HELLENIC REPUBLIC

ARISTOTLE
UNIVERSITY
THESSALONIKI

FACULTY OF ENGINEERING

SCHOOL OF CHEMICAL ENGINEERING
GRADUATE STUDY PROGRAMME
"CHEMICAL AND BIOMOLECULAR ENGINEERING"
Secretariat

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Subject: Education Syllabus of the Graduate Study Programme

Dear Sir/Madam,

Please find below information about the Graduate Study Programme in Chemical and Biomolecular Engineering and its syllabus.

The program is geared towards educating and training highly qualified engineers competent for being employed by any national or international institution. It also enhances research as well as transformation of research results into socially useful products in strategic domains for the country such as medical health, food industry, energy and environmental engineering.

There are two specializations in this program:

1. Chemical and Biomolecular Engineering in Health and Food

2. Chemical and Biomolecular Engineering in Energy and Environment.

To be awarded an MSc in Chemical and Biomolecular Engineering of the Department of Chemical Engineering of the Aristotle University of Thessaloniki, in the first semester the students must successfully complete three (3) compulsory courses, one (1) elective course and compulsory seminars, in the second semester four (4) elective courses and compulsory seminars and a Graduate Diploma Thesis during the third semester of study. To obtain the MSc, it is required to collect 90 ECTS, 30 per semester. To meet the entry requirements the students must hold a Degree in relevant discipline issued either by a Greek University or by a Greek Technological Educational Institute (ATEI). Graduates with an equivalent degree issued by an internationally recognized university can also apply.

Courses of the Programme- Course content (syllabus)

1. **Applied Thermodynamics** *(1st semester compulsory course, 7 ECTS, 39 hours of study)*

   The first and the second law of thermodynamics and other basic concepts, the thermodynamic state functions, phase equilibria and phase stability, chemical equilibrium. Introduction to Statistical Thermodynamics: Quantum states and partition functions, the canonical ensemble, the microcanonical ensemble, the grand canonical ensemble, the NPT ensemble, partition function for an ideal gas, partition function for a real fluid, equations of state from statistical thermodynamics. Phase equilibria for separation processes: Vapor-Liquid and Liquid-Liquid equilibrium, three phase equilibrium, phase diagrams (Types I-VI according to Scott and van Konynenburg classification), Solid-Liquid equilibrium, metastable equilibrium, modeling of phase equilibria using statistical thermodynamic models. Polymer and biopolymer solutions. Thermodynamics of surfaces and nanosystems. Thermodynamics of electrolyte solutions. Thermodynamics of biological processes. Environmental Thermodynamics. Thermodynamics of Energy production systems.

2. **Transport Phenomena** *(1st semester compulsory course, 7 ECTS, 39 hours of study)*

- General form of conservation equations. Conservation of mass, chemical species and energy in integral and differential form. Conduction and diffusion. Initial & boundary conditions in fixed and moving boundaries.
- Heat and mass transfer in solids and stagnant fluids. Conduction and diffusion in steady state and transient conditions. Homo- and hetero-geneous reactions. Heat transfer from extended surfaces. Evaporation & Condensation. Scaling and approximation techniques.
- Fluid mechanics. Stress and rate of deformation tensors. Newtonian fluid. Momentum transfer at low and high values of the Reynolds number in confined geometries and around bodies. Boundary layers near solid surfaces.
- Convective heat and mass transfer. Convection in confined and unncofined laminar flows. The Prandtl, Schmidt, Peclet, Nusselt and Sherwood numbers. Temperature and concentration boundary laminar layers. Buoyancy-driven flows.

3. **Chemical and Biochemical Kinetics** *(1st semester compulsory course, 7 ECTS, 39 hours of study)*

The course aims at instilling into students concurrently integrated and targeted knowledge on kinetics of chemical and biochemical processes. The fundamental nature of this knowledge formulates the field of applications in enzymatic and non-enzymatic processes. Given that kinetics is a key pillar in comprehending a variety of catalytic processes on a research and industrial scale, delving into and consolidating the principles governing the specific field constitutes the foundation for the development of critical exploration and assessment skills of (bio)chemical processes and reactivity. The combination of theoretical knowledge, applications in chemical engineering and simulation of chemical kinetic reactions, through modeling, provide a global experience sought out by any graduate student in (bio)chemical engineering.

