2025

STUDY GUIDE

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES
INTERDEPARTMENTAL POSTGRADUATE PROGRAMME
“MATHEMATICAL MODELING IN MODERN TECHNOLOGIES AND FINANCIAL ENGINEERING“

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES

INTERDEPARTMENTAL POSTGRADUATE PROGRAMME

“MATHEMATICAL MODELING IN MODERN TECHNOLOGIES AND FINANCIAL ENGINEERING“

Study Guide of the MSc Program
for the Academic Year 2024-25

INTERDEPARTMENTAL POSTGRADUATE PROGRAMME
“MATHEMATICAL MODELING IN MODERN TECHNOLOGIES AND FINANCIAL ENGINEERING“

STUDY GUIDE

ACADEMIC YEAR 2024-25

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Coordinating School:
SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES

Participating Schools:

- SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING
- SCHOOL OF CHEMICAL ENGINEERING
- SCHOOL OF RURAL, SURVEYING AND GEOINFORMATICS ENGINEERING
- SCHOOL OF MINING AND METALLURGICAL ENGINEERING

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STUDY GUIDE FOR MSc PROGRAM
“MATHEMATICAL MODELING IN MODERN TECHNOLOGIES AND FINANCIAL ENGINEERING“

A. Introduction

In recent decades, there has been a significant increase in research activity both internationally and in Greece, focusing on the study of natural processes, as well as technological, economic, and social issues using the tools of modern Mathematical Science.
The ever-increasing complexity of technological processes, industrial activities, and business operations demands the substantial contribution of applied mathematics, and more specifically, the so-called industrial mathematics, primarily in the form of mathematical modeling and computational mathematics. Mathematical analysis - deterministic or stochastic - numerical simulation, as well as learning mathematical models from data, can often replace long-term experiments in designing new materials, devices, and complex systems. This, in turn, significantly contributes to the development and implementation of processes that offer greater flexibility of choices, cost-efficiency, and safety in experimental testing. It also enhances the understanding of dynamic behavior within the ever-expanding spectrum of human activities, facilitating a new form of cooperation and interaction between humans and systems.
Today, it is widely recognized that modern perspectives of linear and nonlinear systems, deterministic and stochastic approaches, discrete techniques, as well as mathematical tools of continuity and advanced statistical methodologies capable of leveraging the available plethora of data of all forms, can play a pioneering role in all the aforementioned fields. However, to fully utilize these approaches, systematic development of fundamental research and extensive experience (and feedback) from the application of theoretical results to relevant problems are required.

Mathematical modeling constitutes a crucial branch of the physical, technological, and economic sciences for various reasons:
• It often leads to the discovery of particularly significant new phenomena that arise due to the complexity of systems and the non-local nature of the interactions occurring within them.
• It necessitates the combination of knowledge from different branches of mathematics and harmonizes them with an understanding of the processes occurring in the system under study at a physical, technological, biological, social, and economic level (depending on the case).
• Mathematical models allow for the cost-effective and systematic investigation of the behavior of the systems and processes they represent by adjusting a series of control parameters. They also facilitate the identification of optimal values and behaviors through numerical simulations and/or analytical observations.

B. Aims, Objectives and Discipline of the MS Program

1. Aims of the MSc Program

The aim of the Interdepartmental Postgraduate Programme “Mathematical Modeling in Modern Technologies and Finance” is to impart to students the existing international knowledge in the scientific fields of Mathematics and its applications, Economics and Finance, as well as Data Science and Materials Science. Over time, these fields increasingly demonstrate that they form a common meeting ground for the techniques of Mathematical Modeling, both for the processes that occur in natural phenomena and technological systems, and for the fundamental phenomena of social and economic systems' evolution.

The MSc Program is structured into three (3) specializations:

A) Modern Technologies,

B) Mathematics of Data Science,

C) Financial Engineering.

2. Objectives of the MSc Program

The objective of the program is to provide its students with high-level knowledge in the field of Mathematical Science, specifically in areas such as Mathematical Analysis (Deterministic and Stochastic), Differential Equations and Dynamical Systems, Numerical Analysis, and Statistics, as well as Economics and Finance, Computer Science, and Materials Science. Simultaneously, significant effort is made to initiate students—especially through the completion of their Postgraduate Diploma Thesis (PDT)—into the intricacies of scientific and technological research and to guide them in the production of new knowledge. This way, they will be equipped to pursue positions as executives in the market, in businesses within the broader Financial System, in organizations, and other technological, educational, or research institutions, in both the private and public sectors, both domestically and internationally. They may also seek positions in doctoral programs to compete for roles in universities and research groups domestically and abroad.

In alignment with the specific objectives of the National Technical University of Athens (NTUA), the MSc Program aims to:

• Maintain and enhance the quality of professional training.

• Ensure the control and objective evaluation of all graduate courses to guarantee the undisputed quality of the graduate level.

• Respond to current and future developmental needs.

• Enhance its attractiveness for students from other equivalent universities.

Upon successful completion of the relevant cycle of studies in one of the three specializations, the MSc Program awards a Diploma of Postgraduate Studies (DPS) - Master of Science, with the title:

"Mathematical Modeling in Modern Technologies and Financial Engineering".

3. Expected learning outcomes of the MSc Program

The expected learning outcomes and skills acquired upon successful completion of the program include the ability to use a wide range of mathematical theories and tools across the subjects of all three specializations. These skills are applicable both in daily applications in the market, businesses, and industry, as well as in the advancement of graduates in a variety of research fields—corresponding to academic disciplines—with a proficiency that consistently allows them to collaborate productively in any national and international environment.**.** *A more detailed description* *of the expected learning outcomes is provided for each specialization below.*

- **The Specialization in Modern Technologies:**

The objective of the MSc Program in Mathematical Modeling in Modern Technologies and Finance is to produce highly esteemed scientists and researchers who will work at Greek or foreign universities, research centers, and international organizations, as well as high-level executives who will be engaged in management and research in the fields of industry and business. Specifically, for students interested in the specialization of “Modern Technologies”, the MSc Program aims to:

- Provide comprehensive knowledge with a unified methodological approach to the fundamental tools of mathematical modeling of continuous and discrete systems and processes, both microscopic and macroscopic, deterministic and stochastic.
- Through examples (both in the laboratory and in real-world settings), reinforce the capabilities of modeling across a wide range of systems for the design of products and processes in the fields of biosciences (drug design, structure-activity relationships of biological macromolecules, biomedical engineering) and materials science (structure-property-processing-performance relationships, polymers, nanostructured materials and devices for applications in microelectronics, telecommunications, energy technologies, and environmental protection).

Students will be trained in creating mathematical models based on the physical sciences to describe the behavior of the aforementioned systems at various length and time scales (multiscale modeling) and in solving these models analytically or numerically using methods that ensure high reliability and low computational cost. They will understand how different levels of description and simulation (molecular, mesoscale, and macroscopic) can be interconnected to achieve an in-depth understanding and quantitative prediction of phenomena and the optimization of products and processes for specific applications.

Graduates of this specialization will be able to transform complex problems, encountered daily in the aforementioned fields, into functional models. The mathematical investigation and numerical simulation of these models will significantly impact the technological, scientific, and economic progress of our country.

The great importance of this specialization is evidenced, among other things, by the awarding of the 2013 Nobel Prize in Chemistry to Martin Karplus, Michael Levitt, and Arieh Warshel for the development of multiscale models for complex chemical systems. Additionally, large-scale research programs such as the Materials Genome Initiative in the USA aim to discover, produce, and utilize advanced materials twice as quickly and at a fraction of the current cost.

The structure of the Postgraduate Programme is based on the three fundamental categorizations of systems-models in general: macroscopic-microscopic, deterministic-stochastic, and continuous-discrete. Special emphasis is also placed on the importance and necessity of nonlinear perspectives.

Efforts are made to reflect all three main priorities, at least at the European and national level, namely environmental-life-quality technologies, materials, and information and communication technologies in their broadest sense.

- **The Specialization in Mathematics of Data Science:**

The objective of the MSc Program in “Mathematical Modeling in Modern Technologies and Finance” is to produce highly esteemed scientists and researchers who will work in Greek or foreign universities, research centers, and international organizations, as well as high-level executives who will be engaged in the management and research in the fields of Industry and Business. Specifically, for students interested in the Specialization of Data Science, the MSc Program aims to:

i. Provide comprehensive knowledge with a unified methodological approach to rapidly evolving tools of mathematical modeling based on the broader field of statistics, focusing on model learning from data, or "data analysis", capable of adapting to continuous change and scaling to large volumes.
ii. Through examples (in the Computational Systems Laboratory), reinforce the capabilities of modeling across a wide range of systems, covering the broad spectrum of life technologies (environment, quality of life and services, biology, biotechnology, and biomedical engineering), the information society (informatics, spatiotemporal signal processing, communications), and materials science.

Graduates of this program will be able to transform complex problems encountered daily in the aforementioned fields into operational standards, shaped by the vast availability of data in various formats. This will reflect external emerging reality in a way that is estimated to have a significant impact on the technological, scientific, and economic progress of our country.

Within this specialization, the most modern trends in the development of tools will be presented, capable of adequately analyzing data of any format and size, leading to representative models and intelligent systems.

According to both earlier and recent recommendations of internationally renowned scientists in Applied Mathematics and particularly in Statistics (such as John Tukey, John Chambers, Jeff Wu, Leo Breiman), the international academic community of applied mathematicians is expanding its boundaries beyond its existing fields. This aims to emphasize the preparation and presentation of data in mathematical models with improved predictive capabilities as well as inference provision, incorporating these tools into a recommended scientific example entitled "Data Science".

Drawing conclusions from the methodology of discovering scientific findings in different fields, it becomes apparent that the overwhelming majority of science is already, and will continue to be, in the foreseeable future, initiated from data, which can be extracted in various ways, as well as the application of tools for their appropriate analysis and mathematical modeling.

Furthermore, internationally, the provision of a robust mathematical background in models that also have the capability to learn from data, originating from other scientific fields such as computer science, is deemed of paramount importance. This approach helps avoid the sterile and beyond-their-limits use of these models with the "black box" logic, which can easily lead to their misuse. The aforementioned argument strengthens the adoption of such a specialization by academic schools whose discipline is mathematics.

In line with international developments in academia, particular reference should be made to similar initiatives undertaken by distinguished universities. Specifically, a recent and continually expanding phenomenon is the emergence of "data science" programs at major universities, including UC Berkeley, NYU, MIT, and the University of Michigan, which, in September 2015, announced an initiative called the Data Science Initiative, making significant investments with the aim of hiring several new faculty members. Similar initiatives have recently been announced by distinguished European universities. Teaching in these new programs has significant overlaps with the curriculum of traditional statistics programs. Although many academic statisticians perceive the new programs as a potential “cultural cohabitation”, they nonetheless make significant efforts to develop new methods suitable for application in large-scale data and execution by modern computational systems. Thus, according to international practice, efforts are made to leverage advanced computing techniques in statistical methods for data collection, processing, and analysis, such as process monitoring.

Additionally, indicative of this emerging direction is the launch of a new journal, SIAM Journal on Mathematics of Data Science (SIMODS), with submissions starting from April 25, 2018, covering fields such as numerical algorithms, statistical inference, optimization and control, machine learning, theoretical computer science, signal processing and information theory, applied probability, and functional analysis. This journal aims to reflect contemporary academic and research advancements in the field.

https://www.siam.org/journals/simods.php?utm_source=mbr_blurb&utm_medium=email_pre&utm_campaign=SIMODS_2018

Beyond the aforementioned paragraphs, which justify the establishment of this new Specialization based on modern academic and research developments, it is pertinent to provide a brief but illustrative description of the industry's advancements, which similarly underscore the same need. In the context of the 4th industrial revolution (Industry 4.0), which reflects the current trend of automation and data exchange in manufacturing plants, there is a prominent emphasis on the analysis and modeling of large-scale data, as well as the necessity for the development of robotics and intelligent systems. Furthermore, the emergence of startups offering artificial intelligence as a service to the general public and other companies is noted, creating a significant number of new job positions and mobilizing substantial investments in many countries, including Greece.

From the above, it becomes evident that the field of Data Science, proposed herein as a new Specialization in the MSc Program, is a cutting-edge domain of mathematical standardization characterized by the integration of new technologies that enable model learning from data, which can be scaled to “big data”.

- **The Specialization in Financial Engineering:**

For students interested in the “Financial Engineering” Specialization, the MSc Program aims to offer advanced knowledge, primarily in analytical and stochastic mathematics, as well as in fundamental tools of finance, alongside economic theory relevant to the field.

The aim of the MSc Program is to “produce” high-caliber scientists and researchers who will work in Greek or foreign universities, research centers, international organizations, as well as high-level executives who will be employed in financial advisory firms, financial institutions, or the financial departments of large companies. Special emphasis will be placed on the modeling of financial instruments through the application of stochastic processes, as well as on the evaluation of financial products within the framework of complete and incomplete markets.

Modern rearrangements have either led economic systems to liberalization or their inclusion in supranational formations. This framework has intensified international competition and created an environment characterized by intense challenges and high levels of uncertainty. These high levels of uncertainty decisively affect businesses, making timely and accurate assessment of their prospects critical for economic development

The analysis of the financial sector, one of the most critical pillars of the economy, includes, among other things, the evaluation of financial transactions of households and businesses. To achieve this goal, tools from microeconomics, econometrics, mathematics, and organizational theory are utilized.

The financial sector, aided by stochastic mathematics, has developed highly advanced models that are applied to address uncertainty and risk, both for investors-savers and businesses. This progress in finance, accompanied by corresponding scientific specialization, leads us to a better understanding of the phenomena observed in markets and businesses. Scientific analysis of these phenomena and their approach in the optimal manner, for all market factors, consequently leads the economy to optimal allocations.

