled class once in 24 years, due to severe last-minute illness).

## ASSIGNMENTS, EXAMS, AND ACADEMIC INTEGRITY

**All policies are subject to change at the instructor's discretion:**

Assignments:

- I will give homework assignments every week or two throughout the semester.
- Students not attending in person in New Brunswick should scan their assignments and email them to the instructor.
- Tentatively, homework assignments will account for 30% of your grade.

Exams:

- I will give two take-home exams, one approximately in the middle of the course and one after the last class
- There is to be no communication with anybody other than the instructor about the exams
- If I detect any violation of exam policies, I will prosecute them as a violation of the Rutgers University academic integrity policy outlined here:

    http://academicintegrity.rutgers.edu/

    Students are expected to be familiar with the school's academic integrity policies.
    Additional information may be found at http:/business.rutgers.edu/ai. -
    Each exam is tentatively worth 35% of your grade.

## COURSE TECHNOLOGY

o For material that cannot be publicly released, refer to Canvas
- For computational experiments, we will use MATLAB, including its symbolic toolbox.  This software is site-licensed throughout the university and may be downloaded from https://software.rutgers.edu.

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## SUPPORT SERVICES

If you need accommodation for a ***disability***, obtain a Letter of Accommodation from the Office of Disability Services. The Office of Disability Services at Rutgers, The State University of New Jersey, provides student-centered and student-inclusive programming in compliance with the Americans with Disabilities Act of 1990, the Americans with Disabilities Act Amendments of 2008, Section 504 of the Rehabilitation Act of 1973, Section 508 of the Rehabilitation Act of 1998, and the New Jersey Law Against Discrimination. More information can be found at ods.rutgers.edu.

[Rutgers University-New Brunswick ODS phone (848)445-6800 or email dsoffice@echo.rutgers.edu]

[Rutgers University-Newark ODS phone (973)353-5375 or email ods@newark.rutgers.edu]

If you are ***pregnant***, the Office of Title IX and ADA Compliance is available to assist with any concerns or potential accommodations related to pregnancy.

[Rutgers University-New Brunswick Title IX Coordinator phone (848)932-8200 or email jackie.moran@rutgers.edu]

[Rutgers University-Newark Office of Title IX and ADA Compliance phone (973)353-1906 or email TitleIX@newark.rutgers.edu]

If you seek ***religious accommodations***, the Office of the Dean of Students is available to verify absences for religious observance, as needed.

[Rutgers University-New Brunswick Dean of Students phone (848)932-2300 or email deanofstudents@echo.rutgers.edu]

[Rutgers University-Newark Dean of Students phone (973)353-5063 or email DeanofStudents@newark.rutgers.edu]

If you have experienced any form of ***gender or sex-based discrimination or harassment***, including sexual assault, sexual harassment, relationship violence, or stalking, the Office for Violence Prevention and Victim Assistance provides help and support. More information can be found at http://vpva.rutgers.edu/.

[Rutgers University-New Brunswick incident report link: http://studentconduct.rutgers.edu/concern/. You may contact the Office for Violence Prevention and Victim Assistance at (848)932-1181]

[Rutgers University-Newark incident report link: https://cm.maxient.com/reportingform.php?RutgersUniv&layout_id=7 . You may also contact the Office of Title IX and ADA Compliance at (973)353-1906 or email at TitleIX@newark.rutgers.edu. If you wish to speak with a staff member who is confidential and does **not** have a reporting responsibility, you may contact the Office for Violence Prevention and Victim Assistance at (973)353-1918 or email run.vpva@rutgers.edu]


If students who have experienced a temporary condition or injury that is adversely affecting their ability to fully participate, you should submit a request via https://temporaryconditions.rutgers.edu .


If you are a military *veteran* or are on active military duty, you can obtain support through the Office of Veteran and Military Programs and Services. http://veterans.rutgers.edu/


If you are in need of *mental health* services, please use our readily available services.

[Rutgers University-Newark Counseling Center: http://counseling.newark.rutgers.edu/]

[Rutgers Counseling and Psychological Services–New Brunswick: http://rhscaps.rutgers.edu/]


If you are in need of *physical health* services, please use our readily available services.

[Rutgers Health Services – Newark: http://health.newark.rutgers.edu/]

[Rutgers Health Services – New Brunswick: http://health.rutgers.edu/]


If you are in need of *legal* services, please use our readily available services: http://rusls.rutgers.edu/


Students experiencing difficulty in courses due to ***English as a second language (ESL)*** should contact the Program in American Language Studies for supports.

[Rutgers–Newark: PALS@newark.rutgers.edu]

[Rutgers–New Brunswick: eslpals@english.rutgers.edu]

If you are in need of additional *academic assistance*, please use our readily available services.

[Rutgers University-Newark Learning Center: http://www.ncas.rutgers.edu/rlc

[Rutgers University-Newark Writing Center: http://www.ncas.rutgers.edu/writingcenter]

[Rutgers University-New Brunswick Learning Center: https://rlc.rutgers.edu/]

[Optional items that many faculty include:

 - Students must sign, date, and return a statement declaring that they understand the RU Academic Integrity Policy.

 - Students must sign, date, and return a statement declaring that they understand this syllabus.]