- Reaction properties
- Basic reactor design equations
- Kinetics of catalytic reactions
- Biocatalysis
- Reaction mechanisms
- Enzymatic vs. non-enzymatic catalysis
- Simulation of chemical kinetic reactions

4. **Biology for Engineers** (*1st semester elective course, 7 ECTS, 39 hours of study)*

The scope of the module is to teach the basic biological principles to scientists and engineers who are interested in applying biological principles for addressing technological challenges. Biology has a central role to play in finding solutions to global challenges, such as better healthcare, cleaner environment, sustainable energy, food and better quality of life. In order to be able to apply biological principles in a wide range of issues, scientists and engineers need to be able to gain a good understanding of these principles. Topics that will be covered include: I. Hierarchy in Biology, II. The biological milieu, III. Biological responsiveness. Student evaluation will be based on a final written examination in combination with the option of individual projects.

5. **Resource Management** *(1st semester elective course, 7 ECTS, 39 hours of study)*

The course will introduce students in a multidisciplinary approach of the energy and non-energy natural resources aiming to explore the best strategies for optimizing their use for the production of energy and other economic goods. The following analytical tools are used:

- Evaluation of technologies
- Economic analysis
- Analysis of energy policies and natural resources
- Energy analysis and
- Multidisciplinary sustainability assessment
- Multifactorial system optimization

Part I: Energy resources

- The energy transition to a carbon-free economy and development
- Biomass, household use and the role of the sexes (sociology of energy)
- Thermodynamics of modern power stations
- Modern uses of hydrocarbons
- Evolution of the modern energy economy
- Economic analysis of energy systems
- Life cycle analysis
- Cost-benefit analysis
- Energy efficiency:

- Electrical devices

- buildings and greater energy systems

- Electricity network management
- Gas, fracking, carbon storage
- Renewable energy:

- Solar power

- Wind power, geothermal energy and hydroelectric power

- Industrial bioenergy and competitive land use

- Nuclear energy - technology, waste, risks and finance
- Energy and environmental justice

- International energy policy
- Transport systems and policies
- Climate change:

- Energy and climate change
- Energy policy

Part II: Non-energy natural resources

- Pollution control
- Strategies to increase the efficiency of natural resources

- Dematerialization of production
- Substitution of raw materials
- Recycling of raw materials
- "Extraction of waste"

- The problem of toxicity of recyclable raw materials
- Natural resources as factors of production
- "win-win" Economics
- The role of governments and the public sector
- Employment and productivity of natural resources
- Information requirements for environmental policy analysis
- Case studies for selected raw materials

- Alumina, aluminum and gallium
- Copper, cobalt, silver and male
- Chrome
- Zinc and cadmium
- Sulfuric and sulfuric acid
- Phosphorus, fluorine and gypsum
- Nitrogen based chemicals
- Silicon for electronic applications (eg for semiconductors)
- Waste from wrappers
- Worn tires
- Ash / lignite ash

- The concept of industrial ecosystem
- Benefits of large scale applications
- Benefits of system integration

•Integrated industrial ecosystems

•The example of Kalundborg in Denmark

•Other industrial ecosystems - applications in Greek industry

•Strategic opportunities and policy levers

•Technological gaps and development opportunities

6. **Process & Equipment Design** *(1st semester elective course, 7 ECTS, 39 hours of study)*

   The course focuses on the design, simulation and optimization of processes related to the production of a wide range of products, e.g. food, petrochemicals, etc. Students will combine knowledge from different fields and apply it to the optimall design, both from an economic and an environmental (energy savings, waste reduction etc.) point of view, to design either an individual process equipment or an entire process. The subjects covered are:

- Process design using process simulation software (ASPENplus). Process simulator is a tool that permits the study of complex processes and the prediction of the effect of various design parameters on the process behavior.
- Design, simulation and optimization of process equipment (e.g. reactors, bubble columns, heat exchangers, micro-equipment) using Computational Fluid Dynamics (CFD).
- Application of Design of Experiments (DOE) techniques to determine the necessary "computational experiments" that adequately describe the response of a system to the variation of the design variables. Utilization of Response Surface Methodology (RSM).
- Case studies.
- Design project

  At the end of the course the student will be able to:

- Design optimally a process or an equipment using advanced optimization-based techniques and related computer-aided tools.
- Justify clearly the results of a technical or research project based on underlying assumption and present them both in a technical and non-technical audience.
- Acquire the learning skills which will allow them to continue their studies in an independent way.

7. **Applied Mathematics** (*1st semester supportive/preparatory course for all specializations, 48 hours of study)*

   Objectives

   Working command of pure and applied mathematics for the science of chemical engineering or for problems of interdisciplinary character.

   Course content

   - A brief review of prerequisite concepts on: Linear Algebra, Single variable and Multivariable Calculus, Introduction to Differential Equations.
   - Development of the theory of PDEs.

- Development of mathematical models for systems encountered in Chemical Engineering or in other applied sciences, such as Physics and Biology. Using one Differential Equation or a set of Differential Equations with appropriate boundary and / or initial conditions, we attempt to approximate real processes.

8. **Biomedical Engineering, Nanomedicine, Tissue Engineering** (*2nd semester compulsory course for specialization Health-Food, 7 ECTS, 39 hours of study)*

   The scope of the module is to teach students the basic principles and current trends in the field of Biomedical Engineering, with emphasis on Nanomedicine and Tissue engineering. It includes lectures and laboratory demonstrations. The student evaluation is based on a combination of individual student projects and final written examination. The module includes: basic principles in Biomedical Engineering, introduction to human body function-physiology-anatomy, current trends, clinical applications, the role of chemical engineers, nanomedicine, tissue engineering, prospects.

9. **Pharmaceutical Technology and Engineering** *(2nd semester compulsory course for specialization Health-Food, 7 ECTS, 39 hours of study)*

   Introduction. Basic terms and definitions. Drug Discovery and Development process.

   Innovation in the Pharmaceutical Industry- New (innovative) drugs - Generic drugs -

   Drug properties- Intro to Pharmacokinetics- Pharmacodynamics – Bioavailability-Bioequivalence - Analysis of pharmaceuticals -Quality control of Pharmaceuticals – Good manufacturing practices- Pharmaceutical Quality by Design (QbD)- Scale up in the pharmaceutical industry: from lab to industrial production -Case studies-Pharmaceutical process development-The drug manufacturing process.

   Tablet-Capsules-Ointments-Creams -Emulsions-Suspensions - Drug Delivery Systems.

   Stability – Shelf life of pharmaceuticals- Pollution from pharmaceutical industries - Waste management – Laboratory.

10. **Food Science and Engineering** (*2nd semester compulsory course for specialization Health-Food, 7 ECTS, 39 hours of study)*

    Bioactive food components – Functional Foods: structure, physical and chemical properties, isolation from natural sources, incorporation into foods with an emphasis on the role of food engineering on the manufacturing of such products. Relation of functional foods to nutrition and health.

    Foodomics: a new area of scientific interest, which studies food and nutrition through the use of -omics technologies in order to contribute to consumer's health. Description of the tools used and practical applications. Developments in processing of bioactive materials and foods. Encapsulation, spray drying, freeze drying, sonication, microwave, high pressure processing, 3D food printing. Transport phenomena during these processes and process optimization.