Moreover, technological advancements in recent years are intertwined with corresponding rearrangements in the economic field, often making the technological and economic sectors interdependent.

C. Participating Entities - Infrastructure

The NTUA School of Applied Mathematical and Physical Sciences - SAMPS (as the Coordinating School), in collaboration with the Schools of Electrical and Computer Engineering (SECE), Chemical Engineering (SCHE), Rural, Surveying and Geoinformatics Engineering (SRSGE), and Mechanical Engineering (SME) of NTUA, organizes the present MSc Program in "Mathematical Modeling in Modern Technologies and Finance". Additionally, independent teaching staff and researchers from the Department of Economics of the University of Athens, the Aristotle University of Thessaloniki, the University of the Aegean, the Agricultural University, the Institute of Informatics and Telecommunications (IIT) of the National Center for Scientific Research "Demokritos", the Athens Stock Exchange, Universities Abroad, and distinguished scientists from related Greek Companies are participating.

Participating Schools

The concise description of the collaborating bodies of the MSc Program is as follows:

The School of Applied Mathematical and Physical Sciences (SAMPS), operated for the first time in the academic year 1999-2000, as the ninth School of NTUA, and remains to date the only School in Greece for the education of scientists-engineers in applied mathematics and physical sciences. Today, SAMPS includes the Sections of Mathematics, Physics, Engineering, Humanities, Social Sciences, and Law (HSSL). The curriculum offers two Specializations: Applied Mathematics and Applied Physics. The structure of the School in these Sections reflects precisely the characteristics that shape the profile of the School. All four Sections ensure a solid background of basic knowledge per study specialization, for the profile of the applied scientist, which is enriched by humanities courses. Based on its founding law , the mission of SAMPS is twofold:

(a) To cultivate and promote, through teaching, research, and applications, the disciplines falling within the fields of Mathematics, Physics, Engineering, and Humanities, and to teach courses belonging to these scientific fields in the other Departments of NTUA and

(b) To provide graduates with the necessary knowledge and tools for the application of new technologies and the scientific approach to issues relevant to both the private and public sectors, the organization of production, and decision-making through market data analysis. Additionally, it provides the scientific background necessary for their employment in research and development departments of companies, research centers, and academic institutions in the fields of Mathematics, Physics, and Engineering.

Based on its founding law, it can be succinctly stated that SAMPS aims to educate a new category of engineers of the future, who will act as intermediaries between the basic sciences and applied technology and will serve as conveyors of knowledge produced by research in the basic sciences to technological applications.
The founding objectives of SAMPS are also reflected in Presidential Decree 199, published in Government Gazette 226/14-09-2007/199, which professionally certifies the graduates of the School and describes in detail the fields in which they can operate.
It should be emphasized that during the 20-year operation of the School and following systematic discussions each time, significant improvements to the Curriculum have been decided and implemented. These improvements have, on one hand, clarified the profile of our graduates by adapting it to contemporary needs, and simultaneously reinforced the School's character as an "Engineering Sciences Department", contributing to the further professional accreditation of its alumni (membership in the Technical Chamber of Greece, certification of Pedagogical and Didactic adequacy).

The School is responsible for implementing an undergraduate curriculum as well as postgraduate curriculums, which are distinguished into two postgraduate levels: studies leading to a Diploma of Postgraduate Studies – Master of Science and studies leading to a Doctoral Degree (PhD). At the Master of Science level, there are 5 Interdepartmental - Interinstitutional Postgraduate Programmes (MSc Programs), coordinated respectively by the Sections of:

- Mathematics (MSc Program "Applied Mathematical Sciences", MSc Program "Mathematical Modeling in Modern Technologies and Financial Engineering")
- Physics (MSc Program "Physics and Technological Applications", MSc Program "Microsystems and Nanodevices")
- Engineering (MSc Program "Applied Engineering").

The NTUA School of Electrical and Computer Engineering (SECE) is the third oldest school at the NTUA and the school with the highest admission base among the Engineering Schools for many academic years.
The curriculum offers four specializations, which are as follows:

1. Electronics and Systems
2. Computer Science
3. Communications
4. Energy

Within these specializations, eight Course Streams are offered with varying degrees of participation in each specialization.
The SECE at the NTUA has been a pioneer in establishing postgraduate studies in Greece since the mid-1970s. The school provides numerous Interdepartmental Postgraduate Programmes in collaboration with other Greek universities, leading to a Diploma of Postgraduate Studies – Master of Science in technological and scientific fields. This provides graduates with the opportunity to advance science and successfully meet various labor market needs. Each curriculum has different

admission requirements and regulations outlined in the respective Study Guides.

The School of ECE coordinates the following Interdepartmental Postgraduate Programmes:

1. Energy Production and Management
2. Techno-Economic Systems
3. Data Science and Machine Learning
4. Translational Biomedical Engineering and Science.

The School ECE also participates in a total of 13 Interdepartmental Postgraduate Programmes, including the present MSc Program, and for many years, has operated autonomous Postgraduate and Doctoral Programmes.

The aim of this program is to cultivate engineers and scientists who can take on leadership roles in research and development at an international level, primarily addressing the extremely important and vital issues in the country. Recognizing that true technological knowledge can drive substantial progress and development, our School has endeavored to enhance Postgraduate-Doctoral Studies in conjunction with the execution of significant research projects within them. As a result, the School of ECE is the first School of NTUA to have a Doctoral Programme established since 1999, which confers the title of Doctor of Engineering or Doctor of NTUA. Today, the total number of doctoral candidates in the School of ECE is approximately 600, while the number of newly appointed doctors annually is around 60.

The NTUA School of Chemical Engineering (SCHE) at the NTUA consists of four Sections: Chemical Sciences, Analysis, Design and Development of Processes and Systems, Materials Science and Engineering, and Composition and Development of Industrial Processes. Research for generating new knowledge in all these fields progresses through doctoral theses conducted by postgraduate students. Additionally, both European and national funded research programs promote basic and applied research and enhance the School's collaboration with universities both domestically and internationally, as well as with the private sector, both nationally and internationally. Research, development, and improvement of products, methods, and facilities, the study, construction, operation, and technical service of chemical installations, and the design, production, testing, disposal, and applications of products and materials constitute not only fields of knowledge but also fields of research for the School. As a result of the entire research activity at the level of diploma theses, doctoral dissertations, and research programs, numerous scientific publications in the Greek and international space, as well as awards, have distinguished the scientific and teaching staff and the School in general.

The NTUA School of Rural, Surveying and Geoinformatics Engineering was renamed in July 2020 by the Senate of NTUA, following a comprehensive recommendation from the School, from “School of Rural and Surveying Engineering” to fully reflect the modern content of its disciplines.

In an era where Earth and spatial observation technologies generate an incredible volume of georeferenced data, not only concerning the physical space and its characteristics but also every form of socio-economic activity, while technologies of all kinds record and delve into socio-economic activities, the development and significance of geoservices and geoeconomics are now a reality..

In this new context, the role of the Rural and Surveying Engineer is not given, while simultaneously facing new challenges.

The participation of the School of Rural, Surveying and Geoinformatics Engineering in the development and operation of Postgraduate Programmes for a Diploma of Postgraduate Studies (Master of Science) is absolutely necessary, as it:

(a) supplies the research and scientific community with competent members,

(b) addresses a real need of individuals, organizations, and industry,

(c) promotes interdisciplinary collaboration and cooperation among students, scientists, and Schools, and

(d) connects undergraduate with doctoral studies.

The NTUA School of Naval Architecture and Marine Engineering (SNAME) began its operation in the academic year 1969-70, as a result of the rise of the shipbuilding industry in Greece since the 1950s, along with the increasing needs of maritime and other technical companies within the shipping sector (design offices, construction, and repair units) for highly skilled technical personnel. The School emerged from the curriculum of Naval Mechanical Engineering, which existed at the NTUA, initially as a Section of the School of Mechanical and Electrical Engineering. The curriculum was designed to provide a strong academic background in naval architecture and marine engineering, for which the following three chairs were established:

i. Ship Theory,

ii. Ship Design and Construction, and

iii. Marine Engineering.

From its inception, the Department of Naval Architecture and Marine Engineering had its own number of admissions, which, during the first year of operation, was ten (10), while the first Graduate Naval Mechanical Engineers finished their studies in 1974. From the academic year 1975-76, the NTUA was divided into the Department of Mechanical Engineers and the Department of Electrical Engineers, with the discipline of Naval/Marine Engineering being incorporated into the former. In 1982, an independent Department of Naval Architecture and Marine Engineering was created within NTUA, but it still had a small number of faculty members (three professors and two lecturers), and its laboratory facilities had not yet been adequately developed, except for the newly established 100-meter Experimental Tank. Today, the number of teaching staff is 23, and the laboratory facilities are among the most sophisticated internationally. The curriculum offered has also been significantly renewed, at both undergraduate and postgraduate levels, both in terms of course content and the addition of new subjects. Since 2013, the Departments of NTUA have officially been upgraded to Schools.

The SNAME coordinates the MSc Program in Maritime and Naval Technology, which is offered in collaboration with the National and Kapodistrian University of Athens (NKUA) and the Hellenic Centre for Marine Research (HCMR). Additionally, faculty members of the School participate to a large number of Postgraduate Programmes at NTUA.

The School of Naval Architecture and Marine Engineering engages in intense and multifaceted research activities, with its members being honored with top international distinctions for their research contributions. Moreover, the School is one of the most active in NTUA and Greece in funded research programs financed by Public and Private Bodies and the European Union. The following six established laboratories operate within the School:

i. Naval and Marine Hydrodynamics,

ii. Marine Engineering,

iii. Ship Design,

iv. Shipbuilding Technology,

v. Floating Constructions & Anchoring Systems, and

vi. Maritime Transport.

Additionally, informal laboratory units operate within the SNAME. The School comprises the following four (4) Sections:

i. Section of Ship Design and Maritime Transport,

ii. Section of Naval and Marine Hydrodynamics,

iii. Section of Marine Engineering, and

iv. Section of Maritime Constructions.

Currently, the School of Naval Architecture and Marine Engineering has 957 undergraduate students and 124 postgraduate students, of whom 84 are Ph.D. candidates.

D. Operation and Administration of the MSc Program

1. General Operational Framework

The Interdepartmental Postgraduate Programme "Mathematical Modeling in Modern Technologies and Financial Engineering" first commenced in 2003 (Government Gazette 1737, 26/11/2003, Reg. No. 95133/B7, 29/10/2003) with funding from the European Union and the Ministry of Education, Religious Affairs and Sports within the framework of the Operational Programme for Education and Initial Vocational Training.

According to the current framework for Postgraduate Programmes, the ***Diploma of Postgraduate Studies – Master of Science*** is awarded after successful studies lasting a **minimum of three (3) academic semesters**. The **maximum duration of studies** in the MSc Program cannot exceed **two (2) years**, calculated from the date of initial enrollment in the MSc Program.

The Diploma of Postgraduate Studies (DPS) is a specialization title, equivalent to **90 ECTS credits**, and is considered equivalent to a ***Master of Science***. It serves as a second postgraduate degree for graduates of integrated five-year programs, such as engineers.

The **language of instruction** will be **English** once the transition of the MSc Program to an English-taught Postgraduate Programme is completed.

The **administrative support** for the program is provided by the School of Applied Mathematics and Physical Sciences of the National Technical University of Athens. The necessary **infrastructure** (classrooms, laboratories, libraries, computers) will be provided by the collaborating Schools.

Detailed information about the structure of the MSc Program, courses, activities, alumni, etc., can be found on the website of the MSc Program: https://mathtechfin.math.ntua.gr/

A. Daily Operation of the MSc Program

The daily operation of the MSc Program is supported by the administrative assistance provided by its Secretariat. Students are informed and communicate through all modern means, collectively or individually, as needed, regarding all current issues of the MSc Program, such as:

- Providing information and details about the MSc Program.
- Collecting the application documents of prospective postgraduate students.
- Enrolling postgraduate students at the beginning of each academic period.
- Preparing a student list for each course.
- Maintaining a record for each enrolled student and updating it throughout their studies.
- Issuing transcripts of records.
- Preparing Course Timetables and Examination Schedules.
- Issuing certificates and attestations, which are granted upon request.
- Managing the procedures for awarding degrees.

B. Call for Applications for Admission - Candidate Selection

Admission to the MSc program "Mathematical Modeling in Modern Technologies and Finance" is granted by decision of the Programme Studies Committee (PSC), following a public call for applications, a pre-selection process, and an interview. Eligible applicants include graduates of Higher Education Institutions (HEIs) in Greece, as well as graduates of equivalent and officially recognised institutions abroad. In particular, the programme is open to graduates of Departments of Mathematics, other Departments within the Physical Sciences, Schools of Engineering, Technical Universities, Departments of Economics, and Military Academies. It should be noted that award of the postgraduate degree (MSc) does not confer a basic degree from the National Technical University of Athens (NTUA). Subject to the same condition, applications from graduates of other academic disciplines may also be considered, in line with the relevant provisions of current regulations. Potentially the percentage of admissions from each background may be determined by the PSC.

Final-year undergraduate students from the above-mentioned categories who are accepted into the programme must provide official proof of graduation (degree or diploma) in order to finalise their enrolment.

Candidates are required to submit their applications to the program within the dates specified by the call for applications. Proof of the above-mentioned qualifications is provided either through the detailed contents of previous studies and the postgraduate student's resume or through pre-registration for attendance and successful examination in the NTUA courses as determined by the PSC.

