# MATH 767: Fast Numerical Algorithms
## *Fall 2021 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. Though Matlab has become increasingly popular in academic pedagogical setting and for algorithm prototyping, students are encouraged to use Fortran, C, or Python for homework/projects.

**Course-Section and Instructors:**

| Course-Section | Instructor |
|---|---|
| Math 767-001 | Professor M. Siegel |

**Office Hours for All Math Instructors**: Fall 2021 Office Hours and Emails

**Required Textbook**:

> *There is no textbook for this course since fast numerical algorithms are quite recent and still under active development. We will distribute lecture notes and draw resources from original research papers and lecture notes from similar courses taught elsewhere.*

**University-wide Withdrawal Date**: The last day to withdraw with a **W** is **Wednesday, November 10, 2021**. 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, 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 on 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% |
|----------|-----|
| Midterm Exam | 20% |
| Final Project | 30% |

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.

**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

**Math Tutoring Center**: Located in the Central King Building, Lower Level, Rm. G11 (See: Fall 2021 Hours)

**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 at:

https://www.njit.edu/studentsuccess/accessibility/

**Important Dates** (See: Fall 2021 Academic Calendar, Registrar)

| Date | Day | Event |
|------|-----|-------|
| September 1, 2021 | Wednesday | First Day of Classes |
| September 4, 2021 | Saturday | Saturday Classes Begin |
| September 6, 2021 | Monday | Labor Day |
| September 8, 2021 | Wednesday | Monday Classes Meet |
| September 8, 2021 | Wednesday | Last Day to Add/Drop Classes |
| November 10, 2021 | Wednesday | Last Day to Withdraw |
| November 25 to November 28, 2021 | Thursday to Sunday | Thanksgiving Recess - Closed |
| December 10, 2021 | Friday | Last Day of Classes |
| December 13 and December 14, 2021 | Monday and Tuesday | Reading Days |
| December 15 to December 21, 2021 | Wednesday to Tuesday | Final Exam Period |

# Course Outline

| Week | Topic |
| --- | --- |
| 1 | *Fast algorithms in data science, stochastic gradient descent, logistic regression* |
| 2 | *FFT and Fast Poisson Solver* |
| 3 | *Fundamental Solutions, layer potentials, jump relations* |
| 4 | *Integral equations* |
| 5 | *High order quadratures for integral operators* |
| 6 | *High order quadratures (continued)* |
| 7 | *Integral equation methods* |
| 8 | *Introduction to FMM* |
| 9 | *FMM (continued)* |
| 10 | *Kernel Independent FMM* |
| 11 | *Non-uniform FFT (NUFFT)* |
| 12 | *NUFFT (continued)* |
| 13 | *Randomized algorithms* |
| 14 | *Randomized algorithms (continued)* |