11. **Systems Biology/Biomolecular Kinetics & Cellular Dynamics** (*2nd semester compulsory course for specialization Health-Food, 7 ECTS, 39 hours of study)*

Systems Biology is the mathematical and computational modeling of complex biological systems. It has been developed as a result of convergence and synergy of three scientific areas:

1) Rapid accumulation of detailed biological information in the submolecular, molecular, cellular and physiological level.

2) Technological development that allowed us to analyze biological systems in vivo using sensors, imaging techniques, and biomarker measurements.

3) Combined development of more powerful mathematical, physical, and computational techniques available to a greater part of the scientific community.

It is an interdisciplinary scientific field that focuses on complex interactions within biological systems using a holistic approach to biological research.

Course contents:

- Biological systems
- Introduction to mathematical modeling
- Static network models
- The mathematics of biological systems
- Cellular reaction models
- Parameter Estimation - Model Configuration
- Gene systems
- Protein systems
- Metabolic systems
- Structural analysis of metabolic networks
- Dynamic analysis of metabolic network flows
- Signaling systems
- Population systems
- Multi-dimensional biological analysis - integrated data analysis
- Gene expression, protein and metabolite analysis
- Physiology-based models
- Systemic biology in medicine and drug development
- Systemic biology in personalized prevention
- New horizons in systemic biology

-From neurons in the brain

-Multi-step models of cancer development

- Multifactorial diseases, inflammation and trauma

-Interaction between environment and health

The course includes lectures by the instructor responsible, seminars by

- invited professors and internationally renowned researchers, and laboratory exercises for
- Bioinformatics analysis and simulation of biological systems

12. **Bioreactor Design & Operation** *(2nd semester compulsory course for specialization Health-Food, 7 ECTS, 39 hours of study)*

    <u>COURSE OBJECTIVE</u>

    The purpose of the course is to give an up-to-date overview of a variety of emerging techniques and methods used for the design and efficient operation of bioreactors, given their essential role as artificial harbours for growing and maintaining cell cultures. That task decomposes into several endeavours necessary to accomplish, and generally requires a wide set of engineering theory including among others basic engineering principles, systems biology and conceptual design theory.

    <u>COURSE STRUCTURE</u>

    The course includes:

1. **Lectures and exercises on the following scientific fields:**

- Challenges for bioreactor design and operation
- Bioreactor designs and cell kinetics
- Gas-liquid mass transfer
- Experimental measurement techniques
- Sterility in industrial bioreactors
- Scale-up methodologies for bioreactors
- Bioreactor applications - A case-study
- Integration of Bioreactors with Downstream Processing Steps

2. **Educational project**

13. **Chemical Processes of Energetic or Environmental Importance** (*2nd semester compulsory course for specialization Energy-Environment, 7 ECTS, 39 hours of study)*

    Application of the basic principles and knowledge of Chemical Engineering in chemical processes of energy and environmental interest with emphasis on reactor systems.

    Process overview will include:

    - Basic Process Features - Flow Diagrams

    - Thermodynamics and kinetics of chemical reactions

- Reactor design principles (fixed, moving, fluid bed, membrane reactors, gas-solid)

Processes under study:

- Cleaning flue gases from mobile and stationary sources
- CO_2 capture from flue gases of energy-intensive industries (cement, power plants)
- Production of alternative fuels (H_2, CH_3OH, synthetic fuels)
- Production of environmental fossil fuels

Intensification of energy processes - Application of intensification to hydrogen production - Combined reaction and separation of products using solid sorbents.

14. **Alternative Energy Sources** *(2nd semester compulsory course for specialization Energy-Environment, 7 ECTS, 39 hours of study)*

Primary energy sources and energy carriers. Energy needs and potential

Biomass and Bioenergy. Available potential in residual biomass and energy crops, Biomass combustion systems, Conversion processes - Thermochemical, chemical and biological, Biofuels - Biodiesel, Bioethanol and Biogas, Biomass as source for chemicals and materials, Biorefineries

Solar power. Thermal conversion. Passive solar systems. Photovoltaic elements. Photoelectric conversion. Conversion to electric energy with intermediate heat energy, Energy calculations

Wind power. Availability of wind power available. Types of wind turbines. Wind turbine performance and losses. Use of wind turbines for power generation, Wind parks, Energy calculations.