Specifically, the selection of candidates by the PSC, will be based primarily on the following criteria, upon recommendations from the Selection Committee for postgraduate students appointed by the PSC:

• For the acceptance of degrees from foreign institutions, the institution must be listed in the National Registry of Recognized Foreign Higher Education Institutions (https://www.doatap.gr/home_english/)

• The overall grade of the diploma/degree.

• The ranking of the diploma/degree grade in relation to the grades of other graduates in the same School/Department in the year of graduation.

• Grades in undergraduate courses relevant to the MSc Programme.

• Grade of the undergraduate diploma thesis, where applicable.

• Any other relevant postgraduate degrees related to the subject of the MSc Programme.

• The candidate's research, professional or technological activities.

• Curriculum Vitae and Statement of purpose.

• Adequate command of the English language is required (at level B2, C1, or C2). A basic knowledge of Greek language is recommended for international candidates.

• Computer literacy.

• Letters of recommendation.

• Personal interview.

• If the applicant is employed, consideration will be given to the needs of their organisation and the applicant's future professional prospects.

The selection of postgraduate students places particular emphasis on a strong mathematical background and proficiency in English.

Applications are welcome from students worldwide, and all candidates are evaluated on an individual basis. As of 2023, non-EU students are required to pay tuition fees of 500 euros per semester.

The interview is scheduled by the Programme Studies Committee (PSC) and conducted by a three-member Selection Committee appointed by the PSC. This committee comprises members of the faculty teaching in the MSc program, one of whom is a member of the PSC.

The list of successful candidates, after being recommended by the Selection Committee, is approved by the PSC and ratified by the General Assembly of the Coordinating School. The maximum number of admitted postgraduate students in the MSc Program “Mathematical Modelling in Modern Technologies and Finance” is set at **fifty (50)**. In addition to the number of admitted students, one scholarship holder from the State Scholarships Foundation (IKY) who has succeeded in the relevant domestic postgraduate studies competition for the discipline of the MSc program and one foreign scholarship holder from the Greek State can be admitted. The PSC may decide to increase the number of scholarship holders.

Members of the Special Teaching Staff, Laboratory Teaching Staff, and Technical Laboratory Staff categories who meet the requirements may, upon request, enroll as supernumerary students, with only one per year being admitted to the MSc Program of the School in which they serve, provided there is relevance between the discipline and their work. The total number of admitted postgraduate students each year in the MSc Program is determined by the PSC according to the number of lecturers in the MSc Program, the student-to-lecturer ratio, the infrastructure, and the classrooms available.

For MSc programs conducted exclusively in English, the number of postgraduate students should be determined so that at least half of them are Greek students, provided there is a sufficient number of applications. Consequently, the total number of postgraduate students will be redefined.

Candidates from Technological Educational Institutes (TEI), ASPAITE, or equivalent universities, if selected, are required by the relevant decision of the General Assembly of the respective School to successfully complete specified undergraduate courses within the designated timeframe of the MSc Program in order to be awarded the DPS – Master of Science upon successful completion of the full MSc Program curriculum.

The PSC of the MSc Program may stipulate, on a case-by-case basis, the attendance of prerequisite undergraduate courses for students deemed to require supplementation of their academic and especially mathematical background upon admission to the MSc Program. The number of such courses can be up to four (4) semester-long courses per student and may be drawn from the Undergraduate Curricula of the participating Schools in the MSc Program. If the prerequisite courses are fewer than three (3), the PSC decides whether they can be attended concurrently by the postgraduate student, provided that successful completion of these courses occurs before the start of the postgraduate courses for which they are prerequisites, and certainly before the commencement of the Postgraduate Diploma Thesis.

To attract high-qualified candidates, it is planned to organize an informational day to promote the program to interested parties (every spring) and inform them about the various aspects of the MSc Program. Specifically, to attract students from abroad, promotional materials will be sent to selected countries, institutions, organizations, and other entities abroad to highlight the program's advantages, such as the high level and pioneering nature of the studies, the quality of the SAMPS and NTUA infrastructure, the connection with distinguished universities abroad, and more.

2. Administration of the MSc Program

The administrative support of the Interdisciplinary Postgraduate Programme "Mathematical Modeling in Modern Technologies and Finance" is undertaken by the School of Applied Mathematical and Physical Sciences (SAMPS) of the NTUA. According to Law 4957/2022 (Articles 81, 82, and Article 455 "Final transitional provisions Chapter IX"), the competent bodies for the MSc Program are the Programme Studies Committee (PSC), the Steering Committee (SC) and the Director of the MSc Program.

The **PSC** is formed based on the contribution of the collaborating entities to the postgraduate courses of the program. The collaborating entities are the SAMPS, SECE, SCHE, SNAME and SRSGE of NTUA. The composition of the PSC is documented on the website https://mathtechfin.math.ntua.gr/. According to the above information, the Programme Studies Committee (PSC) consists of nine members and includes faculty members of the collaborating Schools or Emeritus Professors, provided they teach in the MSc Program, with the following distribution per School:

- Four (4) members from the Section of Mathematics of the School of Applied Mathematical and Physical Sciences of NTUA
- Two (2) members from the School of Electrical and Computer Engineering of NTUA
- One (1) member from the School of Chemical Engineering of NTUA
- One (1) member from the School of Naval Architecture and Marine Engineering of NTUA
- One (1) member from the School of Rural, Surveying and Geoinformatics Engineering of NTUA

The members of the PSC of the collaborating Schools are elected by the General Assembly of each School. The representatives of the collaborating entities in the PSC have a two-year term.

The composition of the PSC for the academic year 2024-25 is as follows:

1. **School of Applied Mathematical and Physical Sciences**: S. Lambropoulou, Professor - **Director of the MSc Program**, P. Stefaneas, Associate Professor, S. Sabanis, Professor, N. Stavrakakis, Emeritus Professor.
2. **School of Chemical Engineering**: Th. Theodorou, Professor, M. Kavousanakis, Assistant Professor (alternate member).
3. **School of Rural, Surveying and Geoinformatics Engineering**: K. Kepaptzoglou, Professor.
4. **School of Naval Architecture and Marine Engineering**: K. Spyrou, Professor, K. Belibassakis, Professor, (alternate member).
5. **School of Electrical and Computer Engineering**: H. Glytsis, Professor, G. Goumas, Associate Professor.

The PSC, considering the Regulation of the MSc Program, determines both the courses from the five-year undergraduate programs of NTUA that cover the necessary academic background for admission to the MSc Program, and the advanced courses along with all other requirements of a well-organized Postgraduate Programme. Specifically, by decision of the PSC, taking into account the results of the evaluation procedures, the following must be determined by mid-April each year:

i. The titles and detailed contents of the prerequisite courses from the five-year undergraduate programs of NTUA, as derived from the interdisciplinary requirements for the academic discipline of each MSc Program, including the bibliography and teaching aids,

ii. The titles and detailed contents of the courses,
iii. The weekly teaching hours of each course, including all teaching activities,
iv. The chronological sequence or interdependence of the courses,
v. The technical support characteristics of the course,
vi. The overlaps with other undergraduate and postgraduate courses, and
vii. The grading system.

The PSC of the MSc Program ensures continuous quality control and objective evaluation of all courses required for obtaining the Diploma of Postgraduate Studies (DPS) – Master of Science. This evaluation focuses on the postgraduate level and the interdisciplinary and cross-departmental nature of the teaching material and examination topics, to avoid any overlap with the regular five-year undergraduate programs of the Schools of the University.

The PSC of the MSc Program may, with a reasoned proposal and provided that it does not alter the character of the MSc Program, modify (by addition, deletion, or merging) the courses of the program and redistribute them across the academic periods (semesters), always within the framework of the prescribed procedure for drafting and approving of the detailed curriculum of the MSc Program.

The Steering Committee (SC) may be constituted by a decision of the PSC of the MSc Program with a two-year term. It consists of the Director of the MSc Program and four members of the Programme Studies Committee (PSC).

The composition of the SC for the academic year 2024-25 is as follows:

- School of Applied Mathematical and Physical Sciences: S. Lambropoulou, Professor, S. Sabanis, Professor.
- School of Rural, Surveying and Geoinformatics Engineering: K. Kepaptzoglou, Professor.
- School of Naval Architecture and Marine Engineering: K. Spyrou, Professor,
- School of Electrical and Computer Engineering: G. Goumas, Associate Professor.

The **SC** is responsible for monitoring and coordinating the operation of the program, including:

- Approving the awarding of scholarships, whether remunerative or not, in accordance with the provisions of the establishment decision of the MSc program and the Regulations for Postgraduate and Doctoral Studies,
- Drafting a plan for modifying the curriculum, which it submits to the PSC,
- Proposing to the PSC the redistribution of courses among academic semesters, as well as matters related to the quality enhancement of the curriculum.

The **Director of the MSc Program** is selected from the faculty members of the collaborating Schools, preferably holding the rank of Professor or Associate Professor. They are a member of the PSC and are appointed by decision of the PSC for a two-year term, renewable without limitation. The Director of the MSc Program has the following responsibilities:

i. Chairs the PSC and the SC, prepares the agenda, and convenes their meetings.

ii. Proposes matters concerning the organization and operation of the MSc Program to the PSC.

iii. Proposes to the SC and other bodies of the MSc Program and the University issues related to the effective operation of the MSc Program.

iv. Monitors the implementation of decisions by the bodies of the MSc Program and the Internal Regulations of Postgraduate and Doctoral studies.

3. Duration of Studies - Curriculum

According to the current framework for the operation of Postgraduate Programmes, the **minimum duration of studies** for obtaining a Diploma of Postgraduate Studies (DPS) – Master of Science **is three (3) academic semesters**. In exceptional cases, where the postgraduate student successfully completes the requirements for obtaining the DPS in a period shorter than the minimum prescribed duration of the program, and in any case, within a period not less than one (1) year, they may be awarded the DPS upon recommendation by the PSC to the Senate and its approval.

The **maximum duration of studies** in the MSc Program, calculated from the initial enrollment in the program, is **two (2) years**. Exceptionally, in special cases, a small extension of up to one (1) additional year may be granted, following a reasoned decision by the PSC. Upon completion of the second year, the PSC decides to terminate enrollment and issues a certificate with the courses and the corresponding grades in which the student has been successfully examined.

Postgraduate students in the MSc Program have the option to temporarily suspend their studies with a written request for a period not exceeding two (2) consecutive semesters. The semesters of suspension of student status are not counted towards the maximum duration of enrollment.

The structure of postgraduate courses includes obligatory or elective courses. Obligatory courses may include prerequisite core and specialization courses. At the discretion of the PSC, courses may be offered by other Schools of NTUA or other HEIs. Additionally, at the discretion of the PSC, courses may be offered as elective courses in other MSc Program of NTUA. It is evident that many of the specialization or advanced courses of the MSc Program are eligible for inclusion in Doctoral Programmes.

The Curriculum of the MSc Program includes the following categories of courses:

- **Core,**
- **Interdisciplinary Specialization**, and
- **Horizontal (Interdisciplinary)**,

as well as the completion of a Postgraduate Diploma Thesis (PDT).

For the acquisition of the Diploma of Postgraduate Studies – Master of Science, it is required to attend and successfully pass at least ten (10) courses of the MSc Program from those included in the course table below, as well as to complete and successfully present their Postgraduate Diploma Thesis (PDT). For each of the courses includes lecture hours and tutorials and/or laboratory exercises. During their studies, postgraduate students are obliged to attend postgraduate courses and participate in exercises.

All postgraduate students, to complete their studies, are required to successfully pass at least **four (4) of the core courses.**

Postgraduate students of each Specialization are required to successfully pass at least **four (4) of the Specialization courses**. They **also** have **two (2) elective courses**.

In any case, the Administration of the MSc Program may, if deemed academically necessary, modify the above ratio of course selection in the various categories.

The Administration of the MSc Program has the right, depending on the academic record of each postgraduate student, to determine the number of undergraduate courses from the NTUA Schools that must be attended and successfully completed in order to be examined in the corresponding postgraduate courses. These courses are in addition to the 10 postgraduate courses that the postgraduate student is required to successfully complete.

At the MSc Program, the "Seminar on Mathematical Modeling" operates, attendance of which is mandatory for students. Non-attendance to a significant portion of the Seminar's lectures - the percentage determined by the Administration of the MSc Program - results in exclusion from the final examinations.

