HELLENIC MEDITERRANEAN UNIVERSITY

UNIVERSITY OF SIEGEN

UNIVERSITY OF ORLÉANS

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

NOVA UNIVERSITY LISBON

MODULE MANUAL FOR THE STUDY PROGRAMME

European Master on Embedded Intelligence Nanosystems Engineering – from Nanoscale Technologies to Ubiquitous Smart Sensors (EMINENT)

Master of Science (M.Sc.)

Effective as of 01.10.2024

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(green)	Mandatory course
(orange)	Elective

Module descriptions

1. Hellenic Mediterranean University

Course Title	**Condensed Matter for Semiconductor Physics**
Module ID	4EMINENT101
Responsible Lecturer	Prof. Dr. George Kavoulakis
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Elective
Credit points (ECTS)	4.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 69 h, total number of estimated working hours: 117 h.
Course description	This is an introductory course on condensed-matter physics and of semiconductors. After a very brief review of classical physics, it turns to the basic principles of quantum mechanics. It then examines the consequences of quantum theory, starting with the atoms, turning to the periodic table, to molecules and ending up with solids, paying special attention on various properties of solids.
Learning Outcomes	The students will be able to: • Apply the fundamentals of Quantum Physics to the study of the semiconductor materials and devices. • Understand and solve problems related to semiconductors and semiconductor based devices. • Understand the fundamentals of semiconducting devices such as quantum well, nanowires and quantum dot devices. • Simulate semiconductor and superconductor devices.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • An Introduction to Quantum Physics by Stefanos Trachanas, Willey • An Introduction to Solid State Physics by Charles Kittel

Course Title	**Chemistry of Materials**
Module ID	4EMINENT102
Responsible Lecturer	Prof. Dr. Dimitra Vernadou
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Mandatory course
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147, total number of estimated working hours: 195 h

Course description	Knowledge in the state-of-the-art technologies leading to the materials growth with photocatalytic, thermochromic and electrochromic layers for environmental and energy applications. Understanding the relationship between growth parameters-properties-applications for the best choice of materials. Knowledge in the design and chemistry of materials with improved properties.
Learning Outcomes	The students will be able to: • Understand the operational mechanisms of photocatalytic, thermochromic and electrochromic materials. • Synthesise materials with the aforementioned properties.
Assessment method	final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture. • The Physical Chemistry of Materials: Energy and Environmental Applications by Rolando Roque-Malherbe

Course Title	**Graphene and 2D Materials and Devices**
Module ID	4EMINENT103
Responsible Lecturer	Prof. Dr. Konstantinos Petridis, Dr. George Kakavelakis and Prof. Dr. George Kioseoglou
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Mandatory course
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147 h, total number of estimated working hours: 195 h
Course description	Graphene, a single layer of carbon atoms is a honeycomb lattice. Its single layer isolation in 2010 permitted its study and application thanks to wonderful mechanical, physical and optical properties demonstrate. Graphene triggers the evolution and the increasing research & industrial interest to other 2D materials (e.g. transition metal dichalcogenides - TMDs). In this module, an introduction to graphene-based materials and TMDs will be provided: from fabrication to the deposition techniques of these materials. Continuously selected applications in energy harvesting, in electronics and optoelectronics areas, will be presented.
Learning Outcomes	The students will: • Be able to understand fundamental knowledge of graphene and 2D semiconductor materials • Receive an Introduction to Laboratory techniques of synthesis, deposition and characterisation of graphene & 2D materials – explain how to perform graphene material synthesis experiments • Be aware of graphene and 2D materials applications in energy harvesting, sensing and electronic

Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Scientific Publications (mainly review papers) in the topic • Graphene Fundamentals, Devices, and Applications by Serhii Shafraniuk

Course Title	**Winter School – Introduction of Specialisation Tracks**
Module ID	4EMINENT104
Responsible Lecturer	Prof. Dr. Konstantinos Petridis, Prof. Dr Peter Haring Bolívar, Prof. Dr. Luis Pereira, Prof. Dr. Raphaël Canals, Prof. Dr. Sarunas Paulikas
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Mandatory course
Credit points (ECTS)	3
Teaching type	Face to Face lectures.
Workload	Lecture: 26 h, Additional individual work of the student / homework time: 52 h, total number of estimated working hours: 78 h
Course description	During this school, the academic coordinators of each partner university will give a deep introduction to the specialisation tracks that can be chosen in the third semester. These presentations will be accompanied by technological applications these specialization tracks involves. In the afternoon session a workshop in a critical soft and research skill will be organized for the students to practice it, working in groups. One full day will be dedicated to each specialisation track. In addition to the general introduction of the specialisation topic, invited speakers from within and the beyond the consortium (within the academia and the market world) will give lectures on the respective topics.
Learning Outcomes	The students will: • Understand the fundamentals and applications of the specialisation tracks can follow in the forthcoming semesters. • Be able to present applications of the various tracks can follow in the forthcoming semester. • Be able to demonstrate critical soft & research skills e.g. presentation skills, critical thinking, to collaborate, read a research paper, be able to build a bibliographic research.
Assessment method	• Final exam paper. • Students' Presentations
Literature	• The presentation slides of the presenters and the related supporting material.

Course Title	**Technology Exploitation**
Module ID	4EMINENT105
Responsible Lecturer	Dr. Konstnatinos Rogdakis and Dr. Lazaros Tzounis
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Elective
Credit points (ECTS)	4.5
Teaching type	Lecture and exercises
Workload	Lecture: 24 h, tutorial: 12 h, additional individual work of the student / homework time: 81 h, total number of estimated working hours: 117 h
Course description	This module presents a series of strategic frameworks for management and exploitation of innovation and technology in business. The emphasis is on the development of entrepreneurial skills and strategic thinking in managing technologies. The module gives an overview of different market forces, patterns of technological changes, technology drivers, and the business structure and know-how capabilities. Throughout the module, the aim is to acquire a set of analytical tools that are critical for the development of an entrepreneurial technology strategy as an integral part of business strategy. These tools can provide the framework on how to manage technology and innovation, how respond to market behavior, competitors, suppliers, and customers. The module would be of particular interest to those interested in managing a business for which technology is likely to play a major role, and to those interested in consulting or venture capital.
Learning Outcomes	The students will be able to: • Use terminologies used in the business word. • Read and compose a business plan. • Communicate technological advances to non experts. • Understand factors that determine the technological advances.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Scientific Publications (mainly review papers) in the topic

Course Title	**Polymer Electronics**
Module ID	4EMINENT106
Responsible Lecturer	Prof. Dr. Eletherios Kapetanakis
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Elective
Credit points (ECTS)	4.5
Teaching type	Lecture and exercises
Workload	Lecture: 24 h, tutorial: 12 h, additional individual work of the student / homework time: 81 h, total number of estimated working hours: 117 h

Course description	Organic semiconductors are the key active components giving the name for the whole field of organic electronics. Typically organic materials (defined molecules or polymers) with delocalised p-system perform as such semiconductors. The p-conjugation and their supra-molecular arrangement determine the materials properties in terms of transport or interaction with external stimuli (e.g. light, pressure, magnetic field). The module will focus first on fundamentals of p-conjugated systems and related electrical and optical properties and methodology to tune HOMO and LUMO levels. The history of polymer metals will be discussed. Related to classical processing approaches, the class discusses polymers and small molecules separately. For both systems examples for structures, their synthesis, properties and applications will be presented, classified by the transport properties (p-type, n-type and ambipolar). As key element the thin film morphology (molecular order) and the principles of thin film formation will be discussed for pure materials, blended systems and covalently linked systems.
Learning Outcomes	The students will be able to: • Understand and explain the physical, chemical and electrical properties of organic semiconductors. • Understand and explain the operation of organic based devices e.g. organic field effect transistors and organic light emitting devices.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Polymer Electronics by Mark Geoghegan and George Hadziioannou, Oxford University Press

Course Title	**Journal Club and Research Skills**
Module ID	4EMINENT107
Responsible Lecturer	Prof.Dr. Konstantinos Petridis
University	Hellenic Mediterranean University
Semester	1
Relation to curriculum	Mandatory course
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 30 h, tutorial: 65 h, additional individual work of the student / homework time: 100 h, total number of estimated working hours:195 h
Course description	This is a soft skills course that is called to develop students' presentation, problem solving, leadership, and analytical skills whilst encouraging scientific debate and providing the opportunity to broaden scientific knowledge. At each meeting the students will work together and make a presentation about a recent research or a review high impact paper related to the EMINENT topics. In total 8-10 papers should be presented per team. This will be followed by a chaired discussion / debate about the paper. As a part of the course the leading academic should provide the students with tips regarding the following: (a)

	Introducing yourself, (b) Audience awareness, (c) Explaining a concept, (d) Audience Interaction, (e) Answering audience questions. The leading academic during this module should teach the participants about the research ethics (Belief and Knowledge, Plagiarism & Collusion and Absolute and Relative Truth).
Learning Outcomes	The students will be able to: • Use journal article search machines e.g. Scopus, Web of Science, Google Scholar • Read a scientific paper and mine information such as the motivation, the state of the art, the main results and conclusions of a published research work. • Present a scientific work. • Design the outline of scientific paper.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Whitesides' Group: Writing a Paper, Advanced Materials, 25 th of August 2004 • How to write and publish a scientific paper by Robert A. Day

Course Title	**Research Lab Course: Devices Processing Techniques and Characterisation Methods**
Module ID	4EMINENT108
Responsible Lecturer	Dr. Konstantinos Rogdakis
University	Hellenic Mediterranean University
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147 h, total number of estimated working hours: 195 h
Course description	This module provides an introduction to modern processing techniques that research & industrial laboratories follow towards the fabrication of organic & perovskite semiconductor devices. It will cover the whole range of device fabrication processes, from raw materials to the market. Accordingly, among the proposed technologies only those applicable for large-scale manufacturing of organic semiconductor devices will be addressed
Learning Outcomes	The students will be able to: • Synthesise and characterise graphene, and perovskite thin films. • Construct and characterise (electrical, optical and stability characterisation) graphene and perovskite based solar cells, gas sensing elements. • Use roll-to-roll (R2R) and sheet-to-sheet (S2S) printing processes.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Research Papers

Course Title	**Energy Devices (Solar Cells and Batteries)**
Module ID	4EMINENT109
Responsible Lecturer	Prof. Dr. E. Kymakis and Prof. Dr. D. Vernadou
University	Hellenic Mediterranean University
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147 h, total number of estimated working hours: 195 h
Course description	The management of energy production and storage is a key Energy Policy in Europe, and a requirement for Energy Interventions in Existing Buildings as well as the automotive industry. New constructions must comply to low energy consumption by applying the latest research on materials and devices for Energy Harvesting, Saving and Storage. In addition, the generation of electricity should be contributing in preventing climate change. The main goal is the continuous effort to save Energy, reduce air pollution from internal combustion engines and sustainable development. The subject of this course is the presentation and evaluation of modern efficient technologies aimed at Energy Saving, Storage and Production, providing a variety of concepts.
Learning Outcomes	The students will be able to: • Understand and explain the operation of an energy harvesting device. • Understand and explain the operational principles of energy storage devices. • Fabricate the materials consist the various building blocks of an energy storage device. • Fabricate and characterise energy storage devices (batteries and capacitors).
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Research Papers (mainly Review papers)

Course Title	**Nanomaterials for Energy**
Module ID	4EMINENT110
Responsible Lecturer	Prof. Dr. Ioannis Remediakis
University	Hellenic Mediterranean University
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147 h, total number of estimated working hours: 195 h
Course description	Fundamental theoretical principles and experimental techniques in the study of surfaces and nanomaterials,

	with emphasis on energy and environmental applications (sensing). Nowadays, nanotechnology allows the synthesis and characterisation of systems in which the basic units have dimension of a few nanometers. Such systems are in use in electronics (processors), in the chemical industry (catalysts), in medicine (drugs), in optics (quantum dots), and of course in the field of renewable energy sources (photovoltaics).
Learning Outcomes	The students will become familiar with Nanophysics, Nanochemistry and Surface Science; understanding the basic differences between macroscopic and nano-physics and with the basic mechanisms that take place in solar cells, modern batteries and other system energy conversion. The desired learning outcomes are the introduction to Materials Science and specifically to materials extensively used for data storage, sensors, batteries, photovoltaics, along with an introduction to the fields of crystallography, chemical kinetics and physical solid state.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Scientific Publications (Review papers)

Course Title	**Skills and Ethics in Science**
Module ID	4EMINENT111
Responsible Lecturer	Prof. Dr. Konstantinos Petridis
University	Hellenic Mediterranean University
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147 h, total number of estimated working hours: 195 h
Course description	Soft skills are a combination of people skills, social skills, communication skills, character or personality traits, attitudes, career attributes, social intelligence, and emotional intelligence that enable people to navigate their environment, work well with others, perform well, and achieve their goals with complementing hard skills. The Collins English Dictionary defines the term "soft skills" as "desirable qualities for certain forms of employment that do not depend on acquired knowledge: they include common sense, the ability to deal with people, and a positive flexible attitude. Research skills like Bibliographic research, Academic Writing, Poster Presentation, Promotion of your Research, Grant Writing, Interview Tips and Digital Skills are also important to be taught from the final undergraduate year of any discipline. Ethics in science include: a) standards of methods and process that address research design, procedures, data analysis, interpretation, and reporting; b) standards of topics and

	findings that address the use of human and animal subjects in research ; and c) publication cheating.
Learning Outcomes	The students will be able to: • Provide an overview of the most wanted soft skills the labour market requires • Apply the presented soft & research skills in her daily academic and research life • Cope successfully in an interview process • Analyse a complex problem into smaller units • Present, negotiate and convince of her claims • Write, submit and evaluate her work • Communicate digitally and face to face communication • Come back from fall back • Adapt in any new professional or social environment
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Scientific Publications • Handbook for Research Skill Development by the University of Adelaide (Australia) • The Ethics of Science: An Introduction by David B. Resnik

Course Title	**Principles of Lasers**
Module ID	4EMINENT112
Responsible Lecturer	Prof. Dr. Konstantinos Petridis and Prof. Dr. Nektarios Papadogiannis
University	Hellenic Mediterranean University
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	7.5
Teaching type	Lecture and exercises.
Workload	Lecture: 36 h, tutorial: 12 h, additional individual work of the student / homework time: 147 h, total number of estimated working hours: 195 h
Course description	This module will present the fundamentals of laser devices. The module will start with the Einstein equations, provide the conditions to have lasing and the characteristics of this lasing radiation. An introduction to the generation of laser pulses will be provided with the introduction of the mode locking and Q-Switching techniques. Finally the most common met laser systems in an undergraduate and postgraduate laboratories will be presented. Such systems are: diode lasers, He-Neon Lasers, Ti:Sapphire Lasers, Nd:YAG laser systems.
Learning Outcomes	The students will be able to: • Understand and explain the fundamental processes describing light – matter interactions. • Understand and explain the operational principles of a stimulated emission device. • Understand and explain the continuous and pulsed laser operation.

