MATH 767: Fast Numerical Algorithms
Fall 2022 Course Syllabus

NJIT Academic Integrity Code: All Students should be aware that the Department of Mathematical Sciences takes the University Code on Academic Integrity at NJIT very seriously and enforces it strictly. This means that there must not be any forms of plagiarism, i.e., copying of homework, class projects, or lab assignments, or any form of cheating in quizzes and exams. Under the University Code on Academic Integrity, students are obligated to report any such activities to the Instructor.

COURSE INFORMATION

Course Description: This is an advanced graduate level course. The course covers state-of-the-art, analysis based fast numerical algorithms for computing discrete summations or transforms and for solving differential or integral equations. Specifically, this course discusses fast multiple methods (FMM) for the Laplace kernels, kernel independent FMM,fast algorithms in data science, fast Fourier transform for nonequispaced data (NUFFT), randomized algorithms for numerical linear algebra, fast direct solvers, and integral equation methods for solving elliptic boundary value problems.

Number of Credits: 3

Prerequisites: There are no official prerequisites for this course. But this is an advanced graduate level course. And students are expected to know the material in Numerical Methods and Linear Algebra at either the undergraduate level or graduate level. Students are also expected to be familiar with programming in scientific computing.

Course-Section and Instructors:

Course-Section	Instructor
Math 767-001	Professor T. Askham

Office Hours for All Math Instructors: Fall 2022 Office Hours and Emails

Required Textbook:

"Fast Direct Solvers for Elliptic PDEs" by Per-Gunnar Martinsson. SIAM 2020.

University-wide Withdrawal Date: The last day to withdraw with a **M** is **Monday, November 14, 2022**. It will be strictly enforced.

COURSE GOALS

Course Objectives

- Cover state-of-the-art fast numerical algorithms including FMMs, NUFFT, the butterfly algorithm, randomized algorithms, and fast-direct solvers.
- Present integral equation methods for solving elliptic boundary value problems.
- Provide training in both mathematical analysis and programming skills for fast numerical algorithms.

Course Outcomes

- Provide students a solid foundation in both mathematical analysis and programming skills on fast numerical algorithms.
- Prepare students for further study and applications in related research fields.
- Prepare students into the fields of high performance computing and data science.

Course Assessment: The assessment of objectives is achieved through homework, midterm and final projects.

POLICIES

DMS Course Policies: All DMS students must familiarize themselves with, and adhere to, the Department of Mathematical Sciences Course Policies, in addition to official university-wide policies. DMS takes these policies very seriously and enforces them strictly.

Grading Policy: The final grade in this course will be determined as follows:

Homework	50%
Presenting a Section (One Lecture in Weeks 3-10)	10%
Final Project	40%

Your final letter grade will be based on the following tentative curve.

A	88 - 100	**C+**	70 - 74
B+	83 - 87	**C**	60 - 69
B	75 - 82	**F**	0 - 59

Attendance Policy: Attendance at all classes will be recorded and is **mandatory**. Please make sure you read and fully understand the Math Department's Attendance Policy. This policy will be strictly enforced.

Homework/Projects Policy: All homework and projects must be done independently. NJIT honor code will be strictly enforced. LATE homework/projects are NOT accepted.

Presenting a Section: Part of this course will be seminar style. You will be assigned part of a chapter from Martinsson to present to your classmates. It is recommended that you prepare lecture notes or slides. You can do this with (up to) one partner.

Makeup Exam Policy: To properly report their absence during a midterm or final exam, please review the required steps under the DMS Examination Policy found here:

http://math.njit.edu/students/policies_exam.php

Cellular Phones: All cellular phones and other electronic devices must be switched off during all class times.

ADDITIONAL RESOURCES

Further Assistance: For further questions, students should contact their instructor. All instructors have regular office hours during the week. These office hours are listed on the Math Department's webpage for Instructor Office Hours and Emails.

Accommodation of Disabilities: The Office of Accessibility Resources and Services (OARS) offers long term and temporary accommodations for undergraduate, graduate and visiting students at NJIT.

If you are in need of accommodations due to a disability please contact Scott Janz, Associate Director of Disability Support Services at 973-596-5417 or via email at scott.p.janz@njit.edu. The office is located in Kupfrian Hall, Room 201. A Letter of Accommodation Eligibility from the Office of Accessibility Resources and Services office authorizing your accommodations will be required.

For further information regarding self identification, the submission of medical documentation and additional support services provided please visit the Office of Accessibility Resources and Services (OARS) website.

Important Dates (See: Fall 2022 Academic Calendar, Registrar)

Date	Day	Event
September 5, 2022	Monday	Labor Day
September 6, 2022	Tuesday	First Day of Classes
September 12, 2022	Monday	Last Day to Add/Drop Classes
November 14, 2022	Monday	Last Day to Withdraw
November 22, 2022	Tuesday	Thursday Classes Meet
November 23, 2022	Wednesday	Friday Classes Meet
November 24 to November 25, 2022	Thursday and Friday	Thanksgiving Recess - Closed
November 26, 2022	Saturday	Saturday Classes Meet
December 14, 2022	Wednesday	Last Day of Classes
December 15, 2022	Thursday	Reading Day
December 16 to December 22, 2022	Friday to Thursday	Final Exam Period

Course Outline

Week	Topic (Chapters Refer to the Martinsson Textbook)
1-2	*Fast Fourier transform and applications; fast Poisson solver on rectangles (Lecture notes, Henrici 1979)*
2-3	*A direct solver for variable coefficient PDEs (Martinsson 2013)*
3-4	*Overview, review of linear algebra concepts, interpolative decomposition, intro to randomization (Ch 2-4)*
5	*Randomized range finder and compression (Ch 4)*
6	*Fast-direct method for structured (HODLR) matrices; application to Gaussian processes (Ch 5 and Ambikasaran et al. 2015)*
7	*FMM ideas (Ch 6)*
8	*FMM algorithm (Ch 7)*
9	*FMM extensions and linear algebra interpretation (Parts of Ch 8-9)*
10	*Crash course on integral equation methods (Ch 10)*
11	*Basics of discretizing integral equations (Ch 12)*
12	*Compressing functions and designing quadrature (Bremer et al., 2010)*
13	*Non-uniform FFT (Dutt-Rokhlin 1993, Barnett et al. 2019)*
14	*Non-uniform FFT (continued); intro to butterfly algorithms (Michiellsen-Boag 1996)*
If time	*Butterfly algorithms (O'Neil-Rokhlin 2007)*