The total number of **Credit Units (ECTS)** required for the acquisition the MSc is **at least 90**. At least **sixty (60)** of these **come from courses**, and **thirty (30) from the Postgraduate Diploma Thesis (PDT).** The following courses are offered as part of the Interdepartmental Postgraduate Programme, along with their respective ECTS credits and the semester in which they are taught (as approved by the School General Assembly on 19 September 2024):

WINTER SEMESTER			
CORE COURSES			
Course Code	**Course Title**	**ECTS**	**Semester**
9503	Dynamical Systems and Mathematical Chaos Theory	8	1
9504	Probability Theory	8	1
9541	Numerical Analysis	8	1
9502	Nonlinear Functional Analysis	8	1
9507	Statistical Modelling	7	1
Direction I: Modern Technologies			
9510	Computational Methods in Engineering	6	1
9571	Optimization Problems and Variational Principles of Mathematical Physics	6	1
9544	Electro-Optics and Applications	6	3
9555	Special Topics in Complex Systems (also suggested for Direction II)	6	3
9597	Biostatistics	6	1
9551	Parallel and Network Programming	7	3

9530	Graph Visualization	8	1
Direction II: Mathematics of Data Science			
9568	Stochastic Processes	8	1
9547	Statistical Designs	9	1
9583	Numerical Linear Algebra	8	1
9589	Data Mining	5	1
9599	Advanced Sampling Techniques	6	1
9531	Machine Learning (also suggested for Directions I & III)	8	3
Direction III: Financial Engineering			
9524	Principles of Financial Theory	6	1
9554	Financial Management	6	1
9505	Financial Analysis (Analysis of Financial Information Statements)	6	1
9506	Microeconomic Theory (also suggested for Direction II)	6	3
9598	Valuation of Illiquid PEVC Equity Securities: Quantitative Methods for Complex Equity Valuation	8	3
Horizontal Courses			
9600	Communication Skills for Engineers: Written and Oral Communication	3	1
SPRING SEMESTER			
CORE COURSES			
Course Code	**Course Title**	**ECTS**	**Semester**
9508	Nonlinear Partial Differential Equations	8	2
Direction I: Modern Technologies			
9514	Molecular Simulation of Materials	6	2
9515	Mathematical Modeling in Nanotechnology	8	2
9513	Nonlinear Control Systems	8	2
9518	Computer Vision	7	2
9528	Advanced Remote Sensing Topics. Remote Sensing of Environment	7	2
9587	Finite Differences and Finite Elements for Partial Differential Equations	8	2

9581	Systems Biology - Bioinformatics (Systems and Network Biology)	8	2
9512	Nonlinear Dynamics and Applications	6	2
9548	Knot Theory, Low-Dimensional Topology and Applications	8	2
Direction II: Mathematics of Data Science			
9546	Statistical Quality Control	9	2
9579	Computational Statistics and Stochastic Optimization	8	2
9577	Bayesian Statistics and MCMC	6	2
9575	Earth Observation Big Data and Analytics	7	2
9563	Survival Analysis and Reliability	8	2
9566	Operations Research	8	2
9601	AI Hands-On	8	2
9590	Deep Learning	4	2
9594	Algorithmic and Data Science	6	2
9591	Stochastic Processes & Optimization in Machine Learning	5	2
9582	Complex Networks: Fundamentals and Applications (also suggested for Direction I)	6	2
9580	Technoregulation and Data Science	7	2
Direction III: Financial Engineering			
9521	Stochastic Differential Equations and Applications in Finance	8	2
9570	Financial Derivatives	7	2
9574	Portfolio Analysis and Management (Securities Valuation and Financial Investment Management)	6	2
9520	Financial Econometrics	6	2
9576	Econometrics and Time Series Analysis (also suggested for Directiom II)	6	2
9591	Stochastic Processes & Optimization in Machine Learning	5	2
9542	Mathematical Economics – Equilibrium Theory	6	2
Horizontal Courses			

9602	European and Greek Technical Law	3	2

The Course Outlines of the MSc Program (including course content, prerequisites, recommended bibliography, expected learning outcomes, methods of student assessment, and overall educational process) can be found on the website of MSc Program: https://mathtechfin.math.ntua.gr/ .

Modification of the curriculum and redistribution of courses among the semesters may occur through decisions of the competent authorities with reference to the Regulations of Postgraduate Studies.

Postgraduate students who have been admitted to the program up to and including the academic year 2022-2023 will complete their studies in accordance with the provisions of the previous decision of the Senate (meeting of 5th of September 2018).

4. Teaching Staff

The teaching duties of the Postgraduate Programmes are assigned, following a decision of the competent body of the MSc Programs, to the following categories of lecturers:

a) Faculty Members and Laboratory Teaching Staff (LTS) of the School or other Schools of the same Higher Education Institution (HEI) or Departments of other HEIs or Higher Military Education Institutions (HMEIs),
b) Emeritus Professors or retired faculty members of the School or other Schools of the same HEI or other Departments of other HEIs,
c) Collaborating professors or researchers,
d) Assigned lecturers,
e) Visiting professors or visiting researchers,
f) Researchers and specialized operational scientists of research and technological bodies of Article 13A of law 4310/2014 (Government Gazette 258) or other research centers and institutes of the country or abroad,
g) Scientists of recognized prestige, possessing specialized knowledge and relevant experience in the discipline of the MSc Program.

The assignment of teaching duties of the MSc Program is made by decision of the General Assembly of the Coordinating School, following a recommendation by the Programme Studies Committee (PSC) of the MSc Program. Specific conditions regarding the assignment of teaching duties may be stipulated in the decision establishing the MSc Program.

The right to supervise Postgraduate Diploma Theses (PDTs) is held by lecturers of categories a) to f), provided that they hold a doctoral degree.
By decision of the PSC of the MSc Program, the supervision of Postgraduate Diploma Theses (PDTs) may also be assigned to faculty members of participating Schools who have not undertaken teaching duties in the MSc Program.
By decision of the School's General Assembly, auxiliary teaching duties may be assigned to doctoral candidates of the Department or the School, under the supervision of a faculty member of the MSc Program.

The following is the list of teaching staff for the academic year 2024–2025, along with the contact details of the course coordinators.

Lecturer Name	School/Faculty	Contact Number	Email
N. M. Stavrakakis	SAMPS	210 772 1179	nikolas@central.ntua.gr
S. Sabanis	SAMPS	210 772 1704	s.sabanis@math.ntua.gr
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E. Georgoulis	SAMPS	210 772 1778	georgoulis@math.ntua.gr
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Ch. Caroni	SAMPS	210 772 1707	ccar@math.ntua.gr
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G. Stamou	SECE	210 772 3040	gstam@cs.ntua.gr
G. Alexandridis	SECE	210 772 2262	gealexan@mail.ntua.gr
G. Goumas	SECE	210 772 2402	goumas@cslab.ece.ntua.gr
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D. Tsoumakos	SECE	210 772 2515	dtsouma@cslab.ece.ntua.gr
Aris Pagourtzis	SECE	210 772 1640	pagour@cs.ntua.gr
Th. Souliou	SECE	210 772 1644	dsouliou@mail.ntua.gr
V. Maglaris	SECE	210 772 2503	maglaris@netmode.ntua.gr
M. Grammatikou	SECE	210 772 1450	mary@netmode.ntua.gr
I. N. Glytsis	SECE	210 772 2479	eglytsis@central.ntua.gr
A. Bountouvis	SCHE	210 772 3241	boudouvi@chemeng.ntua.gr
M. Kavousanakis	SCHE	210 772 3147	mihkavus@chemeng.ntua.gr
D. Theodorou	SCHE	210 772 3157	doros@chemeng.ntua.gr
G. Papadopoulos	SCHE	210 772 3204	gkpap@chemeng.ntua.gr
G. A. Athanasoulis	SNAME	210 772 1136	mathan@central.ntua.gr
K. Spyrou	SNAME	210 772 1418	k.spyrou@central.ntua.gr
I. Georgiou	SNAME	210 772 2716	georgiou@central.ntua.gr
K. Karantzalos	SRSGE	210 772 1673	karank@central.ntua.gr
D. Argialas	SRSGE	210 772 2595	argialas@central.ntua.gr
V. Karathanassi	SRSGE	210 772 2695	karathan@survey.ntua.gr
P. Kolokoussis	SRSGE	210 772 2699	polkol@central.ntua.gr
V. Ntouskos	SRSGE	210 772 2593	ntouskos@mail.ntua.gr
K. Kepaptsoglou	SRSGE	210 772 3984	kkepap@central.ntua.gr

NTUA School of Naval Architecture and Marine Engineering (SNAME)

NTUA School of Chemical Engineering (SCHE)

NTUA School of Electrical and Computer Engineering (SECE)

NTUA School of Rural, Surveying and Geoinformatics Engineering (SRSGE)

NTUA School of Applied Mathematical and Physical Sciences (SAMPS)

LECTURERS FROM OUTSIDE NTUA

LECTURERS	CONTACT NUMBER	EMAIL
V. Rothos, Polytechnic School AUTH	2310 994 238	rothos@auth.gr
A. Provata, NCSR "Demokritos"	2106503964	a.provata@inn.demokritos.gr
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P. Boufounou, NKUA	210 3689424	pboufounou@econ.uoa.gr
K. Tountas, Agricultural University of Athens (AUA)	210 529 476	kstoudas@econ.uoa.gr
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Maria Klapa, ICE-HT, Patras	2610 965 249	mklapa@iceht.forth.gr
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S. Paraskevas, External Collaborator, Sphears A.I., Databreathe	698 352 2382	spirosparaskevas@yahoo.gr

5. Academic Timetable

According to the current organization of postgraduate studies at the NTUA, the Academic Year consists of three academic semesters. The Academic Timetable of each academic year is determined by the Senate of the NTUA.

Specifically, the first and third semesters start on the first Monday of October and end on the last Friday of January. They include a minimum of 13 teaching weeks, two weeks for Christmas holidays, and two weeks for special educational needs and examinations. The second semester starts in mid-February and ends in mid-June. It includes a minimum of 13 teaching weeks, two weeks for special educational needs and examinations, and two weeks for Easter holidays. All semesters have a ten-day grace-period for the completion of their examination subject. During the third semester, the elaboration and presentation of the Postgraduate Diploma Thesis are also completed.

6. Attendance, Examinations and Grading

The educational process of the MSc Program in “Mathematical Modeling in Modern Technologies and Finance” is mainly conducted through face-to-face, synchronous, or asynchronous distance learning methods, either entirely or partially. The necessary infrastructure (classrooms, laboratories, libraries, computers) will be provided by collaborating Schools. The organization of courses and other educational activities using synchronous distance learning methods concerns courses and educational activities that can be supported by the use of distance learning methods and do not include practical or laboratory exercises for which their physical presence is required. The organization of courses and other educational activities using asynchronous distance learning methods concerns courses and educational activities to support people with disabilities or within the framework of the university's internationalization. The educational material for asynchronous learning may include notes, presentations, exercises, indicative solutions, as well as recorded lectures, provided that the current legislation on the protection of personal data is observed. All educational material is provided exclusively for the educational use of enrolled students. The management of the distance learning process of the MSc Programs is carried out through the Helios e-learning management platform of the NTUA, the support for which is jointly provided by the IT Center and the Network Center of the NTUA.

Attendance at classes and participation in educational activities and assignments are mandatory. In cases of extremely serious and documented reasons for a postgraduate student's inability to attend, the Programme Studies Committee (PSC) may excuse a limited number of absences, which must not exceed one-third of the lectures. In such cases, the student must promptly inform the secretariat or the course lecturer. Any postgraduate student who has not met the required attendance for each course must repeat the course in the next and final teaching period.

If a postgraduate student has attended courses from another recognized MSc Program and has successfully passed the exams, they may be exempted from up to two (2) corresponding courses of the MSc Program upon request, recommendation from the respective lecturers, and a decision of the PSC.

The final examination takes place after the end of the teaching period, during a two-week examination period, according to the Unified Academic Timetable of the University's Postgraduate Studies and the specific decisions of the PSC. Courses that were not held must be rescheduled to ensure the completion of the 13-week teaching period for all courses. The rescheduling is decided and announced by the PSC of the MSc Program, ensuring compliance with the academic timetable, as far as possible.

Before the examinations, the coordinating lecturer of each course, after consulting the attendance records, calls upon students who have unjustifiably missed more than one-third of the lectures and request them to submit the necessary documentation to the Secretariat of the MSc Program. After the collection of the documentation, the PSC will determine the obligations for each student individually or decide on their dismissal from the MSc Program.

Course grades are assigned on a scale of 0-10, without fractional part, with 5 being the passing grade. The course grade may be derived not only from the Final Examination but also from Progress Tests, Assignments, and other activities conducted during the course. The relative weight of these components is determined by the respective lecturer and must not be less than 30% of the total course grade. Details regarding the implementation of the teaching activities and the evaluation of student performance are explicitly mentioned on each course's webpage. It is also clarified that only the grade for the Postgraduate Diploma Thesis (PDT), given by individual examiners and as an average, may include half fractional points.

Results are issued by the lecturers within two weeks after the final examination.
No provision is made for repeat examinations. In exceptional cases, the PSC may, with a well-documented decision, accept an extraordinary additional examination in up to two (2) courses per student per academic year, provided that the postgraduate student was unable to be examined due to force majeure. The PSC may also, in exceptional cases, schedule repeat examinations.

Students who fail courses can re-enroll in the same (or different if elective) courses the following year. In cases of two-year programs where re-enrollment in the following year is not possible, one additional examination period is exceptionally allowed, scheduled at an appropriate time by the PSC. If a postgraduate student fails up to two courses, thereby failing to complete the program as stipulated in these Regulations, they may be examined, upon their request, by a three-member committee of faculty members of the School. These members must have the same or a related field of expertise as the course in question and are appointed by the PSC of the MSc Program. The course lecturers are excluded from this committee.

7. Postgraduate Diploma Thesis (PDT)

The commencement of the Postgraduate Diploma Thesis (PDT) requires the submission of the relevant form to the Secretariat of the MSc Program, after the completion of the 2nd semester, provided that the postgraduate student has been successfully passed at least six (6) courses of the first and second semesters of studies.

If the PDT is not successfully completed within the third trimester, it may continue into the following semester. However, it must be emphasized that the maximum duration of studies for the MSc Program cannot exceed two (2) years, calculated from the date of the initial enrollment in the MSc Program.

The text of the PDT must be written using an electronic word processing and submitted in digital form. It must include a table of contents, bibliographic references, and an abstract of 300 to 500 words.

The use of sources from the bibliography is very important for documenting the thesis and relating it to existing scientific activity in the specific field. Information, ideas, and data from other sources (conventional or internet) must be cited, indicating their origin. This applies to both information included in the text and especially to figures, diagrams, photographs, and tables from other works, where the source of origin must be mentioned in the caption.

The language of writing for the Postgraduate Diploma Thesis (PDT) can be either Greek or English, as determined by the Programme Studies Committee (PSC). The PDT must include an extensive summary in both Greek and English. For internationalized MSc Programs, the language of instruction and writing for the PDT is English.