	• Realise and understand the use of lasers towards the modification of electrical, physical and chemical properties of nanomaterials.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • LASERS by Siegman • Principles of Lasers by Orazio Svelto

Course Title	**Master Thesis**
Module ID	4EMINENT001
Responsible Lecturer	All professors of the department
University	Hellenic Mediterrenean University
Semester	4
Relation to curriculum	Mandatory
Credit points (ECTS)	30
Teaching type	Individual projects
Workload	Independent work 800h
Course description	For the work on the master's project, candidates will use the knowledge and skills received during the first 3 semesters of Master studies. During the master's project, candidates need the following key qualifications: • Most assignments involve extensive system development work; the related planning/organizational skills are required • The ability to use literature resources and other sources to collect and structure material on the given topic • The ability to read and understand demanding original English professional literature • The ability to draft a lecture on a non-trivial scientific topic in front of a specialist audience (i.e. also to design it didactically correctly) and to present it using standard media • The ability to write texts of approx. 60-120 pages, usually to explain the corresponding scientfic content.
Learning Outcomes	The candidate will independently work on a problem in his or her field of study using scientific methods within a specified period of time
Assessment method	The Master's thesis is evaluated by the supervisors. Evaluation is based on the complexity of the project, quality of the technical report, value of the research, created applications and models, presentation and defense of the thesis
Literature	The literature is specified individually according to a specific problematic task.

2. University of Siegen

Course Title	**Optoelectronics**
Module ID	4ETMA203

Responsible Lecturer	Prof. Dr. Peter Haring Bolívar
University	University of Siegen
Semester	2
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Lecture and exercises
Workload	Lecture: 30 h, exercises: 30 h, additional individual work of the student / homework time: 120h. total number of estimated working hours:180 h
Course description	Content ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analyzing; "E" Evaluation): * Introduction, Literature (K,U) * Principles: understanding light-matter interaction, comparing quantum mechanical descriptions to classical mechanics (K,U) * Optical absorption: classifying optical absorption processes, describing transition rates (K,U) * Optical emission: classifying optical emission processes, describing transition rates (K,U) * Principles semiconductor lasers (K,U) * Modes in semiconductor lasers (K,U) * Electro-optic modulators in bulk (K,U) * Optical modulators (K,U) * Principles of photoconductivity (K,U) * Photodiodes (K,U) * Nonlinear optics (K,U) * Photonic switching and computing (K,U) * Optical storage (K,U) * Optoelectronics in communication technology (K,U) Methods ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analyzing; "E" Evaluation): * Describing optoelectronic processes in semiconductor devices (AP, AN) * Modelling active photonic components (AP, AN) Evaluation ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analyzing; "E" Evaluation): * Understanding the function of optical components and their intrinsic limitations (AN,E) * Having a general view of the modern challenges in optoelectronics and being able to assess them(AN,E).
Learning Outcomes	The Module "Optoelectronics" provides a detailed insight into the functionality of optical components, enabling the ability to assess, model and realize devices and systems. Theoretic concepts are illustrated by application-relevant examples, providing a deeper understanding of the subject and the skillset to survey and comprehend current challenges in optoelectronics
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • K.J. Ebeling, Integrated Optoelectronics, Springer Verlag, 1993.

	• B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics. John Wiley and Sons, Berlin, New York (USA), 1991.

Course Title	**Semiconductor Electronics**
Module ID	4ETMA301
Responsible Lecturer	Prof. Dr. Peter Haring Bolívar
University	University of Siegen
Semester	2
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Lecture, exercises and laboratory practice
Workload	Lecture: 30 h, exercises: 15 h, laboratory practice 15 h, additional individual work of the student / homework time: 120h. , total number of estimated working hours: 180 h
Course description	This is an advanced course in Solid-State Physics that introduces students to the models and principles which determine the fundamental operation of semiconductors, and on the ways to modify and control the electronic conduction within advanced semiconductor materials, nanostructures and devices. Content ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): 1. Solid-State Semiconductor Physics: Wave-Particle Duality (K, U) • Schrödinger-Equation •Kronig/Penney Model • Derivation of Energy Bands in Solids 2. Charge Carrier Concentration: Thermal Equilibrium (K, U) • Density of States • Fermi-statistics 3. Intrinsic Conduction and Doping in Semiconductors: Thermal Equilibrium (K, U) • Fermi-energy • Volume potential 4. The Semiconductor at Non-Equilibrium (K, U) • Fundamental Semiconductor Equations • Continuity (Generation/Recombination) • Poisson Equation • Diffusion- and Field-induced Currents • Quasi-Fermi Energy 5. pn-junction at low-currents (K, U) • Shockley Assumptions •Derivation: IV-Characteristics • Break-down Voltage • Shockley/Read/Hall-Recombination Theory (SRH) 6. MOSFET&JFET(K, U) • IV-Characteristics • MOS capacitors • Theory of MOSFET transistors • Simulation models

	Methods ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): • Calculation, Development and Optimisation of Modern Semiconductor Devices Based on Lecture-mediated Knowledge (U, AP, AN) • Semiconductor Measurement and Characterisation Techniques (AP, AN)
Learning Outcomes	• In Semiconductor Electronics, elementary physical processes in semiconductor materials are discussed and important device characteristics are derived. The exercises comprise application specific device calculations that validate and support the device theory gained in the lectures. • In the laboratory, students can transfer theoretical assumptions to practical measurements of different semiconductor materials and devices. Moreover, students learn how to present their measurement results in an adequate, scientific manner.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	• Simon Min Sze; Physics of Semiconductor Devices; Third Edition; John Wiley & Sons, New York; 2006; ISBN-10: 0-471-14323-5 • Michael Shur; Physics of semiconductor devices; Prentice Hall, Englewood Cliffs, New Jersey; 1990 mit Übungsaufgaben; • Juin J. Liou; Advanced semiconductor device physics and modeling; Artech House, Boston; 1994 mit Übungsaufgaben; ISBN 0890066965 • Edward H. Nicollian, John R. Brews; MOS (Metal Oxide Semiconductor) Physics and Technology; John Wiley & Sons, New York; 1982; ISBN 0471085006 • David J. Griffiths, Introduction to Electrodynamics; Third Edition; Prentice Hall, Englewood Cliffs, New Jersey; 1998 ISBN 0-13-805326-X • Richard H. Bube; Electrons in Solids; An Introductory Survey; Third Edition; Academic Press, San Diego; 1992; nicht lieferbar • Andrew S. Grove, Physics and Technology of Semiconductor Devices; John Wiley & Sons, New York, 1967; ISBN 0-471-32998-3 • Albrecht Möschwitzer, Klaus Lunze; Halbleiterelektronik; Lehrbuch; 8. Auflage; Hüthig-Verlag, Heidelberg 1988

Course Title	**Embedded Systems**
Module ID	4INFBA022
Responsible Lecturer	Prof. Dr. Roman Obermaisser
University	University of Siegen
Semester	2
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Lecture and exercises
Workload	Lecture: 30 h, exercises: 30 h, additional individual work

	of the student / homework time: 120 h, total number of estimated working hours: 180 h
Course description	The variety and number of embedded systems have grown significantly during the last years. This segment has become by far the most important one in the computer market with applications such as consumer electronics, industrial control and transportation systems. Transportation systems such as automotive electronics are of particular interest, because of stringent timing and dependability requirements that act as technology catalysts. The embedded system market is expected to grow significantly during the next decade and it is expected that many embedded systems will be connected to the Internet and form cyber physical systems. This module includes system aspects of distributed embedded real-time systems, central requirements (e.g., determinism, reliability, composability) and methods for supporting them. Coping with contradicting system requirements (e.g., flexibility vs. composability, open system vs. temporal guarantees) and competence for using the most appropriate design principles and methods. Information about new developments (IoT) and basic knowledge. Theoretical knowledge is complemented by case studies and system architectures from different domains (e.g., automotive, avionics). Lab offers practical experience (e.g., programming of embedded systems with microcontrollers, scheduling, timing analysis). Syllabus: Context and requirements of embedded real-time systems Modelling of embedded real-time systems Global time and temporal relations Reliability Real-time communication Real-time operating systems Real-time Scheduling Interaction with the environment Design of embedded systems Validation Internet of things Examples of system architectures
Learning Outcomes	The students: • Learn about different paradigms and design principles for embedded systems. • Can describe requirements, paradigms, concepts, platforms and models of embedded systems. • Can explain nonfunctional requirements of embedded systems. • Can describe and apply concepts and methods for real time and fault tolerance.

	• Will become familiar with different components and design principles to apply them in concrete problem scenarios. • Can evaluate different development approaches (e.g., time-triggered, and event-triggered control) und map them to application scenarios. • Can evaluate platform technologies such as communication protocols, processors and operating systems with respect to their suitability for real-time, safety and reliability requirements.
Assessment method	• Preliminary examination performance (course work): exercises • Written exam (2 hours) – 100% of the grade. Credit points are awarded when the preliminary examination performance and the final examination are passed
Literature	• E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, LeeSeshia.org, 2011 • Peter Marwedel. Embedded System Design, Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition. 2011 • L. Gomes, J.M. Fernandes. Behavioral Modeling for Embedded Systems and Technologies: Applications for Design and Implementation. Information Science Reference. 2009 • P.J. Mosterman. Model-Based Design for Embedded Systems. CRC Press. 2010.

Course Title	**Microelectronics for EMINENT**
Module ID	4EMINENT204
Responsible Lecturer	Prof. Dr. Peter Haring Bolívar
University	University of Siegen
Semester	2
Relation to curriculum	Mandatory course
Credit points (ECTS)	3
Teaching type	Lecture, exercises and laboratory practice
Workload	Lecture: 30 h, exercises: 15 h, laboratory practice: 15 h additional individual work of the student / homework time: 30 h. , total number of estimated working hours: 90 h
Course description	In Microelectronics the students gain fundamental and advanced knowledge in the fields of the most relevant microelectronic devices such as diodes and transistors, and giving insight into their electronic behaviour, circuit integration principles and technological fabrication processes. Content ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): 1. Fundamental transistor parameters and behaviour (K, U) • Input-/Output-/Transfer Characteristics

	• Introduction to BJT, MESFET, HEMT • h-Parameter • S-Parameter 2. Transistor Building-Blocks (K, U) • Current-/Voltage Sources (circuits and applications) • Current Mirror (circuits and applications) 3. Darlington and Cascode Amplifier Circuits (K, U) 4. Differential Amplifiers (K, U) • Benchmarking (Common-Mode Rejection Ratio, Bandwidth, Gain-bandwidth product, Input-/Output Resistance/Capacitance, Voltage-/Current Gain…) (K, U) • Emitter-coupled Differential Amplifier • Base-coupled Differential Amplifier 5. Power Amplifiers (K, U) 6. Operational Amplifier (K, U) • Circuit (K, U, AP, AN) • Technology and Fabrication (K, U, AN) • Applications (K, U, AP) Methods ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): • Measuring, Analysing, and Extracting of Transistor- and Circuit- Key Figures of Merit (FOM) (AP, AN) • Developing, Building and Characterising Operational Amplifier Circuits (AP, AN) Evaluation ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): • Detailed Analysis of Different Transistor Types and Technologies (AN, E) • Analysing, Extracting and Calculating Characteristic FOM of Operational Amplifiers and Operational-Amplifier-based Circuits (AN, E) • Optimising Transistors and Circuits with respect to a specific parameter (AN, E) • State-of-the-Art Transistor Technologies (U, AN, E)
Learning Outcomes	• The students learn how integrated circuits are assembled and passive components can be integrated on a microchip. • The students learn how transistor-based building blocks can be combined to realise complex circuits. Using the example of an operational amplifier circuit, students learn how it works and how it can be designed, optimised and fabricated technologically. Transistor and operational amplifier benchmarks are presented and will be measured, analysed and evaluated in the laboratory. The lecture qualifies the students to develop, and design integrated and discrete circuits for a wide variety of applications.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	• E. Böhmer; Elemente der angewandten Elektronik; Vieweg Verlag

	• U. Tietze, C. Schenk, E. Gamm, Halbleiter-Schaltungstechnik, Springer Vieweg, 2019

Course Title	**Summer School – Preparation for the specialisation tracks**
Module ID	4EMINENT205
Responsible Lecturer	Prof. Dr. Haring Bolívar, Prof. Dr. Konstantinos Petridis, Prof. Dr. Luis Pereira, Prof. Dr. Raphaël Canals, Prof. Dr. Sarunas Paulikas
University	University of Siegen
Semester	2
Relation to curriculum	Mandatory course
Credit points (ECTS)	3
Teaching type	Face-to-face lectures
Workload	Lecture: 40h Additional individual work of the student / homework time: 50h, total number of estimated working hours: 90 h
Course description	The scope of the summer school is to facilitate students' transition from the 2nd to the 3rd semester. In preparation to the school, each student will develop an individual research statement which summarises their individual perception of current challenges and the potential of their planned field of specialisation in general, and what they individually intend to contribute to the field. The school will provide general keynote lectures and general methodological training (scientific work, ethics) in morning sessions. During afternoon sessions, students will be separated in five groups according to their chosen specialisation. Each group will receive topical lessons by representatives of the universities offering the respective specialisation track, in order to homogenise the individual knowledge base of each student and provide fundamental methodological expertise. Guest lecturers from industry will be invited to give lectures in order to provide hands-on experience of challenges and expectations in the field. In addition, fourth-semester students from each specialisation track will be invited to the school to present their master's projects to their peers and to the new student generation.
Learning Outcomes	The students will: • •Have a deep understandingof the underlying theoretical and experimental challenges of their specialisation track. • Understand and be able to apply fundamental methodologies of the specialisation field. • Be able to contextualise and discuss current developments in the field of their specialisation track.