Geothermal energy. Characteristics and uses, Geothermal power in Greece, Electricity generation, Heat pumps

Hydro power - hydroelectric power. Availability of hydrodynamic power, Electricity Generation, Types of Hydro Turbines, Energy Calculations

Alternative fuels and energy storage. Hydrogen - production processes and uses, Solar fuels, Fuel cells, Electric vehicles, Electricity and heat storage systems

Future scientific and technological challenges in the field of energy

15. **Circular Waste Management** *(2nd semester compulsory course for specialization Energy-Environment, 7 ECTS, 39 hours of study)*

The course provides students with a holistic view of integrated waste management based on the principles of circular economy and sustainable development. Provides basic competing tools for work and scientific research for the promotion of circular economy with respect to the protection of public health and the functioning of the ecosystem.

Course contents:

- Introduction to waste management and the circular economy - Basic principles
- Legislative framework for solid waste management (national - community)
- Characteristics of the solid waste stream
- Preventing measures and policies for waste production
- Reduction in source and toxicity
- Collection and Recycling
- Composting of municipal solid waste
- Disposal in landfill
- Incineration of waste with energy recovery
- Gasification and Pyrolysis of waste and scrap
- Biological processes of solid waste treatment for energy recovery and production of high value-added products
- Extraction of municipal waste
- Hazardous Waste Management
- Industrial and Medical Waste - technologies and management systems
- Location of solid waste management facilities
- Combined solid and liquid waste management
- Waste management and public health - a global problem

16. **Dispersion of Pollutants and Environmental Impact Assessment** *(2nd semester compulsory course for specialization Energy-Environment, 7 ECTS, 39 hours of study)*

The aim of this course is to enhance awareness and comprehension of the procedures adopted in the calculation of the toxicity levels concentrations following a toxic gas dispersion in the atmosphere, as well as their effects. At the same time, selected major toxic dispersion accidents are analyzed and studied. A software, specifically developed in the Laboratory of Thermophysical Properties & Environmental Processes, for the investigation of the parameters influencing a dispersion, is employed. The course in concluded with virtual trials.

More specifically, the course is composed of

- Introduction to Major Industrial Accidents through video analysis (Dispersion of chemical, nuclear, and biological substances, as well as terrorist actions).

ΑΡΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ ΤΜΗΜΑ ΧΗΜΙΚΩΝ ΜΗΧΑΝΙΚΩΝ ΠΟΛΥΤΕΧΝΙΚΗ ΣΧΟΛΗ

- Outflow from pipes, vessels, and stacks (Outflow equations).
- Dispersion equations. Meteorological conditions, parameters of influence.
- Toxic gas dispersion cases. Calculation of toxic-gas concentration.
- Calculation of effects from toxic-gas dispersion.
- Terrorist actions (Toxic gases in terrorist actions)
- Case studies.
- Virtual trials.

17. **Biotechnology** *(2nd semester elective course for both specializations, 7 ECTS, 39 hours of study)*

- Biosynthesis of primary and secondary metabolites
- Enzyme production regulation
- Fermentation Kinetics
- Continuous cultures
- Kinetics and mechanics of sterilization
- Enzyme isolation
- Kinetics and immobilization of enzymes
- Enzyme reactors
- Applications

The course seeks and stimulates natural selection of new knowledge, directly related to applications in Fermentation Engineering and Technology, Biochemical Engineering, Microbiology and Genetics. Transfer of this interdisciplinary knowledge to the development of bioreactors, compatible with current synthetic biology and innovative industrial production of new (bio)materials (e.g. proteins, enzymes), simultaneously offers a broad spectrum of applications and motivates graduate students to delve into the intricacies of contemporary biotechnology.

The final grade of the course is based on a final comprehensive examination.