The presentation and grading of the PDT take place after the successful completion of the ten (10) required courses for the diploma, during the examination periods of February, June, and September, by a three-member committee that includes the supervisor and is appointed by the PSC. The minimum passing grade for the PDT is 5.5.

More details about the PDT can be found in the Description of the PDT, the Course Descriptions of the MSc Program, and on the MSc Program's website: https://mathtechfin.math.ntua.gr/

8. Award - Diploma Grade

To be awarded the Diploma of Postgraduate Studies (DPS) - Master of Science, a passing grade in both the postgraduate courses and the Postgraduate Diploma Thesis (PDT) is required. If this is not achieved within the two years, the postgraduate student will receive a simple certificate of attendance for the courses in which they have received a passing grade and will be dismissed from the program.

The overall grade for the Diploma is calculated as the weighted average of the grades of the postgraduate courses and the PDT, where the latter is considered equivalent to the credit units of one (1) semester of courses.

$$Diploma's\ Grade = \frac{\sum(Course\ Grade\ x\ Course\ Credit\ Units) + 30\ x\ PDT\ Grade}{30 + \sum(Course\ Credits)}$$

The grading scale used for performance assessment is a ten-point scale (0-10).

Excellent: 9.00 - 10.00

Very Good: 7.00 - 8.99

Good: 5.00 - 6.99

On the original degree certificate of the Diploma of Postgraduate Studies (Master of Science), the grade will not be displayed numerically but will be represented by the terms "Good", "Very Good", or "Excellent", depending on the final grade achieved, in accordance with the regulations of the National Technical University of Athens (NTUA).

9. Student Support Services

a. Academic Advisor

Immediately after the initial enrollment of the postgraduate students, the Programme Studies Committee (PSC) assigns an Academic Advisor (AA) for each student. The Academic Advisor is not necessarily the same person as the supervisor of the Postgraduate Diploma Thesis (PDT). Initially, all faculty members teaching in the MSc Program can be appointed as Academic Advisors.

During the postgraduate studies:

- The AAs advise and support postgraduate to facilitate the transition from the first to the second cycle of studies. They also guide and support the students as they progress through their studies.
- The AAs inform, advise, and guide the postgraduate students on all matters related to their studies and general orientation issues, whether it concerns elective course orientation, fulfilling prerequisites where necessary, or considering the continuation of postgraduate studies towards a third cycle of studies, and make recommendations to the PSC accordingly.

In addition to advising and supporting students on academic matters, AAs can also support them in dealing with personal, interpersonal, and family difficulties that may affect their academic performance. In such cases, AAs (always with the student's consent) refer the students to the appropriate Structure of the University to receive supportive care.

b. Access to the Library and Internet Connection

Postgraduate students of the MSc Program "Mathematical Modeling in Modern Technologies and Finance" have full access to the Central Library of the NTUA. The new building of the Central Library at Zografou covers an area of 7,000 square meters and includes a reading room with 500 seats, approximately 50 computer workstations, and 3 photocopying machines that operate with cash or magnetic cards. The Library offers lending services and is open from Monday to Friday, 8:30 AM to 8:00 PM.

The network service (Network Center) provides all members of the polytechnic community (faculty, undergraduate and postgraduate students, research associates, administrative staff) with access to the computing systems of the NTUA and the internet.

c. Complaint and Appeal Management Procedure for Students

The MSc Program has a Complaint Management Mechanism to handle complaints from its postgraduate students concerning any form of complaint or appeal related to the quality of educational, administrative, and other services provided. The procedure typically involves the written submission of a complaint by a postgraduate student about an issue related to their studies within the MSc Program which could not be resolved at the initial level by the director of the MSc Program. The MSc Program's website features the Regulations of the Student Complaint and Appeal Management Mechanism.

d. Scholarships

The MSc Program does not have the capacity to provide scholarships to postgraduate students because it currently does not have tuition fees.

10. Evaluation of the MSc Program

a. Assessment of Teaching

As part of the MSc Program's objective to provide “high-level education in contemporary scientific and technological fields” student feedback on the educational process is solicited. At the end of each semester, students complete questionnaires concerning:

- the content of the courses,
- the quality of the educational materials, and
- the interaction with the lecturers.

These questionnaires are anonymous and returned directly to each lecturer, aiming to provide feedback that help in evaluating the outcomes of educational initiatives and potentially modifying some of them.

b. Overall Evaluation of the MSc Program

Regular evaluations of each MSc Program are conducted following the procedure below:

i. Evaluation by an internal evaluator (who is not part of the PSC or faculty member of the MSc Program).

ii. Evaluation by an external evaluator (who is not a member of the faculty of the NTUA).

iii. Evaluation report by the Director of the MSc Program.

iv. Central evaluation by the PSC, taking into account the previous assessments, which is then submitted for approval to the NTUA Senate.

Within these procedures, students are called upon to express their overall opinion on the MSc Program. The information gathered is made available to the PSC for the undertaking of further initiatives aimed at improving the quality of the provided postgraduate studies.

11. Funding Sources

The funding of the MSc Program “Mathematical Modeling in Modern Technologies and Finance” may come from:

- NTUA Budget
- Budget of the Ministry of Education, Religious Affairs and Sports
- Donations, grants, legacies, sponsorships
- Resources from research programs
- Resources from programs of the European Union or other international organizations
- Revenues from the Special Account of NTUA Research Funds
- Tuition fees from non-EU students.

12. Degree Type

HELLENIC REPUBLIC

THE NATIONAL TECHNICAL UNIVERSITY OF ATHENS

BY RECOMMENDATION

OF THE PROGRAMME STUDIES COMMITTEE

OF THE INTEDISCIPLINARY POSTGRADUATE PROGRAMME

"MATHEMATICAL MODELING IN MODERN TECHNOLOGIES AND FINANCIAL ENGINEERING"

UNDER THE COORDINATION OF THE SCHOOL OF

APPLIED MATHEMATICAL AND PHYSICAL SCIENCES

AND THE PARTICIPATION OF THE SCHOOLS OF

ELECTRICAL AND COMPUTER ENGINEERING, CHEMICAL ENGINEERING, RURAL, SURVEYING AND GEOINFORMATICS ENGINEERING, NAVAL ARCHITECTURE AND MARINE ENGINEERING

OF THE N.T.U.A.

AWARDS TO

…

who in (month, year), fulfilled all the academic requirements

DIPLOMA OF POSTGRADUATE STUDIES

MASTER OF SCIENCE

IN THE SCIENTIFIC FIELD OF

“MATHEMATICAL MODELING IN MODERN TECHNOLOGIES AND FINANCIAL ENGINEERING”

IN THE SPECIALIZATION OF (1)

“…”

WITH THE GRADE "GOOD / VERY GOOD / EXCELLENT”

Athens, Greece, (date)

The Director of the Postgraduate Programme   The Secretary of the School of …   The Rector

---

(1) **falls within the scope of evaluation by the PSC**

Appendix: Detailed Presentation of Courses

Contents of the MSc Programme’s Courses

The syllabi of the MSc Programme (course content, prerequisites, recommended bibliography, expected learning outcomes, methods of student assessment, and the overall educational process, etc.) can be found on the website of the MSc Programme:

https://mathtechfin.math.ntua.gr/

Course Contents

WINTER SEMESTER

CORE CORSES

Nonlinear Functional Analysis (corse code 9502)

1. **Introduction**
• Motivations and Historical Background
• Basic Concepts of General Topology
• Concept of Measure, Measurable Sets, Measurable Functions
• Metric Spaces
2. **Banach Spaces**
• Spaces with Norm
• Banach Spaces
• Finite-Dimensional Spaces
• Bases in Banach Spaces
3. **L^p Spaces and ℓ^p Spaces**
• L^p Spaces
• ℓ^p Spaces
4. **Operators**
• Linear and Bounded Operators - Linear and Bounded Functionals
• Non-bounded and Nonlinear Operators
5. **Hilbert Spaces**
• Spaces with Inner Product
• Hilbert Spaces
• Orthogonal Systems - Bases
• Isomorphic Hilbert Spaces
• Convexity - Projections in Hilbert Spaces
6. **Dual Spaces**
• The Dual of a Normed Space
• Riesz Representation Theorem
• The Dual Space X^{**} of X^{*}
7. **Topologies in Banach Spaces**
• Weak Topology on X

• Strong Topology on X and X*
• Weak Topology σ(X,X*)
• Weak* Topology σ(X*,X)
8. **Reflexive - Separable - Uniformly Convex Banach Spaces**
• Reflexive Banach Spaces
• Separable Banach Spaces
• Uniformly Convex Banach Spaces
9. **Differentiability in Banach Spaces**
• Gateaux Derivative
• Fréchet Derivative
• Gateaux, Fréchet Differentiability and Continuity
10. **Fixed Point Theory**
• Banach Fixed Point Theorem
• Brouwer Fixed Point Theorem
• Schauder Fixed Point Theorem
11. **Sobolev Spaces**
• Weak Derivative
• Sobolev Spaces and their Properties
• Applications to Ordinary and Partial Differential Equations
12. **Variational Inequalities**
• Motivation
• Stampacchia – Lax – Milgram Theory
• Variational Formulation of Elliptic-Type Problems

Dynamical Systems & Mathematical Theory of Chaos_notes (cc 9503)

Analytical Qualitative Theory:

- Existence and Uniqueness of Solutions of Differential Equations; Solution Extensibility; Dependence on Initial Conditions and Parameters; Solution Differentiability; Gronwall Inequality.

Geometric Theory - Stability:

- Introduction: Phase Space, Critical Points, Periodic Solutions, Stability, α-(ω-) Limit Sets, Invariant Sets, Attractors.
- Linear Systems: General Theory; Plane Autonomous Systems; Normal Forms; Qualitative Equivalence of Linear Systems; Classification of Phase Images.
- Almost Linear Systems: Introduction; Equivalence of Flows in 1 Dimension; Qualitative Equivalence of Linear Systems in the Plane (Linear - Topological - Differentiable Equivalence); Equivalence of Nonlinear Flows.
- Linearization: Local and Global Behavior, Linearization around a Fixed Point, Linearization Theorem (Hartman - Grobman).
- Lyapunov Method: Lyapunov Functional; Lyapunov Stability & Instability Theorems; Attraction Field; Invariant Principle.

Bifurcation Theory and Applications:

- Elementary Bifurcations in 1-Dimensionality (Saddle-Node, Transcritical, Hysteresis, Pitchfork, Fold & Cusp); Local Perturbations near Stationary Points (Hyperstatic Stationary Points, Stationary Points with Quadratic and Cubic Degeneracy) ,
- Elementary Bifurcations in 2-Dimensionals (Saddle-Node, Pitchfork, Vertical, Poincar\'e-Andronov-Hopf, Homoclinic or Saddle-Loop),
- Presence of Zero Eigenvalue: Stability; Bifurcations; Stable & Unstable Manifolds; Central Manifold.
- Theory of Scalar Mappings: Introduction; Stability; Bifurcations of Monotone Mappings; Period Doubling Bifurcation.
- Scalar Non-Autonomous Equations: Floquet Theory: Introduction - Basic Theory - Mathieu Equation; Introduction to Non-Autonomous Equations; Geometric Theory of Periodic Solutions; Periodic Equations in a Cylinder; Examples of Periodic Equations; Stability of Periodic Solutions; Stability & Bifurcations of Periodic Equations.

- Product System - First Integrals - Conservative Systems
- Presence of Purely Imaginary Eigenvalues: Stability; Poincare – Andronov-Hopf Bifurcations.

Chaos Theory:

- Theory of Invariant Manifolds. Hamiltonian Systems
- Introduction to Chaotic Dynamics Examples of Chaotic Dynamical Systems. Ways of Transition to Chaos: Period Doubling Sequences, Effacement of Strange Attractor.
- Definition of Chaos Invariant Sets and Symbolic Dynamics. Smale Horseshoe. Definition of Chaos. Sharkovskii Theorem. Conley-Moser Conditions. Arithmetical Applications.
- Homoclinic Chaos. Hamiltonian Systems. Brief reference to methods of perturbation theory. Melnikov's theory for the conservation of perturbed homoclinic trajectories (geometrically and analytically). Diffusion through Homoclinic Lattices. Applications to Duffing, Lorentz oscillators. Applications in Mechanics. Numerical Applications (MATLAB).

Probability Theory (cc 9504)

1. **Foundations of Probability**: Events, σ-algebras, probability measures, Carathéodory's extension theorem.
2. **Mathematical Expectation**: Random variables, integration, conditional expectation, basic inequalities.
3. **Product Spaces**: Product measures, Fubini's theorem, independence, Kolmogorov's extension theorem.
4. **Convergence**: Almost sure, in probability, L^1 and weak convergence; Prokhorov's and Portmanteau theorems.
5. **Sums of Independent Variables**: Laws of large numbers, Borel-Cantelli, zero-one laws, large deviations.
6. **Characteristic Functions**: Properties, inversion, uniqueness, continuity theorems, applications.
7. **Central Limit Theorem**: Classical and general versions, Stein's method.
8. **Martingales**: Definitions, stopping times, optional sampling, convergence theorems, applications.

Numerical Analysis (cc 9541)

Introduction (Norms, Spectral Theorem, Stability Estimates of Linear Systems), Numerical Linear Algebra (Direct and Iterative Methods, Conjugate Gradient Methods, Krylov Subspace Iteration Methods, MINRES, GMRES, QR, Least Squares), Nonlinear Systems (Fixed Point Iteration, Newton-Raphson), Iterative methods for Eigenproblems (Power Method, QR algorithm, Schur Decomposition). Approximation-Interpolation (Weierstrass Theorem, Piecewise Linear Approximation, Cubic Splines, Best Approximation Theorems, Chebyshev Polynomials, Asymptotic behavior of Polynomial Interpolation, Runge Divergence Theorem), Arithmetic Integration (Orthogonal Polynomials, Gauss Quadrature).