	• Be able to analyse future trends and demands in academic and industrial research & development in the field of their specialisation track. • Be able to write an analytic statement of a research field. • Understand the expectations and perspective of a master thesis, and gain overview of potential master thesis topics, also in conjunction with industrial partners.
Assessment method	Oral Examination (2/3) and individual assessment of the individual research field summary (1/3)
Literature	Will be announced.

Course Title	**Advanced Semiconductor and Microelectronics**
Module ID	4ETMA352
Responsible Lecturer	Prof. Dr. Bhaskar Choubey
University	University of Siegen
Semester	2
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Laboratory practice
Workload	Laboratory practice: 60 h additional individual work of the student / homework time: 120 h, total number of estimated working hours: 180 h
Course description	The “Advanced Semiconductor and Microelectronics (ASME)” course deals with various current developments on the field of microelectronics. It is intended to be specially addressing issues that are not covered in the “Semiconductor Electronics and Analog Circuits” course. The ASME course is divided into two areas: • laboratory practice with accompanying preparation and • follow-up work or lectures with accompanying seminars and exercises. The content of the lecture ASM is not fixed, but changes with each new lecture in order te reflect the most actual developments in the field. Possible topics are e.g. advanced CMOS design with finfets, simulation models, integrated optical and power devices, memristors, sensors, neuromorphic circuits, advanced integrated sensors.
Learning Outcomes	• Students analyse microelectronics and semiconductor systems at a research-level. This can contain advanced CMOS design with finfets, simulation models, integrated optics and power devices, memristors, sensors, neuromorphic circuits and data converters. • The students learn how to use the simulation software in advance. • They will also take on the preparation and delivery of a presentation following the coursework. The course gives them experience in professional teamwork, knowledge transfer, impact, presentation skills and problem-solving.

	• The students will also acquire an advanced understanding of analog CMOS design. Knowledge and skills will enable the students to obtain advanced positions in industry and research institutions.
Assessment method	• Preliminary examination perform (coursework): laboratory practice • Examination: presentation (30 minutes) – 100% of the grade
Literature	Will be announced. Notes provided in the course.

Course Title	**Physics of nanoelectronic devices**
Module ID	4NANOMA3
Responsible Lecturer	Jun. Prof. Dr. Peter Modregger
University	University of Siegen
Semester	2
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and exercises.
Workload	Lecture: 30 h, exercises: 30 h, additional individual work of the student / homework time: 120 h. total number of estimated working hours:180 h.
Course description	The course provides a detailed physics-oriented introduction into the fundamental working principles and advantages of nanoscale technologies. Crystal structure of solids, elastic properties, phonons, electronic band structure of solids, band structure of direct and indirect semiconductors, pn-junction, electronic devices as MOSFETs, solid state magnetism and magnetic devices. electronic band structure on the nanoscale, application in nano electronics.
Learning Outcomes	The students will: • Know the concepts and methods of solid-state physics and nanophysics. • Be able to understand concepts and operation of nanoelectronic devices. • Be able to think in terms of abstract concepts, recognition of complex problems, application of advanced knowledge and skills in inter-and trans-disciplinary discussion of complex issues, debating and discussing in English.
Assessment method	Preliminary examination performance (course work): successful processing of exercises is prerequisite for the final examination. Final written exam (100% of the grade) – or oral examination (100% of the grade)
Literature	• Kittel, Solid State Physics, Simon M. Sze, Physics of Semiconductor Devices, 3 rd ed., Wiley-Interscience.

Course Title	**Synthetic Aperture Radar**
Module ID	4ETMA251
Responsible Lecturer	Prof. Dr. I. Ihrke
University	University of Siegen
Semester	2
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and exercises.
Workload	Lecture: 30 h, exercises: 30 h, additional individual work of the student / homework time: 120h. total number of estimated working hours: 180 h
Course description	Imaging radar techniques have established themselves in recent years as an indispensable imaging technique in remote sensing of the Earth, especially in the field of environmental observation. The lecture explains the effects and principles that lead to obtaining a high resolution image with radar waves. These include: The electromagnetic wave and its propagation in free space, radiation via antennas, radar equation, backscatter properties, description of the acquisition geometry, etc. Additional content: • Basics of radar signal processing • Structure of a radar sensor • Doppler effect • Scanning and ambiguities • Description and properties of different transmit waveforms • Application of optimal filters for pulse compression • Multi-dimensional location-variant signal processing (processors) for focusing SAR data • Complexity of bistatic SAR signal processing with respect to geometric modeling and synchronisation. • Image analysis and 3D reconstruction The lecture is accompanied by programming work.
Learning Outcomes	• Students learn how to use the principle of synthetic aperture to improve the geometric resolving power of a sensor and thus how to use radar sensors for image acquisition. To this end, the fundamentals of radar signal processing are first taught and then the special properties of this method are discussed. The influences of waveform, wavelength, antenna, acquisition geometry and the properties of the scene on the acquired radar image are presented and explained to the students. • Students apply the learned knowledge by means of simulations and processing of real.
Assessment method	Final oral exam (20-40min) – 100% of the grade.
Literature	• Habilitationsschrift: Alberto Moreira: „Radar mit synthetischer Apertur. Grundlagen und Signalverarbeitung“

	• Christopher Oliver „Understanding Synthetic Aperture Radar Images” • Skolnik, Merrill, I.: „Introduction to Radar Systems“ • Ulaby, Fawwaz : “Microwave Radar and Radiometric Remote Sensing” • Charles V. J. Jakowatz: „Spotlight-Mode Synthetic Aperture Radar: A Signal Processing Approach”

Course Title	**Professional Design Experience Project (PEP)**
Module ID	4EMINENT209
Responsible Lecturer	Prof. Dr.-Ing Peter Haring Bolívar
University	University of Siegen
Semester	2
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture/workshops and small group tutorials
Workload	Total number of estimated working hours: 180 h, details are given in the course description below
Course description	The core principle behind the PEP-projects as a learning experience is for the student to undertake a design and development practice, reflect on it and then critically analyse this experience. Lecture/workshops and small group tutorials will be provided at key points of the process in order to support the individual experiences of the students and provide time for developing reflection and analysis. These sessions will introduce and support students’ work on their assessed reports and presentation. The structure of the programme includes (with information on the average time effort, taking into account 1 ECTS as a 30h total effort): • General introductory lectures (3 x 2 hours (+1 self-work) = 9h) teaching weeks 1,2,3 on general programme presentation, SCRUM methodology, and writing skills and tools training • Coaching with host group / industrial external partner (7 x 2 hours (+1 preparation) = 21h) every 2nd week to continually assess, discuss and reflect the project goals, approach and progress, • PEP: Self-study / group work / placement 100 hours by arrangement over the semester between the student and coaching group. • PEP-Project presentation preparation and written summary of the project (30h) • PEP-Seminar and Final Project Presentation (5 x 2 hours (+2 preparation) = 20h) teaching weeks 12-14 ensuring cross-fertilisation between all groups and overall presentation of the developments to external and project partners
Learning Outcomes	The students are able to familiarise themselves with an engineering-related problem in a defined period of time and to work out a solution with the given tools, as well as to use the knowledge they have already acquired from their studies. A special aspect here is that the students

	working in small teams can freely choose from a range of industry and application-inspired problems according to their inclination and focus of study. The teams are individually coached by experts from all groups and external industrial partners involved in the programme following modern SCRUM development methodologies. The students get introduced in real-world development practises. Students aquire the ability to coordinate team work, conceive and achieve realistic development targets, apply theoretical knowledge to practical use and structure complex development tasks. Furthermore, they are able to learn to assess and make use of globally available knowledge for their specific development task and skills in interdisciplinary and international teamwork across Europe.
Assessment method	Written report and final presentation of the developed project (1 hour) – 100% of the grade
Literature	Will be announced within the first lecture • B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics. John Wiley and Sons, Berlin, New York (USA), 1991.

Course Title	**StartUp Entrepreneurship**
Module ID	4INFMA103
Responsible Lecturer	Prof. Dr. Roman Obermaisser, Prof. Dr. Kristof Van Laerhoven
University	University of Siegen
Semester	2
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and exercises
Workload	Lecture: 30 h, exercises: 30 h, additional individual work of the student / homework time: 120h., total number of estimated working hours: 180h
Course description	This course is intended for all students who have ever thought about starting their own company or actually plan to do so. Also students with an idea who already or not yet know how to market their product will find this course very useful. It will be shown how easy it is to start a business nowadays. The university gives founders the support they need. Within the framework of a cross-faculty university-wide association of institutions, interested students are provided with simple tools for a business start-up. These include working out a business plan, preparing pitches, and how to get funding and support before, during and after the startup. Students learn exciting stories of founders and start-ups around the university and if they are further interested after the course, they can apply for the incubator program "One Small Step". Here they can set the course for your career as a company founder.

	The topics of the course are: - Business Idea / Innovation - Business Model / Team - Market and Competitor Analysis - Start-up Ecosystem in Siegen - Financing Options / The Proposal - Prototyping / Incubator - IP/ forms of enterprise/corporate law - The perfect pitch
Learning Outcomes	The students: • learn skills, analysis techniques and presentation to start up a business. • Know how to Successfully edit and create: - Business Model Canvas - Business plan - Business pitches.
Assessment method	• Seminar presentation (30min 50%) with written term paper (5000 words, 50%)
Literature	Will be announced.

Course Title	**Digital 2D/3D Image Sensing**
Module ID	4ETMA356
Responsible Lecturer	Prof. Dr. P. Haring Bolívar
University	University of Siegen
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Seminar, laboratory practice
Workload	Seminar: 30 h, laboratory practice: 30 h additional individual work of the student / homework time: 120 h, total number of estimated working hours: 180 h
Course description	The seminar "Digital 2D/3D Imaging" addresses the conception and production methods of modern micro-systems for two- and three-dimensional image acquisition. The components of this type of "All-Solid-State" camera system are presented and the influences of the individual components on system performance are derived. Such a camera micro system is the combination of sensor technology, illumination, optics and signal processing. Current Examples and Application will be presented. Content ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): Machine Vision (K, U) • Industrial image processing • image formation Digitale imaging (K, U) • Signal procressing • Digital Images: discretisation, digitisation, digital descriptions, storing Solid-State Image Sensing (K, U)

	• CCD • CMOS APS 3D – Imaging (K, U) • Introduction • Triangulation • Interferometry • Time-Of-Flight(ToF) * PMD - functional principle 3D - camaras (K, U) • Introduction • Range resolution • Device optimisation Fields of application (K, U) Methods ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): • Calculation and determination of resolution/resolution limits (AP, AN) • Calculation and determination of distance information (AP, AN) Evaluation ("K" Knowledge; "U" Understanding; "AP" Applying; "AN" Analysing; "E" Evaluation): • Detailed understanding of the approaches and procedures of 2D and 3D imaging (AN, E) • Knowledge of the functionality of essential imaging techniques (AN, E) General view on modern challenges of 2D/3D imaging (AN, E)
Learning Outcomes	The students will: • Learn how to capture and process a 2D and 3D image. •Understand how an image acquisition system operates.
Assessment method	• Preliminary examination performance (course work): laboratory practice • Final oral exam (20 – 40 minutes) – 100% of the grade
Literature	• Bernd Buxbaum: Optical time-of-flight distance measurement and CDMA based on PMD technology mittels phasenvariabler PN-Modulation. Shaker Verlag, Aachen 2002, ISBN 978-3-8265-9805-0. • Wei Tai: Investigations of 3D-PMD cameras with special regard to optical optimisation. Shaker Verlag, Aachen 2001, ISBN 978-3-8265-8789-4.

Course Title	**Research Lab Course: Nanoscience and Nanotechnology for EMINENT**
Module ID	4EMINENT212
Responsible Lecturer	Prof. Dr. Peter Haring Bolivar
University	University of Siegen
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Laboratory practice

Workload	90h work laboratory, 30 h seminar, 60h individual work of the student/homework total number of estimated working hours: 180 h
Course description	Literature search, elaboration of measurement/synthesis/technological strategies, involvement in current research topics, lab reports and critical evaluation of results.
Learning Outcomes	• Students apply scientific strategies of the chosen research topic. Students are able to design and perform experiments based on literature search on their own.
Assessment method	Graded Report and Presentation (100 %)
Literature	Relevant literature will be distributed in the course.

Course Title	**Deep Learning**
Module ID	4INFMA204
Responsible Lecturer	Prof. Michael Möller
University	University of Siegen
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and exercise
Workload	Lecture: 30 h, exercises: 30 h, additional individual work of the student / homework time: 120 h, total number of estimated working hours: 180 h
Course description	This module will give an introduction to deep learning, describe common building blocks in the network architectures, introduce optimisation algorithms for their training, and discuss strategies that improve the generalisation. • Supervised machine learning as an interpolation problem. • Fully connected layers, rectified linear units, sigmoids, softmax. • Gradient descent for nested functions: Chain rule and backpropagation. • SGD on large data sets, acceleration via momentum and ADAM. • Capacity, overfitting and underfitting. • Training, testing, and validation data sets. • Improving generalisation: data augmentation, dropout, early stopping. • Working with images: Convolutions and pooling layers. Computing derivatives and adjoint linear operators • Training: Data preprocessing, weight initialisation schemes, batch normalisation • Applications and state-of-the-art architectures for image classification, segmentation, and denoising • Architecture designs: Encoder-decoder idea, unrolled algorithms, skip connections +residual learning, recurrent neural networks • Hands-on practical experience by implementing gradient descent on a fully connected network in NumPy.