18. **Modeling & Simulation of Molecular Systems** *(2nd semester elective course for both specializations, 7 ECTS, 39 hours of study)*

Introduction to Computer Simulations-From molecular level to process simulation. Molecular simulations: Introduction to Monte Carlo and molecular dynamics, computational techniques for determination of structure and physicochemical properties of materials. Prediction of thermodynamic properties of pure fluids and mixtures – Mean field theories: Cubic equations of state, activity coefficient models, EoS GE models, association theories and models, the Statistical Associating Fluid Theory (SAFT), the Cubic-Plus-Association equation of state, the lattice fluid hydrogen Bonding EoS, models for electrolyte solutions, applications to systems with Pharmaceuticals, amino acids and polypeptides, partition coefficients of chemicals in environmental ecosystems, thermodynamic models in Process Simulators (ASPEN Hysys etc). Mesoscopic Modeling and Simulation of equilibrium and transport processes: The Lattice Fluid as a model fluid and its connection to the Ising Model. Thermodynamics of the lattice fluid: Density. Functional Theory (DFT) using: Monte Carlo Methods, Mean Field Theory (MFT), equilibrium inside a nanostructure: wetting and non-wetting fluids, comparison with Monte Carlo methods using Lenard Jones fluids, transport Processes using Lattice Fluids, Dynamic Density Functional Theory (DDFT), DDFT with hydrodynamic interactions, connection with other transport theories, transport processes in nanostructures under complete and partial wetting, comparison with Molecular Dynamics using Lenard Jones fluids.

19. **Water treatment Technology** *(2nd semester elective course for both specializations, 7 ECTS, 39 hours of study)*

    Postgraduate students after successful completion of the course will develop the necessary learning skills to allow them to deeply understand and designed water treatment processes through the evaluation of available scientific data and the international literature, as well as to present their work in clear and scientific manner.

    Introduction: Hydrological cycle, water sources, physical and chemical quality of water, strategy on design water treatment plants.

    Suspended solids separation processes: Stability of particulates, coagulation – flocculation, sedimentation, filtration through porous media and surface filtration, process design – cost analysis. Continuous flow lab-experiments on suspended solids separation by coagulation – flocculation and sand filtration and process evaluation through the change of particle size distribution.

    Disinfection processes: Disinfection mechanisms, process alternatives, chemistry of disinfect-ants, UV disinfection, parameters influencing disinfectants' efficiency, design of disinfection facilities, ozonation – industrial implementation.

    Dissolved substances removal: Selective processes: Chemical precipitation, adsorption, ion-exchange. **Non-selective processes:** Reverse osmosis, nanofiltration, process description, mem-brane's fouling and cleaning

    Selected processes for water treatment

    Visiting water treatment plants

20. **Innovation & Entrepreneurship** *(2nd semester elective course for both specializations, 7 ECTS, 39 hours of study)*

    The course provides: a) the theoretical background of managing entrepreneurial activities with i) seminars on introductory issues on Management, Marketing, Finance and Accounting for Small-Medium Enterprises, ii)presentations of best practices, case studies, b) the laboratory experience in business planning of relevant activities (preparation of students' business plans), c) the networking with entrepreneurs (visiting enterprises and entrepreneurs) and d) Drafting and Developing a Business Plan

    The course content includes lectures on a) Innovation and competitiveness as a management process, b) Entrepreneurship and innovation practices, c) Indicators of innovation and entrepreneurship measurement

21. **Measurement Principles and Methodology- Advanced Instrumental Analysis I** *(1st semester compulsory seminars, 2 ECTS, 39 hours of study)* and

Measurement Principles and Methodology- Advanced Instrumental Analysis II *(2nd semester compulsory seminars, 2 ECTS, 39 hours of study)*

The scope of the course is to familiarize students with the choice of opportunities and the field of applications of modern measurement techniques. Initially, the basic principles of measurements will be presented that are independent of the type of measurement yet relate to the functional characteristics of the instrumentation employed and the methodology of designing experiments (Design of Experiments, DOE). A series of seminars will ensue on advanced measurement techniques, accompanied by demonstration of relevant instrumentation equipment. Seminars include:

- Techniques on analysis and characterization, such as Raman spectroscopy, X-ray diffraction, atomic absorption spectroscopy, mass spectrometry in combination with liquid chromatography, nuclear magnetic resonance spectroscopy, TGA, DSC (Differential scanning calorimetry)
- 3D printing of biomaterials
- Measurement of fluid-mechanics parameters through non-invasive techniques, such as μ-PIV, μ-LIF, and optical measurements of rapidly evolving phenomena.

EDUCATION SYLLABUS

GRADUATE STUDY PROGRAMME

CHEMICAL AND BIOMOLECULAR ENGINEERING

Both specializations

1st semester

Code	Course	Attendance type	Hours of study	ECTS
ETH1	Applied Thermodynamics	COR (compulsory course)	39	7
XB1	Chemical and Biochemical Kinetics	COR	39	7
FM1	Transport Phenomena	COR	39	7
BM1	Biology for Engineers	ELC (elective course)	39	7
DE1	Resource Management	ELC	39	7
SD1	Process & Equipment Design	ELC	39	7
EA1	Measurement Principles and Methodology-Advanced Instrumental Analysis-I	CompSem (compulsory seminars)	39	2
EM1	Applied Mathematics	Seminar (supportive/preparatory course)	48	0
SUM of ECTS				30

Specialization: Health-Food

2nd semester

Code	Course	Attendance type	Hours of study	ECTS
NB2	Biomedical Engineering, Nanomedicine, Tissue Engineering	ComSC (compulsory Specialization course)	39	7
FT2	Pharmaceutical Technology & Engineering	ComSC	39	7

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MT2	Food Science & Engineering	ComSC	39	7
BS2	Systems Biology/Biomolecular Kinetics & Cellular Dynamics	ComSC	39	7
LB2	Bioreactor Design & Operation	ComSC	39	7
BX2	Biotechnology	ELSC (elective specialization course)	39	7
MP2	Modeling & Simulation of Molecular Systems	ELSC	39	7
TN2	Water Treatment Technology	ELSC	39	7
KE2	Innovation & Entrepreneurship	ELSC	39	7
EA2	Measurement Principles and Methodology-Advanced Instrumental Analysis -II	CompSem	39	2
SUM of ECTS				30

Specialization: Energy- Environment

2nd semester

Code	Course	Attendance type	Hours of study	ECTS
DE2	Chemical Processes of Energetic or Environmental Importance	ComSC	39	7
EP2	Alternative Energy Sources	ComSC	39	7
DM2	Circular Waste Management	ComSC	39	7
AP2	Dispersion of Pollutants and Environmental Impact Assessment	ComSC	39	7

ΑΡΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ ΤΜΗΜΑ ΧΗΜΙΚΩΝ ΜΗΧΑΝΙΚΩΝ ΠΟΛΥΤΕΧΝΙΚΗ ΣΧΟΛΗ

BX2	Biotechnology	ELSC	39	7
MP2	Modeling & Simulation of Molecular Systems	ELSC	39	7
TN2	Water Treatment Technology	ELSC	39	7
KE2	Innovation & Entrepreneurship	ELSC	39	7
EA2	Measurement Principles and Methodology-Advanced Instrumental Analysis -II	CompSem	39	2
SUM of ECTS				30

Sincerely,

Vasileios Zaspalis

Digitally signed by Vasileios Zaspalis
DN: c=GR, l=Thessaloniki, o=Aristotle University of Thessaloniki, ou=School of Chemical Engineering, ou=Class A - Private Key created and stored in hardware CSP, sn=Zaspalis, givenName=Vasileios, serialNumber=5511485869, cn=Vasileios Zaspalis, email=zaspalis@cheng.auth.gr
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Prof. Vassilis Zaspalis

Director of Graduate Study Programme