Statistical Modelling (cc 9507)

General linear model

Parameter estimates; distributions and properties thereof. Tests of hypotheses.
Variable selection, model development, AIC and BIC criteria, penalised estimation, Lasso technique.
Partial residual and added variable plots.
Diagnostic methods, checking model assumptions, examining residuals. Dummy variables, Multicollinearity, Transformations. Heteroscedasticity.
Weighted regression. Autocorrelation; Durbin-Watson test. Influential points, Cook's distance. Model evaluation; cross-validation.

Generalised linear models

Exponential family distributions. Link functions.
Logistic regression, Poisson regression and other models.
Parameter estimation, hypothesis tests, choice of model, diagnostic tests, examination of residuals, partial residual

plots. Influence, Cook's distance.
Overdispersion, ROC curve

Extensions
Non-linear models. Multinomial and ordered logistic models. Generalised additive models. Special applications.

Direction I: Modern Technologies

Biostatistics (cc 9597)

- Introduction to epidemiology, Epidemiological indices, Incidence and Prevalence, Sensitivity and Specificity
- ROC curves
- Non-parametric X^2 tests and their application to Biostatistics, exact and asymptotic distribution of tests statistics
- Survival Analysis, Censored and/or Truncated data, Parametric and Non-parametric estimation of the Survival function, tests for the comparison of two or more survival curves
- Cox model, estimation and applications to data.

Parallel and network programming (cc 9551)

Parallel Processing Architectures:

Multiprocessor systems, multithreaded architectures, massively multicore architectures, accelerators, and specialized hardware for machine learning applications.

Design and Implementation of Parallel Programs:
Parallelization of machine learning computational kernels on general-purpose parallel architectures and accelerators.

Computational Methods In Engineering (cc 9510)

Discretization of Boundary Value Problems
- Galerkin Weighted Residuals: Residual computation and treatment of boundary conditions.
- Finite Element Basis Functions: Development in 1D and 2D domains, global-local notation, isoparametric mapping.
- Discretization Equations: Derivation through Galerkin integrals, numerical integration, matrix assembly.
- Nonlinear Equations: Newton's method and parametric studies.
- Implementation: Overview of finite element source code.

Electro-Optics and Applications (cc 9544)

Review of basic electromagnetic principles. Introduction to the propagation of electromagnetic waves in anisotropic materials. Jones Calulus. Propagation of rays and beams, ABCD matrix method. Gaussian beams. Optical resonators, Fabry-Perot resonators, stability criterion, resonators with spherical mirrors, resonance frequencies, losses in optical resonators. Interaction of light and matter in atomic systems, spontaneous emission, stimulated emission, absorption. Optical processes (Einstein). Homogeneous and inhomogeneous spectral broadening. Lineshape function, absorption and amplification of optical signals, gain and gain saturation in homogeneous and inhomogeneous broadened materials. Atomic oscillator model. Theory of laser oscillation. Fabry-Perot laser, resonance frequencies, threshold condition, steady-state operation. Lasers of 3 and 4 energy levels. Laser power. Dynamical behavious of lasers, multi-mode operation, mode-locking, Q-switching, saturable absorbers, and amplifiers. Specific laser systems, laser pumping, laser efficiency. Ruby laser, Nd-Yag laser, Nd-glass laser, He-Ne laser, CO_2 laser, Argon-Ion laser, Excimer lasers. Organic lasers. Semiconductor lasers basics. Populations and inversion in semiconductor lasers. Absorption and gain in semiconductors. Electro-optic modulation, electro-optic effect, birefringence. Electro-optic retardation, electro-optic amplitude modulators, electro-optic phase modulators, electro-optic deflection. Interaction of light and sound. Light diffraction by sound waves. Bragg acousto-optic diffraction. Laser application: Holography.

Mathematical modelling of complex systems and applications (cc 9555)

A. Complexity in time (5 weeks)

- Dynamical Systems – Hamiltonian Dynamics; Canonical perturbation theory, KAM theory; Transition from order to chaos– The model of pendulum with periodic perturbation; Non-linear waves and Solitons; Solitons in field theory; Quantum Chaos; Symbolic dynamics; Time series analysis.

B. Complexity in space (4 weeks)

- Fractals and Multifractals; Measures of spatial complexity and applications; Spatial complexity in nanotechnology. Nonlinear wave propagation in inhomogeneous media (Theory and Applications in Photonics).

C. Spatiotemporal complexity (4 weeks)

Complex networks and applications; Neuron networks in brain: structure and dynamics; Complexity of language;.

Graph Visualization (cc 9530)

The course includes the following topics:

1. Introduction to Graph Visualization (Examples of Visualizations)
2. Tree Visualizations
    - Level-based drawings
    - HV-drawings
    - Radial drawings
3. Series-Parallel Graph Visualizations
4. Planar Graph Visualization (with straight edges)
    - Canonical Ordering
    - The Shift method
    - Snyder's algorithm
    - Planar graphs in the yFiles library
5. Orthogonal Graph Visualizations
6. Graph Visualization Based on Laws of Physics
7. Upward Planar Drawings
8. Hierarchical/Layered Graph Visualizations
9. yFiles demo

Direction II: Mathematics of Data Science

Stochastic Processes (cc 9568)

- **Markov Chains & the Markov Property:** Introduction to Markov chains and the Markov property. This section focuses on basic models of Markov chains, especially discrete chains with countable state spaces.
- **Equivalence Classes – Recurrent & Transient States:** Introduction of equivalence classes and their structural properties. This part distinguishes between recurrent and transient classes.
- **Positive Recurrent Classes & Invariant Measures:** Analysis of positive recurrent states and invariant distributions, and the connection between them. Time reversibility is also discussed.
- **Aperiodicity & Asymptotic Behavior:** Discussion of aperiodicity and the asymptotic behavior of a Markov chain's distribution. Methods for studying periodic chains through aperiodic ones are presented.
- **Ergodic Theorems of Markov Chains:** Focus on ergodic theorems related to Markov chains, exploring their long-term behavior.
- **Martingale Theory & Applications:** Examination of martingale theory and its use as a computational tool.
- **Applications: MCMC, Metropolis-Hastings Algorithm & Mixing Times:** Introduction to Metropolis and Glauber dynamics for sampling from complex distributions. Exploration of total variation distance, coupling methods, strong stationary times, and mixing times.

Data Mining (cc 9589)

1. Entity–Relationship Model and the Relational Model
2. The SQL language
3. Query Processing and Optimization in Database Management Systems
4. Data preprocessing methods and algorithms
5. Data Streams: Introduction, methods, and applications using stream algorithms and data
6. Data Warehouses and Online Analytical Processing (OLAP), Data Cubes
7. Introduction to Big Data, the MapReduce programming model, Hadoop, HDFS.

Advanced Sampling Techniques (cc 9599)

- Introduction
- Sampling Errors, Construction of a sample questionnaire
- Sampling Schemes: Simple random sampling, Stratified sampling, Systematic sampling, Cluster sampling (one stage, two-stage cluster sampling), Combinations of sampling techniques
- Parameter estimation: mean, total, percentage, variance, ratio estimators, regression estimators
- Other sampling techniques: Sampling with probability

Machine Learning (cc 9531)

1 Introduction to Machine Learning. Introduction to the foundations of machine learning, including its definition, main categories (supervised, unsupervised, reinforcement learning), and example applications. Discuss the scope, challenges, and limitations of ML systems.

2 Learning Theory. Examine theoretical principles of machine learning, including the bias-variance tradeoff, Probably Approximately Correct (PAC) learning, Vapnik–Chervonenkis (VC) dimension, and the No

Free Lunch theorem.
3 Supervised Learning I: Linear Models. Study linear regression and ridge regression as fundamental methods for supervised learning. Explore objective functions, optimization techniques, and the interpretation of model parameters.
4 Supervised Learning II: Distance-Based and Probabilistic Classifiers. Explore k-nearest neighbors (k-NN) classifiers and Bayes optimal classifiers. Discuss properties, advantages, and limitations of distance-based and probabilistic approaches.
5 Supervised Learning III: Decision Trees. Introduce decision trees for classification and regression. Discuss tree-building algorithms, splitting criteria, pruning techniques, and overfitting control mechanisms.
6 Supervised Learning IV: Neural Networks. Examine perceptrons, multilayer perceptrons (MLPs), and the backpropagation algorithm. Understand the representational power of neural networks and challenges in training deep architectures.
7 Supervised Learning V: Support Vector Machines (SVMs). Study support vector machines (SVMs), the concept of maximum margin classifiers, and the use of kernels to handle non-linear decision boundaries.
8 Ensemble Learning. Explore ensemble learning techniques, including bagging, boosting, and random forests. Discuss how ensembles reduce variance and bias, and improve predictive performance.
9 Unsupervised Learning I: Clustering Techniques. Introduce clustering methods, including k-means, hierarchical clustering, and density-based approaches. Discuss distance measures, clustering evaluation, and model selection.
10 Unsupervised Learning II: Mixture Models and Dimensionality Reduction. Study probabilistic clustering through Gaussian Mixture Models (GMMs) and the Expectation-Maximization (EM) algorithm. Introduce dimensionality reduction methods such as Principal Component Analysis (PCA) and t-distributed Stochastic Neighbor Embedding (t-SNE).
11 Introduction to Deep Learning. Discuss deep feed-forward neural networks and convolutional neural networks (CNNs). Explore hierarchical feature extraction and common deep learning architectures.
12 Evolutionary Algorithms and Fuzzy Systems. Examine genetic algorithms, evolutionary strategies, and fuzzy logic systems. Discuss optimization inspired by natural processes and systems for handling uncertainty and approximate reasoning.
13 Introduction to Reinforcement Learning. Introduce reinforcement learning concepts, focusing on Markov Decision Processes (MDPs), value iteration, and policy iteration algorithms. Discuss basic exploration-exploitation trade-offs

Statistical Designs (cc 9547)

1 ANOVA (Analysis of Variance) models, of Fixed, Random and Mixed Effects.
2 Orthogonal Contrasts.
3 Approximation by Regression
4 Kruskal–Wallis and Friedman Tests.
5 Two–level, three–level and multi–level Factorial Designs.
6 Fractional Factorial Designs. Classification Criteria of Fractional Factorial Designs.
7 Supersaturated Designs.
8 Optimization Criteria and Construction Methods for Supersaturated Designs.
9 Statistical Analysis of Supersaturated and Split–Plot Designs.
10 High–Dimensional Data.
11 Response Surfaces Methodology. 2nd Order Models.
12 Designs and Modelling for Computer Experiments.

Numerical Linear Algebra (cc 9583)

Introduction (Norms, Spectral Theorem, Stability Estimates of Linear Systems), Direct and Iterative Methods, Relaxation Methods (JOR, SOR, SSOR), Gradient and Conjugate Gradient Methods, Krylov Subspace Iteration Methods (Arnoldi, GMERES), Nonlinear Systems (Fixed Point Iteration, Newton-Raphson, Inexact Newton-Raphson, Quasi Newton-Raphson), Approximation of Eigenvalues-Eigenvectors (Power Method, Rayleigh Quotient, Inverse Power Method, Orthogonal Matrices, Householder Matrices, QR method).

Direction III: Financial Engineering

Principles Of Financial Theory (cc 9524)

The present course is an introduction to the general model of stochastic finance , in the case where the set of states and the time horizon are finite. Under this spirit the basic subjects of the course are the following:
---The flow of information and information tree,
---Introduction to measure and probability theory,
--- Financial derivatives (call and put options, exotic options and other types of options)
---Martingales and basic theorems of pricing
----Hedging and applications in the binomial model
---Futures and Swaps
---Introduction to ordered spaces and positive bases and completion of the financial markets by options.

Financial Management (cc 9554)

The aim of the course is to teach the most important concepts of finance, focusing both on the company and the markets. Special emphasis is given to corporate finance and understanding the process of making business-investment decisions under conditions of certainty and uncertainty. The course content combines theory with practice, including the study of real cases and applications. The material is divided into the following thematic units:
Introduction to Company Theory, Investment Evaluation
Financial Models, Long-term Planning, Risk,
Return and Risk Assessment
Market Efficiency
Capital Structure Theory
Leverage, Cost of Capital
Limits on the use of debt
Financial Distress, Interactions of Investment & Financing,
Dividend Policy
External Financing
Investment Banking
Risk Management
International Corporate Finance
Derivatives
Firms' Valuatio

Financial Statement Analysis (cc 9505)

A combination of teaching and learning methods will be used, aiming at the active participation of the students and the practical application of the thematic units under examination; there will also be lectures using audiovisual media, discussions, and analyses of case studies on real business issues, experiential (group) activities, as well as projections of relevant videos. The students will also potentially undertake an individual or group project. Furthermore, articles, web links/addresses, useful information, case studies and exercises for further practice are posted in digital form on the Open e-Class platform.

Introduction in Financial Accounting
General Accounting Principles
Financial Statements, Balance Sheet (Financial Position)
Financial Statements, Income Statement
Owner's Equity Statement and Annex
Cash Flow Statements (Direct method)
Cash Flow Statements (Indirect method)
Common Size Statements
Liquidity ratios
Activity ratios
Profitability ratios
Viability ratios
Investing ratios

Valuation of Illiquid PEVC Equity Securities (cc 9598)

- **Section 1:** Quantitative Option Pricing Techniques

○ Option Pricing Method – Combination of call options calculations based on the relative risk characteristics, contractual economic rights and privileges of the various equity classes as well as certain market participant and company specific assumptions.