	Introduction to PyTorch for training complex models on GPUs
Learning Outcomes	The students will: • Understand the basic concepts of deep learning. • Be able to analise the chain rule for nested functions with several variables and implement the gradient descent algorithm for simple networks from scratch. • Be familiarised with a deep learning framework and can implement architectures for regression and classification problems on their own. • be familiarised with different design patterns for the architecture of neural networks, and can explains crucial steps for the successful training and generalisation of neural networks.
Assessment method	• Preliminary examination performance (course work): Reaching 50% of the points on the exercises / homework is mandatory for being admitted to the written exam • Final written exam (1,5 hours) – 100% of the grade. Credit points are awarded when the preliminary examination performance and the final examination are passed
Literature	• "Deep Learning" by Ian Goodfellow, Yoshua Bengio and Aaron Courville (available at http://www.deeplearningbook.org/) • Introduction to Python, e.g. at https://github.com/jrjohansson/scientific-python-lectures • Coursera course "Machine Learning" by Andrew Ng

Course Title	**Microelectronic Sensors**
Module ID	4ETMA350
Responsible Lecturer	Prof. Dr. Bhaskar Choubey
University	University of Siegen
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture, exercises, and laboratory practice.
Workload	Lecture: 30h, exercises: 15h, laboratory practice: 15h, additional individual work of the student / homework time: 120 h., total number of estimated working hours: 180 h
Course description	The course is dedicated to the integration of physical sensors with microelectronic circuits. At first, the students will understand the concepts of physical measurements as well as various sources of error. They will be able to analyse and distinguish different types of sensors for the same physical phenomenon. They will also learn advanced circuit concepts for interfacing with these sensors. Finally, they will analyse advanced concepts of at least two different sensor systems. The first area will be optical sensors, specifically CMOS image sensors and their various circuits and applications. The second one is microelectromechanical sensors, including concepts of mechanical and chemical sensing and their integration into microelectronic circuits.

	• Physical quantities and their measurement • Measurement errors and concepts of sensitivity/accuracy/resolution/accuracy/bias/random error / calibration standards / interference / noise • Optical sensors - CCD and CMOS image sensors • Microelectromechanical sensors - types, manufacturing processes, simulation and design, check • Sensor interface circuits and their physical implementations
Learning Outcomes	The students will: • Be able to analyse and distinguish different types of sensors for the same physical phenomenon. • Learn advanced circuit concepts for interfacing with these sensors. • Analyse advanced concepts of at least two different sensor systems.
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture. • Böhm, M.: Microelectronics; Script

Course Title	**Embedded Control**
Module ID	4INFBA100
Responsible Lecturer	Prof. Dr. Roman Obermaisser
University	University of Siegen
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and exercise
Workload	Lecture: 30 h, exercises: 30 h, additional individual work of the student / homework time: 120 h. total number of estimated working hours: 180 h
Course description	The purposes of the course are to become acquainted with application fields of embedded control systems, understand models and working methods to develop embedded control systems and comprehend the interplay of software and hardware with the physical environment. Syllabus: 1. Modeling and Mathematical Descriptions of Dynamic Systems • Discrete Dynamics • Hybrid Systems • Composition of State Machines • Concurrent Models of Computation 2. Design of Embedded Control Systems • Embedded Processors • Memory Architectures • Input and Output • Multitasking • Scheduling

	3. Analysis and Verification • Invariants and Temporal Logic • Equivalence, Refinement, Simulations • Reachability Analysis and Model Checking • Quantitative Analysis 4. State-of-the-Art Tools for Embedded Controller Development Scilab/Xcos
Learning Outcomes	The students: • Become acquainted with application fields of embedded control systems, • Understand working methods to develop embedded control systems, • Understand models of embedded control systems and comprehend the interplay of software and hardware with the physical environment. • Work with state-of-the-art development tools (e.g.,Scilab/Xcos) • Gain knowledge and understand the functionality of these development tools. • Perform a practical experiment in the lab.
Assessment method	• Preliminary examination performance (course work): successful processing of exercises is prerequisite for the final examination. • Final written exam (2 hours) – 100% of the grade. Credit points are awarded when the preliminary examination performance and the final examination are passed
Literature	• E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, LeeSeshia.org, 2011 • Peter Marwedel. Embedded System Design, Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition. 2011 • L. Gomes, J.M. Fernandes. Behavioral Modeling for Embedded Systems and Technologies: Applications for Design and Implementation. Information Science Reference. 2009 • P.J. Mosterman. Model-Based Design for Embedded Systems. CRC Press. 2010

Course Title	**Nanotechnology**
Module ID	4ETMA358
Responsible Lecturer	Prof. Dr.-Ing. Peter Haring Bolívar
University	University of Siegen
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Laboratory practice
Workload	Lecture: 30 h, exercise: 15 h, laboratory practice: 15 h,

	additional individual work of the student / homework time: 120 h, total number of estimated working hours: 180 h
Course description	Nanotechnology is an advanced course on the technological, physical and chemical methods used in modern semiconductor nanoelectronics fabrication. This subject will bring the students more towards the development of chips, will bring out the detailed analysis how actual fabrication works and what all processes and methods are involved in the development of a chip design from scratch. Along with theoretical teaching of each such aspect, students will have the opportunity to perform laboratory sessions, where students will explore and work in the environment of clean room. Development of nano level, fabrication of FET devices and careful measurement and characterisation of fabricated devices are some of the domains, students will work on. The theoretical teaching will include complete study of modern processes with all necessary understanding of the advanced fabrication processes. Detailed laboratory in clean room to get practical experience on the technological, physical and chemical methods for the production of semiconductor-based, nanoelectronic components. The experiments concentrate on a series (10) 3-4h experimental lab work. At the end a fully functional device is fabricated. Outcome device varies and is e.g. an amorphous Silicon thin filum solar cell, or a graphene-based field-effect transistor.
Learning Outcomes	The students are able: • To describe technological processes for the production of nano and microelectronic components and circuits, • To compare them with alternative production methods, • To realise specific component performance parameters with the help of learned knowledge about unique and targeted selection of technological processes, • To classify advantages and disadvantages of technological processes such as • Combine manufacturing processes, thus to develop complicated process chains for functional components and circuits (e.g. for transistors, solar cells, optoelectronic components...)
Assessment method	• Preliminary examination performance (course work): successful processing of Lab Reports is prerequisite for the final examination. • Final written exam (2 hours) – 100% of the grade. Credit points are awarded when the preliminary examination performance and the final examination are passed
Literature	• Plummer, Deal and Griffin, Silicon VLSI Technology: Fundamentals, Practice and Modeling • Simon M. Sze, VLSI Technology, McGraw-Hill • Hilleringmann, Silizium-Halbleitertechnologie: Grundlagen mikroelektronischer Integrationstechnik, Vieweg + Teubner,

	• Widmann, Mader, Technologie hochintegrierter Schaltung, Springer Verlag • Madou, Marc: Fundamentals of Microfabrication • Sze, Simon M.: Physics of Semiconductor Devices

Course Title	**Practical Course Communications Technology**
Module ID	4ETMA206
Responsible Lecturer	Prof. Dr. C. Ruland
University	University of Siegen
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Laboratory practice
Workload	Laboratory practice: 60h, individual work of the student / homework time: 120 h, total number of estimated working hours: 180 h
Course description	This is an additional lab module providing a hands-on practical training in diverse areas of telecommunications, in laboratories at different institutes, in order to provide a broad overview of photonic, wireless and coding technologies and using advanced methods for characterising telecommunication components and systems of communication technology.
Learning Outcomes	• Practical understanding of components of Communication Technology • Basic practical experience with modern communication systems • Experience with various measurement techniques of communication technology
Assessment method	Laboratory practical course – 100% of the grade All experiments must be completed, written laboratory lab reports must be prepared and submitted and presented final
Literature	• M. Bossert, M. Breitbach: Digitale Netze. Verlag B.G. Teubner, Stuttgart, 1999. • F. Kaderali: Digitale Kommunikationstechnik I und II. Verlag Vieweg, Braunschweig, 1991. • J.-R. Ohm, H.D. Lüke: Signalübertragung, Springer-Verlag, Berlin, 2002. • B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics. John Wiley and Sons, Berlin, New York (USA), 1991. • E. Voges, K. Petermann (Hrsg.): Optische Kommunikationstechnik. Springer Verlag, Berlin, 2002. H.-G. Unger: Optische Nachrichtentechnik, Teil I, 3. Auflage. Hüthig Buch Verlag Heidelberg, 1992. H.-G. Unger: Optische Nachrichtentechnik, Teil II, 2. Auflage. Hüthig Buch Verlag Heidelberg, 1993. • B. Walke: Datenkommunikation I und II: Verteilte Systeme, ISO/OSI-Architekturmodell u. Bitübertragungsschicht. Hüthig Verlag, Heidelberg, 1987.

Course Title	**Semiconductor Electronics Design**
Module ID	4ETMA300

Responsible Lecturer	Prof. Dr. Bhaskar Choubey
University	University of Siegen
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and laboratory practical course
Workload	Lecture: 30 h, laboratory: 30 h, additional individual work of the student / homework time: 120 h, total number of estimated working hours: 180
Course description	This course looks at the elementary design processes in the microelectronics industry. Students are first taught lecture-based courses followed by advanced learning of software tools. It consists of: Design approaches - top-down, bottom-up, divide and conquer, structured design, object-oriented design. Fabrication techniques for VLSI. Materials - microelectronic properties. Analog and digital modules of integrated electronic systems. Modeling and simulation methods including SPICE. Practical knowledge in an advanced design tool leading to a complete system design with communication, analog and digital components. In this course, the students will acquire working knowledge of computer-based modelling, simulation and testing tools used in electronics design and will understand manufacturing processes and supply chain of electronic components needed in design. Students will be taught properties of materials used in integrated systems and will understand building blocks of integrated electronic systems. The course will emphasise on problem definition, design conceptualisation, modelling, approximation techniques, optimisation and prototyping in the context in microelectronic systems.
Learning Outcomes	The students: • Understand the design principles that are used in electronic systems. • Know the fundamentals in computer-aided modelling, simulation and test equipment, which are used in electronic design. • Are familiar with the design process and the supply chain of the electronic components that are necessary for the construction. • Understand the modules of integrated electronic systems, and the building blocks of integrated electronic systems. • Strengthen their skills in problem solving, design conception, modelling, approximation techniques, optimisation and prototyping in the context of microelectronic systems.
Assessment method	• Preliminary examination performance (course work): laboratory practical course

	• Final written exam (2 hours) – 100% of the grade. Credit points are awarded when the preliminary examination performance and the final examination are passed
Literature	It will be anounced in the first lecture • Böhm, M.: Semiconductor Electronics; Script

Course Title	**Master Thesis**
Module ID	4EMINENT002
Responsible Lecturer	All professors of the department
University	University of Siegen
Semester	4
Relation to curriculum	Mandatory
Credit points (ECTS)	30
Teaching type	Individual or group projects
Workload	Independent work 900h
Course description	For the work on the master's project, candidates will use the knowledge and skills received during the first 3 semesters of Master studies. During the master's project, candidates need the following key qualifications: • Most assignments involve extensive system development work; the related planning/organisational skills are required • The ability to use literature resources and other sources to collect and structure material on the given topic • The ability to read and understand demanding original English professional literature • The ability to draft a lecture on a non-trivial scientific topic in front of a specialist audience (i.e., also to design it didactically correctly) and to present it using standard media • The ability to write texts of approx. 60-120 pages, usually to explain the corresponding scientific content.
Learning Outcomes	The candidate will independently work on a problem in his or her field of study using scientific methods within a specified period of time
Assessment method	The Master's thesis is evaluated by the supervisors. Evaluation is based on the complexity of the project, quality of the technical report, value of the research, created applications and models, presentation and defense of the thesis
Literature	Individually specified for each thesis

3. NOVA University Lisbon

PL = Labs classes, TP = Theoretical classes with practical exercise ,TL = Pure theoretical lectures

Course Title	**Biosensors**
Module ID	5324/4EMINENT301
Responsible Lecturer	Hugo Manuel Brito Águas
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Lecture, exercises and laboratory practice.
Workload	TP:21h; PL:35h; OT:6h. total number of working hours: 168h
Course description	This module is designed to transmit to the students the knowledge on transduction mechanism, most suitable transducers and detection mechanism for a specific biological sample. The focus is on innovation, showing the state of the art adopting a technological approach as well on micro fabrications and lab on chip systems, supported by a strong laboratory immersion. This module will provide to the students concepts behind the design and fabrication of biosensors. It is the objective to introduce the students to the new sensoric technologies associated with biotechnology and microelectronics. Syllabus: • Introduction to biosensors. • Bioreceptors and bioafinity. • Transduction systems. • Physical properties of biological samples. T • emperature, pressure, force and displacement. Piezoelectric transduction systems. • Microelectronic instruments. • Optical transduction systems: fiber optics, evanescent waves, Surface Plasmon Resonance. • Electrochemical transduction systems: amperometric and potenciometric sensors. Surface immobilisation. Supports for immobilisation. Sol-gel, membranes, silica and polymeric supports. • Calorimetric sensors. Immunosesnors. • Enzimatic sensors. Micro-organisms based sensors. DNA sensors. • Development of immunosensors to detect IgG/ELISA. Instrumentation and data processing. • Building of prototypes. • Interdigital electrodes and electronic-nose. Microfabrication. Microfabricated systems. • Integrated systems. MEMS. Lab-in-a-chip. Instruments for the human health. • Instruments for applications in biotechnology. • Instruments for the monitoring of the environment. Biochips.

Learning Outcomes	The students will be able to: • Understand the physical, chemical, and biological variables capable of being monitored in a biological process. • Identify the various transduction systems available. • Be able to master the main processes involved in the microfabrication. • To propose a sensorial system capable of detecting a biological agent by mean of physical, chemical and biological means involving microelectronics.
Assessment method	Students can opt between 2 written tests or an exam. The average of the tests or exam must be above 9.5/20 (50% of the final grade). 40% of the final grade are given by a written project and the evaluation of this project includes the written document, presentation and discussion. The practical lab classes are mandatory to be approved and there is a 5 questions quiz for each lab that the students answer on-line. This accounts for 10% of the final grade.
Literature	• Handbook of Biosensors and Biochips, 2 Volume Set, Robert S. Marks (Editor), Christopher R. Lowe (Editor), David C. Cullen (Editor), Howard H. Weetall (Editor), Isao Karube (Editor), (2008) Wiley • Handbook of Modern Sensors: Physics, Designs, and Applications, Jacob Fraden, 3rd ed, (2004) Springer Sensor Technology Handbook, Jon S. Wilson (Editor), (2005) Elsevier • Biosensors (Practical Approach S.) Jon Cooper, Tony Cass, 2nd Ed. (2004) Oxford University Press John L. Vossen, Werner Kern, Thin Film Process II, Academic Press, 1991. • Cantilever transducers as a platform for chemical and biological sensors; Review of Scientific Instruments, Vol 75, nº 7, (2004) • BioMEMS: state-of-the-art in detection, opportunities and prospects; Rashid Bashir; Advanced Drug Delivery Reviews 56 (2004) 1565– 1586; (online na sciencedirect) • Microfabrication Techniques for Chemical/ Biosensors ; Proceedings of the IEEE, Vol. 91, nº 6, (2003)

Course Title	**Biomimetic materials and applications**
Module ID	7452/4EMINENT302
Responsible Lecturer	Maria Helena Godinho / Luis Pereira
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Lecture, exercises, and laboratory practice.
Workload	TP:21h; PL:35h; OT:6h. total number of working hours: 168h
Course description	Cellulose has a unique role among polymeric materials: It is biocompatible and biomimetic polymer and studying it requires interdisciplinary skills.

