MATH 451-H04: Methods of Applied Mathematics II (Capstone II) *Spring 2025 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: Small teams of students conduct research projects under the guidance of faculty members who perform applied research. Effective From: Spring 2009.

Number of Credits: 3

Prerequisites: Math 450H with a grade of C or better.

Course-Section and Instructors

Course-Section	Instructor
Math 451-H04	Professor L. Kondic

Office Hours for All Math Instructors: Spring 2025 Office Hours and Emails

Course Materials:

(1) Korvin, G. Statistical Rock Physics, Chapters 1 – 4, Springer (2024) (to be provided by the instructor)

(2) Probstein, R. F., Physicochemical Hydrodynamics, Willey (1994) (to be provided by the instructor)

(3) Porter, M., Feng, M., Katifori, E., High accuracy capillary network representation in digital rock reveals permeability scaling functions, Phys. Today 76, 36 (2023).

(4) Liu, J., etal, ChatGPT for computational topology, Foundations of Data Science 6, 221 (2024)

(5) Röding, M., etal, Predicting permeability via statistical learning on higher-order microstructural information, Scientific Reports 10, 15239 (2020).

(6) Neumann, R. F. etal, High accuracy capillary network representation in digital rock reveals permeability scaling functions, Scientific Reports 11, 11370 (2021).

(7) Sudakov. O. etal, Driving digital rock towards machine learning: Predicting permeability with gradient boosting and deep neural networks, Computers and Geoscience 127, 91 (20119).

(8) Alqahtani, N. etal, Machine learning for predicting properties of porous media from 2d X-ray Images, J. Petroleum Science and Engineering 184, 106514 (2020).

(9) Linden, J. H. etal, Machine learning framework for analysis of transport through complex networks in porous, granular media: A focus on permeability, Physical Review E 94, 022904 (2016)

(10) Suzuki A. etal, Flow estimation solely from image data through persistent homology analysis, Scientific Reports 11, 17948 (2021).

University-wide Withdrawal Date: The last day to withdraw with a **W** is **Monday, April 7, 2025**. It will be strictly enforced.

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:

Projects and Presentations	70%
Final Report and Presentation	30%

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.

Religious Observance: NJIT is committed to supporting students observing religious holidays. Students must notify their instructors in writing of any conflicts between course requirements and religious observances, ideally by the end of the second week of classes and no later than two weeks before the anticipated absence.

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: Spring 2025 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.

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

Accommodation of Disabilities: Disability Support Services (DSS) 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 Chantonette Lyles, Associate Director of Disability Support Services at 973-596-5417 or via email at lyles@njit.edu. The office is located in Fenster Hall Room 260. A Letter of Accommodation Eligibility from the Disability Support 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 Disability Support Services (DSS) website at:

http://www5.njit.edu/studentsuccess/disability-support-services/

Important Dates (See: Spring 2025 Academic Calendar, Registrar)

Date	Day	Event
January 21, 2025	Tuesday	First Day of Classes
January 27, 2025	Monday	Last Day to Add/Drop Classes
March 16, 2025	Sunday	Spring Recess Begins
March 22, 2025	Saturday	Spring Recess Ends
April 3, 2025	Thursday	Wellness day
April 7, 2025	Monday	Last Day to Withdraw
April 18, 2025	Friday	Good Friday - No Classes
April 20, 2025	Sunday	Easter Sunday - No Classes Scheduled
May 6, 2025	Tuesday	Thursday Classes Meet
May 7, 2025	Wednesday	Friday Classes Meet
May 7, 2025	Wednesday	Last Day of Classes
May 8, 2025	Thursday	Reading Day 1
May 9, 2025	Friday	Reading Day 2
May 10 - May 16, 2025	Friday to Thursday	Final Exam Period

Course Outline

From structure to performance of porous media using image processing, topological data analysis and machine learning

Introduction and Background (2 weeks)

Porous media transport: relevance and basics of continuum modeling;

Established formulations and results: Darcy's law, successes and limitations; Kozeny-Carman regression model

Computational methods for porous media flow: Partial differential equations based approaches; lattice Boltzmann based approach

Experimental and computational data for porous media flow in applications

Reading: Reference (1) and (2) (selected chapters)

Project 1

Methods for producing synthetic porous media data

Computing flow and permeability of synthetic data

Characterizing various microstructures

Development of predictive models

***AI component*:** AI/ML methods for predicting flow performance: comparison of linear regression-based approaches with neural network results; compare with the results of Project 2

Literature: Reference (5), which also contains links to publicly available software, see also TensorFlow; Additional references: (4, 7, 8)

Goal: Reproduce selected results of Ref. (5) and discuss the comparison of various AI methods

Project 2

Methods for reducing image data to pore networks

Computing flow through pore networks using the same data as in Project 1

Computing permeability and comparing the results with the ones obtained by Project 1

AI component: Application of AI/ML methods to flow through networks; compare with the results of Project 1

Goal: Discuss the applicability of network representation through a comparison of the results with the ones obtained using original images

Literature: References (6, 9); See also TensorFlow for AI/ML methods, and Porespy for reduction of images to pores; Additional references: (3, 8)

Project 3

Application of computational topology to the data used in Project 1 and 2

Computing persistence diagrams to quantify the image based data (Project 1) and networks based data (Project 2); formulate the methods for comparing topological properties of the data from Projects 1 and 2; for computing persistence diagrams consider the Gudhi library:

***AI component*:** Use persistence diagrams information to enhance ML methods, and discuss improvements of the results if persistence results are used or not.

Goal: Quantify the usefulness of computational topology based methods for analysis of porous media

Literature: References (1, Chapter 4, 10) ; Additional references: (3)