○ Current Value Method – Assumes an imminent liquidation event and the distribution mechanics follow the contractual economic rights and privileges assuming acceleration of vesting of equity awards upon the satisfaction of predetermined vesting conditions.

○ Probability Weighted Expected Return Method – Involves estimating expected future potential liquidation events of a company and weighting them by the probability of each scenario occurring accounting for the uncertainty of the future cash flows of the company. An assessment of different risk profile & return characteristics or waterfall economics is necessary depending on the type of liquidity events.

○ Hybrid Methods – Combine multiple valuation techniques that cover the potential spectrum of the exit strategies of companies under consideration and a modeling application of various economic payoffs in order to derive fair value considerations that are consistent with the market participants view as of the measurement date or the date of the consummation of a contemplated transaction.

- **Section 2:** Discounts for Lack of Marketability/ Lack of Control

○ Quantitative Put Option Methods based on the Chaffee, Longstaff, Ghaidarov, Finnerty or Asian Protective Put Option. – Estimate the risk profile of each equity instrument with specific option pricing assumptions and infer a specific discount relative to primary equity securities based on a combination of different parameters.

○ to primary equity securities based on a combination of different parameters.

○ Benchmark Studies: Multiple theoretical empirical studies across different time windows and different specifications within specific range estimates depending on the stage of the company, type of transaction etc.

○ Other Approaches: Quantitative Marketability Discount Model (QMDM), Nonmarketable Investment Company Evaluation (NICE) etc.

- **Section 3:** Dynamic Optimization Techniques

○ Multi-step Monte Carlo Simulation with various correlated variables: Simulation of various variables in a correlated way and an application of different risk adjustments depending on the risk profile of the underlying metric; application of size adjustments or market participant characteristics for calibration purposes; illustration on antithetic variate techniques and standard error minimization procedures.

○ Least Square Monte Carlo Simulation: Dynamic simulation technique to calculation optimal payoffs of embedded derivatives either conditional or mutually exclusive.

○ Optimal Foresight Techniques: Dynamic simulation techniques that involve perfect foresight assumptions and valuation of exotic-like option structures or more sophisticated embedded derivatives.

- **Section 4:** Standard Valuation Practices/Calibration/Backtesting

○ Calibration: Case study illustration with calibration of fair value indications to cash considerations or purchase consideration in connection with contemplated transaction
○ Mark to Market: Overview of valuation procedures for purposes of marking to market subject equity interests as part of financial reporting requirements for the biggest asset managers, private equity funds.
○ Backtest/Roll Forward: Various consideration for adjustments of Income/Market Approaches when initiating fair value measurements or rolling forward valuation models.

HORIZONTAL CORSES

Communication Skills for Engineers (cc 9600)

Week 1 - Introduction to academic writing.
Week 2 - Managing, evaluating and organizing academic sources.
Week 3 - The language and structure of research papers.
Week 4 - The language and structure of MSc dissertations.
Week 5 - The language and structure of abstracts.
Week 6 - The language and structure of critical literature reviews.
Week 7 - Writing reports.
Week 8 - Crafting effective presentations: content and visual aids.
Week 9 - Crafting effective presentations: presentation skills and delivery.
Week 10 - Advanced writing techniques.
Week 11 - Integrating writing and presentation skills.
Week 12 – Presentations.

SPRING SEMESTER

CORE CORSES

Nonlinear Partial Differential Equations (cc 9508)

Lecture 1: Overview of Operator Theory

1.1 Bounded Operators

- Linear and Bounded Operators - Linear and Bounded Functionals
- Operator norms and continuity.
- Non-bounded and Nonlinear Operators
- Resolvent and Spectrum
- Self-adjoint and symmetric operators.
- Relation to functional analysis and PDEs

Lecture 2: Sobolev Spaces

- Weak Derivative
- Sobolev Spaces and their Properties
- Sobolev embedding theorem and Rellich-Kondrachov compactness theorem
- Applications to Ordinary and Partial Differential Equations

Lecture 3: Variational Inequalities

- Motivation
- Stampacchia – Lax – Milgram Theory
- Variational Formulation of Elliptic-Type Problems

Lecture 4: Calculus of Variations
- Functionals and their minimization.
- Variational derivative and Euler-Lagrange equations.
- Application of Sobolev spaces in elliptic and parabolic PDEs.

Lecture 5: Discussion and Future Directions

Lecture 6: From Linear to Nonlinear PDEs
- Method of linear PDEs separation of variables
- Fourier Transform
- Nonlinear Waves (group velocity, dispersion relation)
- Introduction to Solitary Waves and Solitons

Lecture 7: Hamiltonian PDEs
- Special solutions of 1D nonlinear PDEs
- Review of finite dimensional Hamiltonian Systems
- Variational Principles and the Euler-Lagrange equations
- Infinite dimiensional Hamiltonian Systems

Lecture 8: Nonlinear Dispersive Waves and Whitham's Equations
- Linear Dispersive Waves
- IVP and Asymptotic Solutions
- Whitham's Equations

Lecture 9: What is ….a soliton?
- Introduction
- Definition and properties of solitons
- Appliactions

Lecture 10: The Nonlinear Schrodinger (NLS) Equation
- NLS equation and solitary waves
- Properties of solutions of NLS
- Conservation Laws for the NLS
- The Inverse Scattering Method for NLS

Lecture 11: The NLS equation as both a PDE and a Dynamical System

Lecture 12 and 13 : The Evans Function

Direction I: Modern Technologies

Advanced Remote Sensing Topics Remote Sensing of Environment (cc 9528)

- Introduction to Remote Sensing
- Machine Learning in Remote Sensing Trend, Applications, Evaluation
- Supervised Classification in Remote Sensing: Datadriven
- approaches, Linear Classifiers
- Pixelbased
- Classification & Optimization: Stochastic Gradient Descent, Backpropagation,

- Intuitions
- Neural Networks I: Setting up the Architecture, Setting up the Data and the Loss
- Neural Networks II: Learning and Evaluation Putting it together: Minimal Neural Network
- Case Study
- Convolutional Neural Networks I: Architectures, Convolution/ Pooling Layers
- Convolutional Neural Networks II: Understanding and Visualizing, Transfer Learning and
- Finetuning
- Objectbased
- Image Analysis.

Non Linear Control Systems (cc 9513)

- Stability notions for dynamical systems.
- Lyapunov functions for dynamical systems.
- The state feedback stabilization problem for control systems.
- Backstepping for triangular control systems.
- Control Lyapunov Functions and the Artstein-Sontag theorem.
- Control Lyapunov Functions for nonlinear triangular control systems.
- Input-to-State Stability.
- The observer design problem for control systems.
- The output feedback stabilization problem for control systems.
- High-Gain observers for globally Lipschitz nonlinear systems.

Computer Vision (cc 9518)

Course Contents:

- **Image formation and physics**: Elements of perspective, sensors, and optical systems.
- **Radiometry–Photometry**, shading and 3D reconstruction, color.
- **2D/3D Image Analysis**: Brief review of linear filters and Fourier analysis, with emphasis on Gabor filters and wavelets.
- **Nonlinear filters and operators** (morphological, order-statistics, lattice-based) for shapes and images.
- **Multiscale and pyramid-based image analysis** (Gaussian and nonlinear scale spaces).
- **Edge, corner, and geometric feature detection** (SIFT, SURF, HOG).
- **Shape analysis**: Curvature, distance and skeleton transforms, size histograms. Geometric diffusion, heat kernels. 2D and 3D shape matching.
- **Texture analysis/modeling**: Textons, Gabor filter banks, fractals, Markov random fields.
- **Image segmentation**: Geometric, statistical, and graph-based methods.
- **Detection and estimation of 2D optical flow and 3D motion**, tracking of visual objects.
- **Stereopsis**: Elements of projective geometry, camera models, estimation of 3D structure and shape, multi-view geometry.
- **Active contours**: Curve/surface evolution using level set methods, variational calculus, and PDEs.
- **Object detection and recognition** in images.
- **Recognition of spatiotemporal actions and video understanding**.

Brief overview of selected applications across artificial intelligence, biomedical imaging, robotics, digital arts, and the internet—interwoven throughout the above topics.

Finite Differences and Finite Elements for Partial Differential Equations (cc 9587)

Review of the Theory of Partial Differential Equations (PDEs). Linear PDEs of the first and second order, Cauchy problem, Dirichlet and Neumann boundary problems. Finite differences and the three-point method for the one-dimensional boundary value problem. Finite differences for parabolic problems: stability, consistency, convergence. Finite differences for hyperbolic problems: CFL condition, stability, consistency, convergence. Finite differences for elliptic problems. Weak derivative and weak form of elliptic boundary value problems. The Finite Element Method for elliptic problems: a priori and a posteriori error analysis. The Finite Element Method for parabolic problems and a priori error analysis. The Discontinuous Galerkin Method for hyperbolic problems.

Nonlinear Dynamics And Applications (cc 9512)

Introduction to Nonlinear Dynamics

- Qualitative Differences between Linear and Nonlinear Systems: Understanding the fundamental differences of behavior of these two types of systems.
- Historical Evolution of Nonlinear Dynamics Theory: Overview of key developments in the field.
- Steady-State and Transient Behavior: Analysis of stages of system response over time.
- Phase Space Analysis: Examining stationary points, periodic orbits, coexistence of multiple solutions, and stability analysis.
- Concept of Attractors and Basins of Attraction: Understanding how systems evolve toward specific states.
- Flows in Phase Space: Studying system trajectories in phase space and their significance.
- Real-World Examples and Applications: Connecting theoretical concepts to natural and engineering systems.

Mathematical and Analytical Methods

- Numerical Analysis of Stationary Points and Stability Control: Computational approaches for assessing system stability.
- Poincaré Maps and Floquet Theory: Tools for analyzing the stability of periodic solutions.
- Perturbation Theory Methods: Analytical techniques, their usefulness, and limitations in highly nonlinear systems.

Bifurcations and System Evolution

- Parameter Variations and System Evolution: Understanding how dynamical systems change when parameters are altered.
- Bifurcation Theory: Local bifurcations and qualitative descriptions of fundamental bifurcation types.
- Mechanical System Applications: Practical examples in engineering.
- Codimension and Structural Stability: Exploring the robustness of dynamical systems.
- Global Bifurcations and Their Role in Engineering Safety: Assessing critical transitions in mechanical systems.
- Reduction of Complex Systems to Simpler Forms: Strategies for simplifying nonlinear dynamics problems.

Chaos and Fractal Properties

- Chaos in Nonlinear Dynamics: Introduction to chaotic behavior and simple examples.
- Strange Attractors and Sensitivity to Initial Conditions: How small changes can lead to unpredictability.
- Loss of Predictability and Its Consequences: Understanding the implications of chaotic systems.
- Pathways to Chaos: Different mechanisms leading to chaotic behavior.
- Fractal Dimension and Self-Similarity: Understanding complex structures in dynamical systems.
- Applications and Examples: Exploring real-world uses of chaos theory.

Direction II: Mathematics of Data Science

Survival Analysis And Reliability (cc 9563)

Lifetime data. Censored observations.

Survival and reliability function. Hazard function.

Basic models: Exponential, Gamma, Weibull, Log-logistic, Generalised Gamma, Generalised F and other distributions.

Non-parametric estimation. Kaplan-Meier and Nelson-Aalen estimators. Comparison of survival curves. Log-rank test.

Model fitting. Testing fit.

Regression models. Proportional hazards. Cox's semi-parametric model and extensions.

Accelerated failure time model.

Model fitting and development. Diagnostic methods. Residuals (C ox-Snell, Schoenfeld and others).

Frailty models. Repeated events.

Practical sessions using statistical packages (R and others). Special applications.

Statistical Quality Control (cc 9546)

Part I. On-line Quality Control

- Basic concepts of Univariate Statistical Process Control.
- The Pareto Chart.
- The cause-effect diagram.
- Shewhart control charts for variables and attributes.
- CUSUM, EWMA and MA memory type control charts.
- Acceptance sampling. Operating-characteristic (OC) curve.
- Single, double and multiple sampling plans.
- Process capability indices.
- Basic concepts of multivariate Statistical Process Control (MSPC).
- Multivariate Hoteling T^2, MCUSUM and MEWMA control charts.
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Part II. Off-line Quality Control

- Response Surface Methodology (RSM).
- 2nd order designs and models.
- Central Composite and Box-Behnken designs.
- Robust parametric designs.
- Taguchi methodology and performance measures.
- Location and dispersion modeling.
- Response Surface Modeling.
- Crossed and Combined Arrays.
- Comparison of crossed and combined arrays.

Bayesian Statistics And MCMC (cc 9577)

- **Introduction to Bayesian thinking.** Bayesian Statistics and Probability. Informative and non-informative prior distributions. Conjugate priors. Statistical modelling and prior compatibility. Sufficiency. Posterior distribution. Bayesian estimation. Bayesian interval estimation and hypothesis testing. Bayesian predictive distribution.
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- **Introduction to MCMC.** Stochastic simulation. Markov chains. Metropolis Hastings algorithm. Gibbs sampler. Examples using R. Introduction to Winbugs. Diagnostic tests using CODA. MCMC in generalized linear models.

Computational Statistics And Stochastic Optimization (cc 9579)

Kernel Density Estimation and Applications. Nadaraya-Watson kernel regression. Stochastic Simulation. Inversion Method. Rejection Sampling. Methods for Reducing Variance: Hit and Miss Method, Importance Sampling. Resampling Methods. Bootstrap, Jacknife. Cross-Validation. Stochastic Optimization. Genetic Algorithm, Simulated Annealing, Tabu Search. EM Algorithm. Variable Selection Methods. Shrinkage Techniques: Ridge, Lasso.