	This module is recommended for students who want to deepen their learning in the characteristics of cellulose and other natural materials and their impact on industrials sectors on the development of new functional materials. The module starts by addressing fundamental aspects about the structure of natural polymers, their chemical modifications, and their major applications. The central scientific objective is to consolidate and extend students' knowledge in the field of polymeric materials by introducing natural materials which is a potential source of new materials with exceptional mechanical, optical and electrical properties. Syllabus: • Introduction: Natural polymers. • Hierarchical structures in nature: Structure-property (function) relationships • Lignocellulosic composites: Wood, Cork, Cotton. Paper manufacture. • Cellulose Derivatives: Classification of cellulose derivatives. • Modification reactions of cellulose. • Preparation of films and fibers and their characterisation. • Applications of Cellulose and Its Derivatives as Biocompatible Materials. • Biomimetic materials based on cellulose and chitin: • Photonic structures • Materials with functional gradients • Smart materials based on natural materials • Bioinspired materials for medical applications
Learning Outcomes	At the end of the semester students are expected to know about: - hierarchical structures present in nature and various biomimetic materials to determine relationships between structure-functionality-properties, - the main methodologies used for the extraction of natural polymers, namely extraction of cellulosic fibres and chitin from wood and to acquire knowledge how to produce synthetic products available on the market. applicability of biomimetic materials in photonics, electronics, energy harvesting, biomedicine and 4D structures.
Assessment method	Two tests or exam together a written report on the lab work . The final grade is given based on the weighted average of tests/exam with written work and lab work presentation made by the students..
Literature	• P.J. Flory "Principles of Polymer Chemistry", Cornell University Press, Ithaca, N.Y. (1953) • R.D. Gilbert, Cellulosic Polymers, Blends and Composites, Hanser, Munich (1994) • W. Hamad, Cellulosic Materials, Kluwer Academic Publishers, London (2001) • P.A. Williams, Cellulosic pulps, fibres and materials, Woodhead Publishing ltd, Cambridge (2000) N.-S. Hon,

	N. Shiraishi, Wood and Cellulosic Chemistry, Marcel Dekker, N.Y. (2000) • Articles to be distributed during the lecture classes

Course Title	**Soft Skill Course - Entrepreneurship**
Module ID	1210/4EMINENT303
Responsible Lecturer	Aneesh Zutshi / António Carlos Bárbara Grilo
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	3
Teaching type	Seminars; team work; mentoring
Workload	TP: 48h, Total 84h
Course description	This soft skill course is focusing on providing to the study an immersion in an entrepreneurship experience, combining lectures, seminars, contact with industry and investors. Some specific topics to be addressed are: 1. The beginning: needs, opportunities and challenges 2. Definition of the idea and development of the solution 3. Value Proposition and Business Model 4. Market Analysis and Marketing Plan 5. Elevator-pitch 6. Study of Financial Flows 7. Development plan 8. Implementation and Financing.
Learning Outcomes	This curricular unit aims to make students aware of the importance of an entrepreneurial attitude, innovation and experimentation, as well as the development of social skills and entrepreneurship techniques for innovative and technological projects. This course proposes to motivate and prepare students to undertake innovative projects in companies or to develop technology-based startups. This is done by acquiring basic knowledges in market search/analysis, IP search, development of business cases/plans and seeking for investments to finance their ideas. This is made with “virtual” cases, but all ideas are presented to be evaluated by experts from different areas, and the three best ones received a prize and the opportunity to process with a “real” development of their idea
Assessment method	Based on the principles of multidisciplinarity, classes will integrate students from different degrees with a view to promoting the integration of knowledge derived from various scientific areas and will involve professors and "mentors" with diverse backgrounds in the fields of engineering, science, management and business. . The assessment comprises the presentation and defense of the idea in an elevator pitch and the respective report (carried out in a group of 4-5 elements). The presentation will contribute 50% and the report 50% towards the final grade.

Literature	• Paul Burns, (2010), "Entrepreneurship and Small Business: Start-up, Growth and Maturity", Palgrave Macmillan, 3rd Ed. • Shriberg, A. & Shriberg (2010), "Practicing Leadership: Principles and Applications", John Wiley & Sons, 4th Ed., USA. • Spinelli, S. & Rob Adams (2012). "New Venture Creation: Entrepreneurship for the 21st Century". McGraw-Hill Higher Education; 9 Ed. • Thomas H. Byers, Richard C. Dorf, Andrew Nelson (2010) "Technology Ventures: From Idea to Enterprise", 3rd Ed., McGraw-Hill Higher Education

Course Title	**Research Lab Module**
Module ID	10603/4EMINENT304
Responsible Lecturer	Francisco Ferreira/Rui Igreja/Carlos Damásio/Maria Alexandra Fernandes
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	9
Teaching type	Research project under mentoring on topics related to elective courses. The focus will be on specific research work that combine the topics of a module of elective courses, under the supervision of the proponent of the theme, which will allow students to have preliminary contact with the research methods. The specific problem and the methods to be applied are those indicated in the research proposal carried out by the mentor of the topic selected by the student.
Workload	Lab:80h
Course description	Allow the students to have a first contact with the practice of scientific research. Its main objective is to give them the opportunity to combine different fields related to the elective courses and apply it a multidisciplinary approach to address a specific challenge. The research lab course consists of the development of a small project around one of the topics addressed in the elective courses with the possibility of a deep immersion in a research project running at UNL
Learning Outcomes	The student will gain autonomy in performing literature reviews, lab practices, presentations, and reports, exploring the critical thinking. The activity will be linked to the courses offered at UNL with a strong engagement in the research labs activities. By the end, the students must be able to: Presentation of the problem Make a state-of-the-art presentation Select tools and methods to use in solving the problem Propose a work plan
Assessment method	The evaluation is based in a written report and a presentation

Literature	Literature to be provided by the mentor depending on the scientific topic to be addressed

Course Title	**Environmental Monitoring and Big Data**
Module ID	12676/4EMINENT305
Responsible Lecturer	Francisco Manuel Freire Cardoso Ferreira
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	3
Teaching type	Lecture and exercises
Workload	TP:56. total number of working hours: 168h
Course description	This module allows for an understanding the different conceptual strands on data acquisition, processing, and interpretation in the framework of environmental monitoring design and for decision-support purposes for different environmental engineering areas. All this is supported by the use of data services available on the market, allowing for the interpretation of case studies that ensure critical thinking about their value for decision making in the context of environmental engineering practice. Syllabus: - Environmental system analysis integrated approach. - Identification of the characteristics and key variables associated to environmental systems, such as in air, soil use, cities, and ecosystems. - Definition of monitoring strategies and sampling procedures of environmental systems and the respective quality assurance / quality control procedures. - Data acquisition techniques by monitoring equipment, sensors, drones, and Earth observation satellites. - Knowledge of data services and their access and gathering procedures. - Selected statistics for data analysis (review and application of methods associated with both univariate and multivariate analysis). - Automatic learning tools. - Data visualissation fundamentals and examples, with practical hands-on approach using state of the art visualisation tools. - Development of monitoring plans, supported with case studies examples.
Learning Outcomes	The students will be able to: • Understand, within the environmental engineering area, the appropriate temporal and spatial scales to provide solutions to problems in domains such as air, soil use, and cities, enabling the design of strategies for their monitoring, from data acquisition, data service access, data processing and interpretation of big data. • Evaluate different monitoring means to be used under a particular problem-solving objective, from standard

	monitoring equipment and stations to sensors, drones and Earth observation satellites. • Access environmental global data services and develop skills to get to use them. • Handling and processing of environmental big data through public and/or tailor-made tools. • Introduction to scientific visualisation techniques, including for large amount of data. • Understand the importance of data in environmental engineering as a fundamental support for informed decisions with add-value recognised by the market.
Assessment method	Two tests (25% weighting of each towards the final grade) and several group works (weighting 50% of the final grade). It is necessary that the average of the tests and the average of assignments is in both cases equal to or higher than 9.5.
Literature	- Acevedo, M. F., 2012. Data Analysis and Statistics for Geography, Environmental Science, and Engineering, CRC Press, 557 pp. - Berthouex, P. M. and L.C. Brown, 1994. Statistics for Environmental Engineers, Lewis Publishers, Boca Raton, 335 pp. - Davis, J.C., 2002. Statistics and Data Analysis in Geology, 3rd edition, John Wiley & Sons, New York. - Gilbert, R.O., 1994. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York. - Hereden, R.A., 1998. Ecological Numeracy: Quantitative Analysis of Environmental Issues, John Wiley & Sons Inc., New York, 331 pp. - Kumar, L. & Mutanga, O. (Eds) 2019. Google Earth Engine Applications, MDPI DOI 10.3390/books978-3-03897-885-5.Lillesand T.M., Kiefer R.W., J. Chipman (2015) Remote Sensing and Image Interpretation 7th Edition, John Wiley & Sons, ISBN: 978-1-118-34328-9. 736 Pages. - Moreira, J., Carvalho, A. and Horvath, T., 2018. A General Introduction to Data Analytics. John Wiley & Sons

Course Title	**Sensors: Materials and applications**
Module ID	7460/4EMINENT306
Responsible Lecturer	Rui Alberto Garção Nascimento Igreja
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture, exercises, and laboratory practical classes
Workload	TP:21h; PL:35h; OT:6h. total number of working hours: 168h
Course description	The general objective of the module is to make available to the students the concepts that are in the origin, development, and manufacture of sensors, as well as the

	properties of materials used to make them. Moreover, the module also addresses the technologies associated with the measurements of physical and chemical properties in both lab and industrial environments. Syllabus: 1. Sensors and signals. Physical principles of measurement. 2. Temperature sensors - Resistance temperature sensors (RTDs). The thermistor. Thermocouples; Temperature measurements with semiconductors and integrated circuits. Radiant sensors; pyroelectric detectors; pyroelectric effect; methods and materials; pyrometers. 3. Strain and stress sensors - Resistance-type strain gages. The stress gage. Linear variable differential transformer. 4. Force, torque and pressure measurements - Load cells; Torque measurements; torque cells. Pressure measurements. 5. Displacement, velocity, and acceleration measurements - Optical measurements methods; LVDT; Seismic transducers. Accelerometer; piezoelectric-type accelerometers; 6. Fluid flow measurements - insertion-type transducers; pitot tube; Hot-wire and hot-film anemometers. Drag-force velocity transducers. Venturi meters. 7. Chemical Sensors and multisensors systems - Transducers for chemical sensing; Multisensor systems.
Learning Outcomes	The students start by having an introduction to sensors and their main features, being able to understand the main physical principles used in sensors and transducers as well as materials used. Then the students are supposed to understand in detail the transduction mechanisms and the characteristics of the sensors. It includes the most important types of chemical sensors as well as systems with multi-sensors. The knowledge about these topics is supposed to be demonstrated both a theoretical and laboratory level
Assessment method	Set of tests or exam and reports of the laboratory work. The final grade is given based on the weighted average of tests/exam with practical work
Literature	• Instrumentation for Engeneering Measurements, James Dally, Wiley • Les Capteurs en Instrumentation Industrielle, Georges Asch, Dunod. • Measurement Systems Applications and Design, Ernest O. Doebelin, McGraw-Hill. Instrumentação Industrial, Gustavo da Silva, Escola Superior de Tecnologia de Setúbal. AIP Handbook of Modern Sensors, Jacob Fraden, AIP Series in Modern Instrumentation. • The Measurement, Instrumentation and Sensors Handbook, ed John g Webster, IEEE Press. • Sensors Update - Wiley – VCH. Revistas: Sensors and Actuators A and B, Elsevier. Sensors (IEEE).

Course Title	**Biomaterials and Biomedicine**
Module ID	4EMINENT307
Responsible Lecturer	Paula Isabel Pereira Soares
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	3
Teaching type	Lectures and lab
Workload	TP:24h; PL:24h. Tutorial: 2h, autonomous study: 42h Total number of working hours: 86h
Course description	The main learning objective is directed towards raising awareness and provide general knowledge on Nanomedicine and its innovation driven impact in biomedicine. Specific goals are to develop critical thinking and reasoning on nanoscale events and their impact on medical applications, such as (but not limited to) diagnostics, research in biomedicine (tools and novel approaches), therapeutics (drug delivery, nanoformulations, molecular actuators), tissue regeneration and precision medicine. Syllabus: 1. Nanotechnology and biologic systems a. Scale effects and properties of nanomateriais b. Characterization of nanomaterials in a biology context c. Nanosystem-cell/nanosystems-organism interaction d. Pharmacology of nanodrugs 2. Nanoparticles in biomedicine a. Metal NPs, polymers, lipidic, VLPs b. Nanovectors for drug delivery/gene therapy c. Controlled release mechanisms in nanodrugs d. Imaging via nanoplatforms e. Nanodiagnostics 3. Multifunctional NPs for therapeutics a. Molecular Targeting b. EPR c. Multimodal: PTT, PAT, PDT, etc and applications thereof d. Nanoteheranostics 4. DNA nanotechnology– self assembly and origami 5. Lab-on-chip/organ-on-chip 6. Nanotoxicology in humans
Learning Outcomes	Short focused lectures on the key topics from syllabus, followed by discussion of selected papers on those themes – this ensures in depth discussion and reasoning on the matters. The short focused monographies, together with oral presentations, allow to correlate and critical discuss the apprehended concepts within the broader Framework of nanomedicine. These steps should allow the development of critical reasoning on the fundamental aspects of Nanomedicine, oral and written presentation of

	scientific Works, open discussion and team work. – all fundamental in contemporary education. Teaching methodologies (including evaluation): Lectures/lab work/discussion for presentation of topics and discussion of case studies. Paper presentation and discussion (team work). Monography and oral presentation of particular theme. Assessment: Presentation and discussion of selected papers.; monography on selected theme with subsequent oral presentation and discussion.
Assessment method	Presentation and discussion of selected papers.; monography/lab work on selected theme with subsequent oral presentation and discussion
Literature	• Handbook of Nanoparticles (M. Aliofkhazraei Ed.), Springer. ISBN 978-3-319-15337-7; • Nanomedicine (Seifalian A., Mel A., and Kalaskar D. M. Ed.), One Central Press (OCP), UK; • Nano-Oncologicals: New targeting and delivery approaches, Advances in Delivery Science and Technology (M.J. Alonso and M. Garcia-Fuentes Ed), Springer; Controlled Release Society – Springer- ISBN: 978-3-319-08084-0.

Course Title	**Smart Materials and Systems**
Module ID	4EMINENT308
Responsible Lecturer	Rui Alberto Garção Barreira do Nascimento Igreja
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lectures and lab
Workload	TP:28h; PL:42h; OT:14h. Autonomous work: 74h Total number of working hours: 168h
Course description	The discipline of Smart Materials and Systems is an introduction to how materials response to certain stimuli can be well understood by modelling properties that couple electrical properties and other properties such as mechanical, optical and rheological properties. Module 1 - Introduction to the concept of smart materials and systems - Physical properties most relevant to sensory systems and actuators. Advantages and disadvantages of different combinations of the characteristics of sensors and actuators. Intelligent material classes. Electroactive Materials (piezoelectric, piezoresistive) - Physical properties of piezoelectric materials. Piezoelectric crystals. Polymers and piezoelectric ceramics. Mathematical representation of the electromechanical coupling in piezoelectric materials. Harvesting energy. Piezo actuators and sensors. Piezo-resistive, electro-restrictive and magnetostrictive materials. Module 2 - Chromogenic, electrochromic, photochromic and halochromic materials. Categories of electrochromic

	materials. Conductive polymers, organic and inorganic materials. WO3 transition metal oxides. Applications Thermochromism and materials. Windows and smart roofs. Preparation methods and characterization techniques. Module 3 - Shape memory effect. Superelasticity. Classes of metal alloys with shape memory. Alloys with ferromagnetic memory. Physical properties depending on the structural state. Damping. Actuation force. Design and dimensioning of systems based on alloys with shape memory. Module 4 - Electroreological fluids - electro and magneto rheological fluids. Basic concepts of rheology: Newtonian and non-Newtonian fluids, viscosity and viscoelasticity, differences in normal stresses, flow curves and viscosity. Particular case of electroreological (ER) and magnetoreological (MR) fluids: composition of ER and MR fluids and effects of electric and magnetic fields on their viscosity. Each module will have practical demonstration classes. After the set of demonstration classes students must choose a theme to carry out a mini project
Learning Outcomes	Concept of smart materials and systems. Most relevant physical properties for sensory systems and actuators. Classes of smart materials: piezoelectric materials, chromogenic materials, shape memory materials, biomimetic materials, electroreological fluids. Advantages and disadvantages of different combinations of the characteristics of sensors and actuators. Characterization of smart materials. Implementation of engineering solutions using materials and intelligent systems. Adequate selection of materials and smart depending on the application. Design and dimensioning of smart systems.
Assessment method	For the continuous evaluation is compulsory to answer tests/assignments, one for each module, and the presence at the practical/lab classes. The final mark is computed by weighting the mark of each module according to the weeks taken in each module
Literature	• K. Ohtsuka, C.M. Wayman, "Shape memory materials", Cambridge University Press, 2002. MV Gandhi and BS Thompson, "Smart materials and structures", Chapman & Hall, London, 1992. ISBN 0-412-37010-7. • DM Addington and DL Schodek, "Smart materials and technologies for the architecture and design professions", Architectural Press (Elsevier Science), Oxford, 2005. ISBN 0-7506-6225-5. • V Srinivasan and DM McFarland, "Smart structures: analysis and design", Cambridge University Press, Cambridge, 2000. ISBN 0-521-65977-9. • Electroceramics AJ Moulson and JM Herbert Chapman and Hall.

	• Smart materials and structures, MV Gandhi and BS Thompson, Chapamn and Hall

Course Title	**Adv. Programming for Data Science and Engineering**
Module ID	12529/4EMINENT309
Responsible Lecturer	Carlos Augusto Isaac Piló Viegas Damásio
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture and exercises
Workload	TP:28h; PL:28h. total number of working hours: 168h
Course description	The main objective of the module is to provide science and engineering students the knowledge and skills necessary to develop programmes that enable him / her to perform data processing, using a pedagogical translational approach adequate to the target population. Syllabus: 1. Introduction to Programming for Data Analysis. a) Data Science b). CRISP Methodology 2. Software structuring and organisation. a) Modules, Classes, and API Usage b) Functional data processing (map, flatmap, reduce, etc. operators). c) Programme deployment models (e.g. libraries, Jupyter Notebooks) 3. Data processing and querying. a) Spatio-temporal and complex data. Methods for data access. b) Relational Data Interrogation Language: SQL. Projections, selections, joins and aggregations. c) Manipulaton of data series and tabular data. 4. Data Visualisation. a) Fundamentals of interactive data visualisation b) Main data visualisation tools for exploratory data analysis c) Using python libraries for data visualisation and small interactive dashboard design. 5. Scalability and Cloud Services. a) Challenges and approaches b) Parallel computing frameworks (e.g. Spark)
Learning Outcomes	By the end of this course the students with prior programming skills will have acquired knowledge, skills and competences that will allow them to: • Understand the role of interaction and know the main interaction techniques • Be able to express computations using an imperative model or functional operators • Understand and be able to develop processing and processing activities for raw experimental or sensor data for supporting data analysis • Understand the challenges associated with processing large amounts of data.

	• Understand the basic principles and algorithms of machine learning. • Know and be able to express computations on complex and spatiotemporal data. • Know and choose the data views that best fit data analyses.
Assessment method	Practical work (50%) and 2 tests (each 25%).
Literature	• Database System Concepts, 7th Edition (chapters 2,3 and 4) Abraham Silberschatz, Henry F. Korth and S. Sudarshan McGraw Hill, 2019 • Anand Balachandran Pillai, Software Architecture with Python, Packt Publishing, 2017. • Interactive Data Visualization: Foundations, Techniques, and Applications, Second Edition. Matthew O. Ward, Georges • Grinstein, Daniel Keim, 2015, ISBN 9781482257373 Moreira, João, Andre Carvalho, and Tomás Horvath. A General Introduction to Data Analytics. John Wiley & Sons, 2018.

Course Title	**Molecular Diagnostics**
Module ID	10915/4EMINENT310
Responsible Lecturer	Maria Alexandra Núncio de Carvalho Ramos Fernandes
University	University NOVA Lisbon
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	3
Teaching type	Lectures, laboratory practice.
Workload	TP:14h; PL:18h; S:1OT:3h. total number of working hours: 84h
Course description	The main objective of this Module is to explore the more recent and innovative advances in the context of human disease diagnostics. It is intended that students understand all the steps from biological sample collection, nucleic acid extraction, the techniques used for amplification and/or detection and how to deal with results. Theoretical Molecular Diagnostics 1.Genetic Test • Prenatal Diagnosis • Molecular Cytogenetics • Biological samples: harvesting and processing. • Molecular Biology Laboratory 2.Molecular Biology Techniques in Diagnostics 3.Strategies in Genetic Diagnostics 4.New Technologies for Genetic Diagnosis 5.Aplications Lab Fusion transcripts detection in CML
Learning Outcomes	It is intended that students understand all the steps from biological sample collection, nucleic acid extraction, the

	techniques used for amplification and/or detection and how to deal with results. Moreover, it is intended that the students understand the advantages and disadvantages of the different methodologies and the advances of nanotechnology for point-of-care. An objective of this module is the development of critical analysis, especially in what concerns laboratory results, fostering attitudes that enable students to explore, in autonomy, more advanced or more particular themes of the Molecular Diagnosis.
Assessment method	Theoretical Exam - 60% of the final grade Laboratorial classes report - 40%
Literature	1. Principles and Applications of Molecular Diagnostics. Nader Rifai, Andrea Rita Horvath and Carl T. Wittwer. Elsevier. 2018. 2. Textbook of Clinical Chemistry and Molecular Diagnostics. Nader Rifai. Saunders. 2017. 3. Molecular Diagnostics: Fundamentals, Methods and Clinical Applications Lela Buckingham, Maribeth L. Flaws F.A Davis Company, 2011. 4. Molecular Diagnostics: Techniques and Applications for the Clinical Laboratory. Wayne W. Grody, Robert M. Nakamura, Frederick L. Kiechle, Charles Strom, Academic Press, 2010 5. Molecular Diagnostics: For the Clinical Laboratorial. William B. Coleman, Gregory J. Tsongalis. Humana Press, 2006 6. Fundamentals of Molecular Diagnostics, David E. Bruns, Edward R. Ashwood, Carl A. Burtis. Sauders, Elsevier, 2007

Course Title	**Master Thesis**
Module ID	/4EMINENT003
Responsible Lecturer	All professors of the department
University	NOVA University Lisbon
Semester	4
Relation to curriculum	Mandatory
Credit points (ECTS)	30
Teaching type	Individual or group projects
Workload	Independent work 800h
Course description	For the work on the master’s project, candidates will use the knowledge and skills received during the first 3 semesters of Master studies. During the master’s project, candidates need the following key qualifications: • Most assignments involve extensive system development work; the related planning/organisational skills are required • The ability to use literature resources and other sources to collect and structure material on the given topic • The ability to read and understand demanding original English professional literature

	• The ability to draft a lecture on a non-trivial scientific topic in front of a specialist audience (i.e., also to design it didactically correctly) and to present it using standard media The ability to write texts of approx. 60-120 pages, usually to explain the corresponding scientific content
Learning Outcomes	The candidate will independently work on a problem in his or her field of study using scientific methods within a specified period of time
Assessment method	The Master's thesis is evaluated by the supervisors. Evaluation is based on the complexity of the project, quality of the technical report, value of the research, created applications and models, presentation and public defense of the thesis.
Literature	The literature is specified individually according to a specific topic.

4. University of Orléans

Course Title	**Processor architectures**
Module ID	IoT0/4EMINENT401
Responsible Lecturer	Prof. Dr. Raphael Canals, A. Rimlinger (industrial staff: Arrow Electronics)
University	University of Orléans
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	3
Teaching type	Lecture, Laboratory works, Case study.
Workload	Lecture: 10 h, TP: 18 h, additional individual work of the student / homework time: 62 h, total number of estimated working hours: 90h
Course description	The Internet of Things (IoT) entry point, often considered as the third evolution of the Internet, is a set of architectures that allow communicating systems to generate data, capture the environment, and then automatically transfer it to the Internet. This course introduces the basic hardware and software bricks to design the acquisition system (sensor) according to the application needs defined in the specifications, including embedded system architecture, functioning of a microcontroller-based system, advantages of integration, programming, etc. • Embedded system architecture • Functioning of a microcontroller-based system Syllabus: **Processor system architectures** • Different processor families • Architecture of a processor board

	• Programme memory, data memory and input/output devices **Microcontroller architectures** • Microcontroller architecture • ARM processor architecture: RISC architecture, operation, pipeline, operating modes • Interruption: role, asynchronism, management, multitasking • Timers, meters and PWM • Development tools and environments • Understanding of the high-level language to machine code compilation chain.
Learning Outcomes	Students will be able to: • Understand how a processor architecture works • Choose a hardware architecture • Understand the advantages of integration: consumption, dimensions, reliability, ... • Realise the acquisition of a sensor data • Manage asynchronous events.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works.
Literature	• Rimlinger, Alain, " Overview of embedded architectures", 2021. • Canals, Raphael, "Microcontroller systems", 2022.

Course Title	**Data analytics**
Module ID	IoT1/4EMINENT402
Responsible Lecturer	Prof. Dr. Frédéric Ros (equally director of the Metropolitan incubator), Prof. Dr. Philippe Ravier
University	University of Orléans
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	5
Teaching type	Lectures, Laboratory works, Case study.
Workload	Lecture: 17.5 h, Tutorial: 7.5 h, TP: 25 h, additional individual work of the student / homework time: 100 h, total number of estimated working hours: 150 h
Course description	In any system, signals are acquired using analog or digital sensors. Thanks to signal processing, these signals must be processed to detect, elaborate and interpret these signals carrying information. The exploitation of all this information stored in our database requires the use of tools for analysis to extract useful information for the user: this is where the added value of the IoT is positioned. This course introduces some statistical data analysis tools as well as tools for pre-processing data and extracting characteristic attributes from the data, with a complement to understand the principles and to use basic classification methods such as SVM and neural networks. Introduction to signal processing • Signals and systems • Classification of signals and systems

	• Linear systems • Frequential representations of signals and systems • Sampling and quantification • Filter design Analysis tools • Linear and logistic regression • Principal Component Analysis (PCA) • Factor analyses Time series Data mining and visualisation • R language (introduction) and descriptive graphs • Practicum in multimedia data analysis (images and audio) using R and/or Python Data pre-processing and attribute extraction • Some data denoising techniques • Characteristic attributes: audio and image examples • Attribute selection Classification methods • SVM Method • Classification by neural networks • Introduction to Deep Learning.
Learning Outcomes	Students will be able to: • Master the mathematical tools for characterisation and manipulation of noise and signals • Use statistical data analysis tools such as linear or logistic regression, PCA and factor analysis • Use data visualisation or representation tools in MATLAB or R languages • Use tools for pre-processing data and extracting characteristic attributes from the data • Understand the principles and use basic classification methods such as SVM and neural networks.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works.
Literature	• Ros, Frédéric, "Data mining and AI", 2021. • Ravier, Philippe, “Signal processing”, 2020.