Technoregulation For Data Science (cc 9580)

The course content consists of the following sections:

1. Introduction to the techno-regulatory approach for solving data science problems
2. Intellectual Property Policies, Law and Data Science – Study Cases from Culture and Research
3. Public Information Policies and Law I (Access to Information and Its Further Use): Study Cases from the Field of Public Administration and Information Entrepreneurship
4. Public Information Policies and Law II (Geospatial and Meteorological Information): Study Cases from the Field of Public Administration and Information Entrepreneurship
5. Research and Education Policies and Law: Study Cases from Research and Education
6. Personal Data Protection Policies and Law and Bioethics: Study Cases from Life Sciences (Biology, Genetics, Medicine)
7. Future Trends in the Field of Technoregulation: Legal Issues of Digital-Physical (phigital) Objects, Meta-Products and the Internet of Things
8. Ethical and Legal Issues of Artificial Intelligence and Robotics
9. Issues of Deontological Logic and Ethics of Robots
10. Legal Issues in Natural Language Processing and Human-Machine Interaction

NetworksFundamentals and Applications (cc 9582)

The course focuses on the Theory of Complex Networks and the analysis of real data from natural world networks using the R programming language. Specifically, after an introduction to the mathematical concepts that quantify data from real or artificial networks, the three basic models that simulate physical networks will be analyzed: a) The Erdos-Renyi model which simulates purely random networks, b) The Watts and Strogatz model devised to simulate "small-world" networks and c) The Barabasi-Albert model, which introduces a mechanism assimilating the scale-free networks. Each of the three models is explained by examples and by its implementation in the R programming language. Finally, depending on the interests of the students, other relevant chapters will be presented, such as fractal networks, networks of biological neurons, energy networks, etc. The course structure and teaching hours are as follows:

- Introduction to the theory of Complex Networks: a) Examples of real-world networks, b) Examples of technological networks and c) Basic concepts in Network Theory
- Current Challenges in Physical, Social and Economic Networks: The example of the Enron Corpus.
- Introduction to R programming language
- Graph Theory and its applications using R
- Erdos-Renyi Random networks and its applications using R
- The Watts and Strogatz (WS) model of small-world networks. Realizations of WS networks using R.
- The Barabasi-Albert (BA) model of scale-free networks. Realizations of BA networks using R.
- Fractal and hierarchical networks. Deterministic and stochastic fractal networks

- Evolving and multilayer networks. Percolation networks.
Models of the neurons network of the human brain

Earth Observation Big Data And Analytics (cc 9575)

- **Lecture 1:** Earth observation big data introduction
- **Lecture 2:** Earth observation data analytics
    - **Lab 1:** Google Earth Engine
- **Lecture 3:** Introduction to deep learning #1
    - **Lab 2**: Introduction to pytorch
- **Lecture 4:** Introduction to deep learning #2
    - **Lab 3**: Introduction to pytorch
- **Lecture 5:** Convolutional Neural Networks
    - **Lab 4**: Classification
- **Lecture 6:** Transfer learning & Autoencoders
    - **Lab 5**: Semantic segmentation
- **Lecture 7:** Transformers
    - **Lab 6**: Time series classification
- **Lecture 8:** Vision Transformers
    - **Lab 7**: Time series classification
- **Lecture 9:** Generative & diffusion models
- **Lecture 10:** Self-supervised learning
- **Lecture 11:** Object detection
- **Lecture 12:** Vision-language models and beyond
- **Lecture 13**: RSLab applications

Operations Research (cc 9566)

- Introduction to Operations Research and Mathematical Programming:
- Basic concepts, definitions, and historical background are provided, along with the general process of model development.
- Linear Programming: Basic Elements and Problem Formulation:
- Fundamental aspects of linear programming are covered, including problem formulation with appropriate examples.
- Linear Programming: Graphical Solution:
- The graphical solution method for linear programming problems is presented through suitable examples.
- Linear Programming – Simplex and Big-M Methods: The main methods for solving linear programming problems are introduced.
- Linear Programming – Computer-Based Solutions: Computational tools such as MS Excel Solver, Lindo, and Solver are presented for solving problems.
- Linear Programming – Duality and Sensitivity Analysis: These concepts are analyzed through appropriate examples.
- Transportation Models: Transportation problems are formulated and solved using examples.
- Project Scheduling: Project scheduling problems are formulated and solved using CPM and PERT methods.

- Integer Programming: Basic concepts are introduced, general formulation is described, and examples are provided.
- Network Problems: Network problems are formulated and solved through examples.
- Inventory Problems: Inventory problems are formulated and solved through examples.
- Multicriteria Evaluation: The main methods of multicriteria evaluation are presented and solved through examples.
- Dynamic Programming and Queueing Theory: Fundamental concepts are introduced, and problems are formulated and solved through examples.

AI Hands On (cc 9601)

Module 1: AI Programming Foundations

- Data structures and libraries (NumPy, Pandas, Matplotlib)
- SQL fundamentals
- Object-oriented & functional programming for AI
- Best coding practices
- Dockerization techniques for AI applications

Module 2: Data Fundamentals for AI

- Data types: Structured, unstructured, and semi-structured
- Data preprocessing & feature engineering
- Hot and cold data storage (SQL, NoSQL, Big Data)

Module 3: AI Core Tasks

- Unsupervised learning: Clustering, dimensionality reduction
- Self-supervised learning: Reinforcement learning, contrastive learning, masked language modeling
- Supervised learning: Classification, regression, ranking, and generative models (text, image, sound, video)

Module 4: Modeling

- Classical ML algorithms: PCA, k-Means, SVM, Decision Trees, etc.
- Learning to rank
- Neural networks: CNNs, RNNs, Transformers, LLMs
- Advanced AI techniques: Graph neural networks (GNNs), NeRF, computer vision models

Module 5: AI Applications

- Customer ranking in marketing
- Retrieval-augmented generation (RAG)
- Retail market product retrieval
- Virtual Try-On & Virtual Try-Off
- Time series forecasting
- Agentic text-to-SQL and function calling
- Ethical AI and fairness considerations

Algorithms And Data Science (cc 9594)

- Association rules mining and identification of data sets that occur frequently in big data.
- Hashing methods, modular and multiplicative. Universal families, closed and open addressing. Peferct hashing. Linear and quadratic probing, double hashing, Cuckoo hashing.

- Multidimensional spaces and dimension reduction, singular value decomposition, Johnson-Lindenstrauss lemma.
- Recommendation systems, electronic advertising, applications.
- The web as a graph and as a Markov chain, link analysis, PageRank.
- Analysis of social networks, identifying communities. Girvan-Newmann and Louvain algorithms. Spectral and MLE methods.
- Data streams, sampling and sketching in data streams. Morris-Flajolet and DGIM algorithms. Frequent itemsets mining via exponentially decaying windows.
- Data clustering, k-means method, spectral clustering.

Stochastic Processes & Optimization in Machine Learning (cc 9591)

- Overview of Optimization Algorithms in Machine Learning: Relationship between Machine Learning (ML) and Artificial Intelligence (AI), supervised, unsupervised, and reinforcement learning, Discriminative & Generative Models, ChatGPT. Training, Validation & Testing Datasets, Linear & Logistic Regression.
- Neural Networks, Hebb's rule, supervised learning parameter estimation, Rosenblatt's Perceptron, Back-Propagation Algorithm.
- Unsupervised Learning: K-Means Clustering, Principal Component Analysis (PCA), Self-Organizing Maps (SOM), Autoencoders.
- Fundamental concepts of Statistical Mechanics in Machine Learning: Markov chains, state classification, transition probabilities, Chapman–Kolmogorov equations, recurrence–transience, invariant distributions, asymptotic behavior.
- Monte Carlo simulation methods for Markov chains, Metropolis–Hastings algorithm, Simulated Annealing, Gibbs sampling. Generative Learning Models, Boltzmann Machines, Restricted Boltzmann Machines (RBM), Deep Belief Networks (DBN).
- Reinforcement Learning and Dynamic Programming: Markov Decision Processes (MDP), Bellman's Optimality Criterion, Dynamic Programming algorithms (Value & Policy Iteration), approximate dynamic programming methods, Temporal Difference (TD) & Q-Learning.
- Reinforcement Learning for Internet Routing: Bellman–Ford Algorithm, Border Gateway Protocols (BGP).
- Kernel Algorithms and Pattern Separability: Cover's theorem, applications to Radial-Basis Function (RBF) Networks, Hybrid Learning, Support Vector Machines (SVM).
- Non-parametric classifiers, classification according to known classes, K-Nearest Neighbors (KNN).
- Statistical evaluation of binary classification, Confusion Matrix, Receiver Operating Characteristics (ROC) & Area Under Curve (AUC), Parametric probabilistic classification – Bayes rule, approximate methods, Naïve Bayes algorithm.
- Decision Trees: CART algorithms (Classification And Regression Trees), Gini Index, Random Forests, Bagging algorithms (Bootstrap & aggregating).
- Recurrent Neural Networks (RNN): Associative Memory models (Content Addressable Memory – CAM), Hopfield networks, RNNs & sequential data models (time series, speech processing), Long-Short Term Memory (LSTM).

Explainable Artificial Intelligence (XAI): Definitions, Intrinsic & Model-Agnostic XAI Methods, Permutation Feature Importance (PI), SHAP (Shapley Additive exPlanations), LIME (Local Interpretable Model Agnostic Explanation).

Direction III: Financial Engineering

Stochastic Differential Equations and Applications in Finance (cc 9521)

- Continuous time stochastic processes
- Filtrations

- Stopping times
- Basic properties of continuous time martingales
- Markov processes
- Definition and basic properties of the Brownian motion process (Wiener process)
- Itô stochastic integral - Itô stochastic processes
- The quadratic variation of the Brownian motion process
- Itô formula
- Stochastic differential equations
- Applications and examples
- Girsanov’s Theorem
- Continuous time Financial (market) modelling – The Black-Scholes model – Option pricing – European options.

Financial Derivatives (cc 9570)

- **Part A:** Types and Structures of Financial Derivatives (Futures, Forwards, Options, Swaps, Swaptions)
- In Part A, the types of derivatives and their significance in the financial sector are analyzed.
- **Part B:** Valuation Models for Financial Derivatives
- In Part B, the basic methods (models) for pricing financial derivatives are presented based on the type of derivative.
- **Part C:** Applications and Use of Financial Derivatives
- In Part C, applications (via coding) for the pricing of derivatives are presented, along with their utilization for hedging financial risks.

Portfolio Analysis (cc 9574).

- Introduction to Financial Concepts, Time Value of Money, Investment Analysis and Portfolio Management
- Return and Risk, Money and Capital Markets
- Valuation and Analysis of Fixed Income Securities (Bonds), Duration and Convexity
- Stock Valuation and Analysis
- Portfolio Theory
- Single Index Model
- Capital Asset Pricing Model – Market Efficiency Hypothesis
- Investor Profile
- Asset Allocation
- Portfolio Management Strategies
- Technical Analysis
- Introduction to Derivatives

Valuation and Hedging

Mathematical Economics (cc 9542)

Basic knowledge of the theory of metric spaces, continuity and convexity of functions, compactness in metric spaces.
Preference relations, utility functions, representation of preference relations with utility functions.
Budget set, maximization of utility functions, demand function. The concept of allocation, optimal and weakly optimal allocation according to Pareto, equilibrium allocation, welfare theorems.
Convex sets, separation theorems,
Elements of the theory of multivalued mappings and fixed point theorems.

Production economies.
Equilibrium in competitive economies.
Game Theory: Introduction to game theory,
pure strategy games and mixed strategy games,
competitive (zero sum) games,
Elements of Linear Programming theory and
the mini-max theorem.
Nash equilibrium theorem,
Sequential games.

Econometrics And Time Series Analysis (cc 9576)

- Multiple Linear Regression
- Basic Assumptions
- Student's t and F Statistics
- Violations of Multiple Linear Regression Assumptions
- Probability Models and Dummy Variables
- Nonlinear Models
- Systems of Equations
- Time Series Analysis
- Integration and Cointegration of Time Series
- Causality and Short-Run Causality Tests
- Vector Autoregressive (VAR) Models
- Error Correction Models (ECM)
- Global Vector Autoregressive (GVAR) Models

HORIZONTAL CORSES

European and Technical Law (cc 9602)

International Law

- Introduction to International Law
- Private International Law

European Law & Institutions

Greek Public Law

- Constitutional Law
- Administrative Law

Tax Law

- European Tax Law
- Greek Tax Law

Greek Civil Law

Environmental Law

- European Environmental Law
- Greek Environmental Law

Energy

- Investments in the Energy Sector (ECT & Paris Agreement)
- Energy Transit
- EU Energy Law

Law of the Seas & Maritime Law

- International Law of the Seas

Greek Maritime Law

Differences and Finite Elements for Partial Differential Equations (cc 9887)

Review of the Theory of Partial Differential Equations (PDEs). Linear PDEs of the first and second order, Cauchy problem, Dirichlet and Neumann boundary problems. Finite differences and the three-point method for the one-dimensional boundary value problem. Finite differences for parabolic problems: stability, consistency, convergence. Finite differences for hyperbolic problems: CFL condition, stability, consistency, convergence. Finite differences for elliptic problems. Weak derivative and weak form of elliptic boundary value problems. The Finite Element Method for elliptic problems: a priori and a posteriori error analysis. The Finite Element Method for parabolic problems and a priori error analysis. The Discontinuous Galerkin Method for hyperbolic problems.