Course Title	**Robotics 1**
Module ID	4EMINENT403
Responsible Lecturer	Prof. Dr. Pierre Vieyres, A. Fonte, L. Nouaille, C. Novales, S. Miossec, G. Poisson
University	University of Orléans
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	5
Teaching type	Lecture and exercise, laboratory practise.
Workload	TP: 52 h, additional individual work of the student / homework time: 100 h, total number of estimated working hours: 152 h
Course description	This course will introduce major steps of robotics:

	• Design strategy and principles of 3D CAD modelling. • Mechanical robot design: transmission of movement and power. Mechanisms adapted for robotics handling and mobile. Integration of the electric, pneumatic, or hydraulic actuator. gripping devices, assembly, and handling effectors; proprioceptive and external sensors. • General introduction to robotics: anatomy and technology; industrial classification. Design and modelling of robotic serial manipulators: Spherical robots, scara and dedicated structures. Denavit-Hartenberg notation. Direct and Inverse Kinematic Modelling. Jacobian matrix. Industrial applications of robotics: Introduction to cooperative robotics, teleoperation • Design and modelling of wheeled mobile platforms; Formalism of Campion for the development of direct and inverse kinematic models. Degrees of mobility, path planning and motorisation of wheeled robots. Advanced courses will be developed within the following syllabus: • Computer aided design • Transmission and mechanical design • Modelling and identification of robots • Modelling of mobile robotic systems.
Learning Outcomes	Students will be able to: • Identify and configure the articulated mechanical system in relation to the robotic task. • Identify and adapt peri-robotic systems to equip the articulated mechanical system. • Address a complex mechatronic system using the basic concepts of articulated robots and associated automation elements. • Develop a model, analyse, and control the movements of a robotic manipulator. • Design a mobile robotics platform
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Phillip J. McKerrow. Introduction to robotics, Ed. Addison Wesley Publishing Company, 1991. • John J. Craig. Introduction to robotics mechanics and control, 2nd Ed. Addison Wesley Publishing Company, 1989. • Modeling Identification and Control of Robots, W. Khalil, E. Dombre CRC Press, 2002 - 480 pages • Handbook of robotics, Bruno Siciliano, Oussama Khatib, 2nd edition Springer

Course Title	**Control 1**
Module ID	4EMINENT404
Responsible Lecturer	Prof. Dr. Dominique Nelson-Gruel
Responsible academic staff	D. Nelson-Gruel, N. Ramdani, M. Fruchard, D. Aubry, Y. Becis
University	University of Orléans

Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	5
Teaching type	Lecture and exercise. Simulation tools.
Workload	TP: 52 h, additional individual work of the student / homework time: 100 h, total number of estimated working hours: 152 h
Course description	When a reliable model of a system has been validated, in addition to using it in a control strategy, it is often necessary to use this model in order to monitor the dynamic operation of the system. This active diagnostic approach aims to detect the presence of defects (sensors, actuators) in order to generate alerts or reconfigure the steering of the system. This course therefore presents the basic methods and principles of diagnosis, the focus will be on the algorithmic surveillance based on residues of observations derived from an estimation of the state of the system by observers or filters. An introduction to non-linear phenomena is presented including multiple equilibrium points, boundary cycles, entry-dependent stability, bifurcations. This will cover also: Control of non-linear systems, Exact linearisation and link with a platitude control, Control by sliding modes. Advanced courses will be given on: • Diagnosis and observers. • Advanced control.
Learning Outcomes	The students will be able to: • Implement a model-based diagnostic strategy. • Synthesise estimators: adequate observers or filters. • Analyse the stability and convergence of these estimators. • Generate and analyse observations residues. • Detect and isolate system faults, actuators or sensors. • Be aware of the non-linear problems encountered in automatic systems and for the control of robotic system. • Give some basic methods of analysis and control of non-linear systems
Assessment method	Final written exam (2 hours) – 100% of the grade
Literature	Will be announced within the first lecture • Isidori. Nonlinear Control Systems. Springer, New York, 3rd edition, 1995. • H. K. Khalil. Nonlinear Systems. Prentice Hall, Englewood Cliffs, NJ, 1996.

Course Title	**Research Lab Course: IoT and data**
Module ID	4EMINENT405
Responsible Lecturer	Prof. Dr. Raphaël Canals, D. Nelson-Gruel, P. Vieyres, R. Weber
University	University of Orléans
Semester	3

Relation to curriculum	Mandatory course
Credit points (ECTS)	3
Teaching type	Lecture, Lab and Project
Workload	PL: 20 h, additional individual work of the student / homework time: 70 h, total number of estimated working hours: 90 h
Course description	The teaching referring to the Research Lab Course will allow to develop an IoT solution to meet an application specification. It will then be necessary to study all or part of the value chain of the solution and to implement it, from the installation of the sensor(s) to the data exploitation and visualisation of the results.
Learning Outcomes	The students will be able to: • Understand the complete value chain of an IoT solution • Construct all or part of an IoT system in accordance with a mechanical structure • Analyse each part of the system • Exploit the acquired data and interpret them in order to provide the user with a graphic representation of the phenomena to be studied.
Assessment method	Lab Course (100 %)
Literature	Relevant literature will be distributed in the course.

Course Title	**Full-stack Integration**
Module ID	POLIoT15/4EMINENT406
Responsible Lecturer	Prof. Dr. Jean-Yves Cadorel (equally industrial staff: 3ZA engineering), R Beaudenon (industrial staff: IBM), N. Ramdani
University	University of Orléans
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	5
Teaching type	Lectures; Laboratory works; Case study.
Workload	Lecture: 7.5 h, Tutorial: 7.5 h, TP: 25 h, additional individual work of the student / homework time: 110 h, total number of estimated working hours: 150 h
Course description	This course focuses initially on technologies involved in end-to-end IoT solutions and protocols for local & global connectivity. Then the architecture and concept of different cloud models are presented (IaaS, PaaS, SaaS, cloud virtualisation, cloud storage, data management). Finally, the decisive factors for the user interaction in the context of IoT are introduced. A concrete practical exercise permits to design the architecture and technologies needed to implement IoT devices and to create an application by utilising cloud platforms. **Syllabus:** Device hardware: IoT objects (sensors, actuators, smartphones, gateways)

	Device software: Embedded / firmware programming, edge operating systems and applications Communications: Models, data exchange formats, protocols (MQTT, CoAP, HTTP REST, ...) Cloud Platform & Middleware Programming Delivery models – IaaS, PaaS, SaaS, cloud platform; micro-services using Docker Security and regulations IoT security standard: identity, authentication, authorisation, confidentiality, integrity, availability, lifecycle management (OTA upgrades) GDPR, ePrivacy regulation, privacy by design. Practical cryptography for the Internet of Things Scalability and Management (devices, applications, network) IoT interoperability and scalability Integration with IT & other systems Open data management & API. Aggregations. **Laboratory** • Case studies: Smart homes/buildings, smart cities, smart industry, smart medical care. Human activity recognition. Air quality analysis, industrial internet (IIoT).
Learning Outcomes	Students will have: • Knowledge and understanding of: - Technologies involved in end-to-end IoT solutions. Protocols for local & global connectivity - The architecture and concept of different cloud models: IaaS, PaaS, SaaS, cloud virtualisation, cloud storage, data management - The decisive factors for the user interaction in the context of the Internet of Things (IoT). • Practical skills. They will be able to: - Design the architecture and technologies needed to implement IoT devices - Design usable functional prototypes of interactive systems - Create application by utilising cloud platforms.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group work/paper.
Literature	• Cadorel, Jean-Yves, "Full-stack integration", 2021. • Beaudenon, Rémy, "Implementation of server-based applications and visualisation of data-results for the client", 2021. • Ramdani, Nacim, "IoT and robotics: case studies", 2022.

Course Title	**Data transmission**

Module ID	POLIoT07/4EMINENT407
Responsible Lecturer	Prof. Dr. Rodolphe Weber, C. Alayrac (industrial staff: CRESITT Industrie)
University	University of Orléans
Semester	3
Relation to curriculum	Elective course
Credit points (ECTS)	2
Teaching type	Lecture, Laboratory works, Case study.
Workload	Lecture: 15 h, TP: 5 h, additional individual work of the student / homework time: 40 h, total number of estimated working hours: 60 h
Course description	The main objectives of this module are to present digital communications and to be able to choose a wired or wireless transmission protocol depending on the constraints, to understand the architecture of a digital radio transmission system and the basics of antenna design and antenna impedance adaptation • Digital communication • Wired and wireless communications Syllabus: **Communicating systems** • Different types of serial link, implementation **Introduction to digital communication** • The overall architecture and associated parameters (source, channel, bandwidth, data rate, signal to noise ratio, bit error rate) • Linear and non-linear digital modulations and associated parameters (inter symbol interferences, spectral efficiency, pulse shaping, bit error rate, Eb/No) • Software defined radio (SDR) architecture and et associated tools (eye diagram, constellation, carrier and symbol synchronisation) • Demultiplexing techniques OFDM, FDMA, TDMA, CDMA • Implementation on a SDR GnuRadio demonstration board **RF considerations** • Antenna characteristics (gain, directivity, VSWR, …) • Antenna design and antenna adaptation issues • The certification procedure for IoT systems • Measurement tools for antenna and EMC studies **Link budget** **Standard wired communication protocol** • RS232, RS485, Profibus, Profinet, Modbus, Ethernet, CPL, … **Standard radio communication protocol** • Short range (WPAN, WLAN): BT, BLE, Wi-Fi, ZigBee, Thread, Z-Wave, RFID, NFC, EnOCEAN, Ant+

	• Long range (WNAN, WWAN, LPWAN): ZigBee-NAN, WirelessHART, Wi-SUN, 4G/5G, LTE-M, Sigfox, Lora, 6LoWPan, NB-IoT, Telensa … • Standardisation, industrial alliances
Learning Outcomes	Students will be able to: • Implement a serial communication • Choose a wired or radio transmission protocol depending on the constraints (data rate, latency, power consumption, transmission range, bit error rate, regulations and standards, EMC...) • Understand the architecture of a digital radio transmission system • Understand the basics of antenna design and antenna impedance adaptation • Assess a link budget • Know the certification procedure for IoT systems
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper.
Literature	• Weber, Rodolphe, "Data transmission for IoT", 2021.

Course Title	**Servers and database**
Module ID	POLIoT10/4EMINENT408
Responsible Lecturer	Prof. Dr. Matthieu Exbrayat, I. Todinca
University	University of Orléans
Semester	3
Relation to curriculum	Elective course
Credit points (ECTS)	2
Teaching type	Lectures, Laboratory works, Individual projects, Case study.
Workload	Lecture: 7.5 h, TP: 12.5 h, additional individual work of the student / homework time: 40 h, total number of estimated working hours: 60 h
Course description	When the acquired data are received at the server level, they must be stored in databases whose model is to be defined according to the need. Beforehand, it is necessary to set up this server as well as all the software services that will allow the implementation of the functionalities useful to the application framework. This course gives major steps in setting up a server, the related services, the management of data, including: Servers and software services, SQL and NoSQL databases. Syllabus: **Servers and services** • http protocols - REST architectures • Client/Server • Address an API design framework • Introduction to REST Web Services – Design, request and authentication

	• API testing tools
	• Notions about microservices
	
	Relational database
	• Relational model and properties
	• SQL language:
	  - Creation of a database
	  - Update in a database
	  - Query (simple queries, aggregates, etc.)
	• Security concept in relational databases
	
	NoSQL database
	• The different typologies of NoSQL databases
	  - Key/value
	  - Columns
	  - Document
	  - Graph
	• The Map/Reduce programming model
	• Query languages associated with the different typologies (SPARQL, etc.)

Learning Outcomes	Students will be able to: • Design and implement a REST web service to collect and transmit data in connection with an existing relational or NoSQL database • Propose a client/server architecture with possibly several services to answer a problem • Test and secure this API • Implement a Python framework to develop this type of service • Understand the relational database model • Update and query a relational SQL database • Understand the different types of NoSQL databases • Update and query a NoSQL database • Choose a database model • Design the architecture of a database
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper.
Literature	• Exbrayat, Matthieu, "Servers and services", 2021. • Todinca, Ioan, “Databases for IoT”, 2022.

Course Title	**Smartphones**
Module ID	POLIoT10/4EMINENT409
Responsible Lecturer	Prof. Dr. Aladine Chetouani
University	University of Orléans
Semester	3
Relation to curriculum	Elective course
Credit points (ECTS)	2
Teaching type	Lectures and Laboratory works
Workload	Lecture: 5 h, TP: 15 h, additional individual work of the student / homework time: 40 h, total number of estimated working hours: 60 h
Course description	Smartphones can be considered today as connected objects in themselves. Indeed, they integrate various types of sensors allowing to acquire numerous data which can be

	processed by in-situ processors before transmitting this information to other systems. In addition, they offer a graphical interface that facilitates their use and data entry. This course presents these objects and how to programme them. Syllabus: **Java** • Introduction to JAVA (Android) programming • Programme Development **Android** • Interface management (design and XML) • Basic "Hello Word" application • Multi-activity application • Control management • Transfer of information • Use of sensors • Communication **Complements** • Cross-platform • PWA (Progressive Web Apps): nomadic continuous access to information without reliable connection
Learning Outcomes	Students will be able to: • Develop applications on Android • Manage the packaging of activities • Communicate between activities and transmit data • Use the different existing data sensors (accelero-meter, gyroscope, camera, audio, GPS, ...) • Use communication channels (bluetooth, Wifi) • Transmit data between smartphones
Assessment method	Report and defense of laboratory works.
Literature	• Chetouani, Aladine, "Smartphones and tablets", 2022.

Course Title	**Cybersecurity**
Module ID	4EMINENT410
Responsible Lecturer	Prof. Dr. Raphaël Canals, Laurent Moulin (industrial staff: Spartan conseil), Benjamin N'guyen (external Prof. Dr.: INSA-CVL), Laurent Bobelin (external Prof. Dr.: INSA-CVL)
University	University of Orléans
Semester	3
Relation to curriculum	Elective course
Credit points (ECTS)	2
Teaching type	Lectures and Laboratory works
Workload	Lecture: 5 h, TP: 15 h, additional individual work of the student / homework time: 40 h, total number of estimated working hours: 60 h
Course description	Moving towards the Industry of the Future or Agriculture 4.0 inevitably leads to the consideration of cybersecurity notions. Indeed, connecting electronic systems exposes

	them to risks that were previously unknown to many companies. This course provides an awareness of the subject of cybersecurity and allows a first level of measurement of the risks to which a connected electronic system and therefore a company is exposed. **Introduction** • What is cybersecurity? • Information technology • Hacker motivation and strategy **Networks, protocols and infrastructure** • The cyber-physical industry area • Impacts of network technologies on infrastructures **Implementation strategy** • Respecting simple rules • Key points to secure • Cybersecure by design **Attack surface** • Sources of threats • Attack vectors • IIoT: a "revolution" for hackers **Good practices** • Risk management, analysis and processing • Risk reduction • Managing and governing cybersecurity **Risk management** • Protection means • Identifying risks • Assessing and treating risk
Learning Outcomes	The students will be able to: • Understand the current issues, processes and methods of cybersecurity for electronic systems that are becoming hyperconnected • Evaluate and control the cyber risk specific to companies.
Assessment method	Final written exam (1 hours)(50 %) + Lab report (50 %)
Literature	Relevant literature will be distributed in the course

Course Title	**Master thesis**
Module ID	4EMINENT004
Responsible Lecturer	All professors of the department
University	University of Orléans
Semester	4
Relation to curriculum	Mandatory
Credit points (ECTS)	30
Teaching type	Individual or group project
Workload	Independent work 800h
Course description	For the work on the master's project, candidates will use the knowledge and skills received during the first 3

	semesters of Master studies. During the master's project, candidates need the following key qualifications: • Most assignments involve extensive system development work; the related planning/organisational skills are required • The ability to use literature resources and other sources to collect and structure material on the given topic • The ability to read and understand demanding original English professional literature • The ability to draft a lecture on a non-trivial scientific topic in front of a specialist audience (i.e., also to design it didactically correctly) and to present it using standard media • The ability to write texts of approx. 60-120 pages, usually to explain the corresponding scientific content.
Learning Outcomes	The candidate will independently work on a problem in his or her field of study using scientific methods within a specified period of time.
Assessment method	The Master's thesis is evaluated by a supervisor assigned to monitor the work and a defense committee. Evaluation is based on complexity of the project, quality of the technical report, value of the research, created applications and models, presentation and defense of the thesis.
Literature	The literature is specified individually according to a specific problematic task.

5. Vilnius Gediminas Technical University

Course Title	**Intelligent Systems**
Module ID	ELESM17105/4EMINENT501
Responsible Lecturer	Prof. Dr. Arturas Serackis
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	6
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 28h; Laboratory works: 15h; Consultations: 2h; Independent work: 115h. Total number of working hours 160h.
Course description	This subject provides knowledge and ability to creatively apply the fundamentals of the natural science and mathematics, thoroughly knowledge and understanding of the electronics engineering study field principles that correspond to the study programme and be able to apply them for solving new engineering problems. Ability to identify, locate and evaluate the data needed for

	required engineering tasks by using databases and other sources of information. Understand in theory the technology of intelligent systems and be able to apply the acquired knowledge to solve various type signal processing tasks. Syllabus: Introduction. Artificial Neural Networks Artificial Neural Networks. Multi-Layer Perceptron Network Artificial Neural Networks. Radial Basis Function Networks Artificial Neural Networks. Support Vector Machines. Artificial Neural Networks. Kohonen Network Optimisation. Evolutionary Computations Knowledge Systems Rule-based Systems Uncertainty. Fuzzy Logic Intelligent Agents Hybrid Systems Application of the Intelligent Systems
Learning Outcomes	The students will: • Acquire knowledge about intelligent systems, their composition and working principles based on artificial neural networks, evolutional algorithms or fuzzy logic, is acquired. • Be able to simulate with Matlab intelligent systems or their parts, and learn the application of intelligent systems to process and analyse sounds, images or other signals of technical nature.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper. Final mark FM evaluation formula: FM = IE × 0.1 + FE × 0.6 + 1/4 × (L1 + L2 + L3 + L4) × 0.1 + R × 0.1 + 1/2 × (N1 + N2) × 0.1, here: IE - evaluation of the intermediate exam; FE - evaluation of the final exam; L - total evaluation of the laboratory; N - evaluation of the group or individual homework; R - evaluation of the Report. Evaluation formula of the group or individual homework N: N= N1 × 0.2 + N2 × 0.6 + N3 × 0.2, here: N1 - evaluation of the analysis methodology and hardware selection; N2 - evaluation of amount and quality of analysis performed, results received; N3 -evaluation of the conclusions.
Literature	• Haykin, Simon S. 2009. Neural networks and learning machines. 3rd ed. Pearson Education, 2009. 934 p. • Hopgood, A. A., 2000. Intelligent systems for engineers and scientists // CRC Press LLC.

Course Title	**Microcontrollers of ARM Architecture**
Module ID	ELKRM17306/4EMINENT502

Responsible Lecturer	Prof. Dr. Algirdas Baškys
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	9
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 28h; Laboratory works: 30h; Consultations: 2h; Independent work: 180h. Total number of working hours 240h.
Course description	The subject provides knowledge and critical assessment of the latest achievements in the study field of the electronics engineering. Ability to plan and carry out analytical, modelling and experimental studies by applying new problem-solving methods and critically evaluate their results and draw conclusions. Ability to apply their knowledge and understanding to see the standard and non-standard computer systems and embedded systems engineering problems, clearly formulate and practically solve them by applying theoretical models and innovative research methods, including mathematical analysis, computational modelling and experimental research methods. Syllabus: Introduction to Internet of Things Embedded Systems based on the high performance. Microcontrollers ARM microcontroller architecture 1: Memory, Protection Unit, CPU, Registers ARM microcontroller architecture 2: Stacks, Instruction set, Timers ARM microcontroller architecture 1: Power modes, Floating Point Unit ARM embedded software development 1: Standards, Barrier usage scenarios, Determinism ARM embedded software development 2: Fault tolerance, Code generation, Image generation ARM embedded software development 3: Real Time Operational Systems (RTOS) ARM embedded software optimisation. ARM embedded software debug: System startup: what happens when a processor starts. Implementation of Cortex-M series processors
Learning Outcomes	The students will: • Acquire general knowledge about the ARM microcontrollers purpose, classification, architecture, functional blocks and programming are obtained in the ARM architecture microcontrollers course. • Be able to analyse the specific representative of ARM microcontrollers family in details. • Know about the microcontroller features, hardware and software used for the editing and debugging of programmes. • Have the theoretical and practical skills of development

	of programmes for the ARM microcontrollers.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper. Formula for calculating the final grade G: G = 0,4 E + 0,2 KL + 0,1 N1 + 0,1 N2 +0,2 L, where: E - grade of final exam; KL - grade of intermediate examination; N1 ir N2 - grades of first and second homework; L -grade of laboratory works.
Literature	• Yiu, Joseph, "The Definitive Guide to the ARM Cortex-M0", 1st edition, Newnes, 2011. • Yiu, Joseph, "The Definitive Guide to the ARM Cortex-M3 and Cortex-M4 Processors", 3rd edition, Newnes, 2013. • Martin, Trevor, "The Designer's Guide to the Cortex-M Processor Family: A Tutorial.

Course Title	**Research Lab Course: Internet of Things (with course project)**
Module ID	ELKRM17309/4EMINENT503
Responsible Lecturer	Prof. Dr. Darius Guršnys
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Mandatory course
Credit points (ECTS)	9
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 42h; Laboratory works: 15h; Consultations: 3h; Independent work: 180h. Total number of working hours 240h.

Course description	Subject is focused on Internet of Things (IoT) technologies, hardware and software solutions for standalone internet connected devices. Module content includes: IoT architecture, communication protocols, cloud platforms, IoT data processing and visualisation, IoT security. Requires scientific investigation and experimentation. Elevates ability to combine theoretical and practical elements, to apply information technologies, to assess and analyse literature and data. Syllabus: Introduction to the subject IoT architecture IoT hardware IoT software IoT communication protocols IoT data protocols Programming of IoT devices IoT security IoT cloud platforms IoT data processing and visualisation
Learning Outcomes	The students will: • Be able to plan and carry out analytical, modelling and experimental studies of the internet of things by applying new problem-solving methods and critically evaluate received data. • Be able to make engineering decisions when faced with multiple, uncertain and inaccurately defined engineering problems that corresponds to the internet of things. • Be able to effectively work independently and in a team, be the leader of the team, will have very good knowledge on project management and business aspects, and will be able to know how to communicate with the engineering community. • Know the organising principles and requirements of engineering activities related to the internet of things, will be able to assess the engineering activities in a sense of workplace safety, environmental, ethical, and commercial aspects.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper. Formula for calculating the final grade G: G = 0,5 E + 0,1 N1 + 0,1 N2 + 0,2 K + 0,1 L, here: E - grade of final exam; K - grade of colloquium; N1 and N2 - grade of first and second homework; L - cumulative grade of laboratory works.
Literature	• Waher, P. Learning Internet of Things. Packt Publishing. 2015. 242 p. • Buyya, R.; Dastjerdi, A., V. Internet of Things: Principles and Paradigms. Morgan Kaufmann. 2016. 378 p.

	• Monk, S. Raspberry Pi Cookbook: Software and Hardware Problems and Solutions. 2nd edition. O'Reilly Media. 2016. 510 p.

Course Title	**High Frequency Circuit Design**
Module ID	ELKRM17307/4EMINENT504
Responsible Lecturer	Prof. Dr. Vaidotas Barzdėnas
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 28h; Laboratory works: 15h; Consultations: 2h; Independent work: 115h. Total number of working hours 160h.
Course description	The course of the High-Frequency Circuit Design delivers knowledge of the impedance importance for RF circuits design, analysed LC resonances, matching and distributed circuits, Smith charts using to solve tasks, analysed RF filters and transistor amplifiers design, provides design features of a printed circuit boards for radio frequency circuits. Syllabus: Introduction Review of AC Analysis and Network Simulation LC Resonance and Matching Networks Distributed Circuits The Smith Chart Matrix Analysis Electromagnetic Fields and Waves Filter Design Transistor Amplifier Design Design Features of a Printed Circuit Boards for Radio Frequency Circuits
Learning Outcomes	The students will: • Know and critical assess the latest achievements in the electronics engineering that correspond to the high frequency circuits design subject. • Be able to make engineering decisions when faced with multiple, uncertain and inaccurately defined engineering problems that corresponds to the high frequency circuits design subject. • Based on the knowledge of the high frequency circuits design subject, will be able to merge knowledge from different study fields, properly choose engineering equipment and software, will be able to deal with multiple engineering problems.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper.

	An expression for an evaluation of a final mark G: G = 0,4 × E + 0,3 × TE + 0,2 × P + 0,1 × N, here: E - mark of session exam; TE - mark of midterm exam; P- total mark of practical works; N - mark of group homework. An expression for an evaluation of the practical works P: P=(PDG1+PDG2)/2 here: PDG1 - the first defence of practical works; PDG2 - the second defence of practical works. An expression for an evaluation of the homework's N: N=(N1 + N2 + N3)/3 here: N1 - the first homework; N2 - the second homework; N3 - the third homework. Note: E, K, P and N grades must not less than 5.
Literature	• C. Bowick. RF circuits design. Newnes, 2014, 176 psl. • Joseph F. White. High Frequency Techniques: An Introduction to RF and Microwave Design and Computer Simulation. 2016 John Wiley & Sons, 528 psl. • Razavi, Behzad. RF microelectronics. 2012. Pearson, 2012, 932 p. • Sobot, Robert. Wireless communication electronics: introduction to RF circuits and design techniques. http://link.springer.com/book/10.1007%2F978-1-4614-1117-8

Course Title	**Data Mining Techniques**
Module ID	ELKRM17308/4EMINENT505
Responsible Lecturer	Prof. Dr. Nerijus Paulauskas
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 28h; Laboratory works: 28h; Consultations: 2h; Independent work: 115h. Total number of working hours 160h.
Course description	Subject is focused on modern data mining techniques and their application to find previously unknown and potentially useful information analysing big data sets. Module content includes: data pre-processing and exploratory data analysis, classification methods (nearest neighbour's method, naive Bayes classifier and decision trees), regression analysis, data clustering and evaluation of model performance. Syllabus: Introduction to the subject. Common knowledge Data preprocessing Exploratory data analysis Data classification methods. Distance metrics Classification using nearest neighbours Classification using naive Bayes Prediction methods. Regression analysis

	Decision trees Cluster analysis. Clustering with k-means Evaluating model performance Enhancing model performance
Learning Outcomes	The students will: • Know and critical assess the latest achievements in the electronics engineering that correspond to the data mining techniques. • Be able to make engineering decisions when faced with multiple, uncertain and inaccurately defined engineering problems that corresponds to the data mining techniques. • Based on the knowledge of the data mining techniques, will be able to merge knowledge from different study fields, properly choose engineering equipment and software, will be able to deal with multiple engineering problems.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper. Assessments methods of students' formula: Formula for calculating the final grade G: G = 0,4 E + 0,05 N1 + 0,05 N2 + 0,05 N3 + 0,25 TE + 0,2 P, here: E - grade of final exam; TE - grade of midterm exam (colloquium); N1, N2 and N3 - grade of first, second and third group homework; P - cumulative grade of practical works.
Literature	• Larose D. T., Larose C. D. Data Mining and Predictive Analytics. Wiley, 2nd Edition. 2015. 824 p. • Lantz B. Machine Learning with R. 2nd Edition, Packt Publishing. 2015. 454 p. • Zumel N., Mount J. Practical Data Science with R. Manning Publications, 2014. 416 p.

Course Title	**Data Centres**
Module ID	ELKRM17303/4EMINENT506
Responsible Lecturer	Liudas Duoba
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 28h; Laboratory works: 15h; Consultations: 2h; Independent work: 115h. Total number of working hours 160h.
Course description	Subject is focused on modern data centres, their architecture. The module includes fundamental knowledge of data centers and cloud computing. During the lecture will be discussed about data networks, data storage systems, data centres and cloud platform

	architecture, data centre security, data traffic engineering, resource management, types of data centres. Below are listed some, but not all, of the core technology to be discussed during lectures: VXLAN, MLAG, ECMP, LPG, OpenStack, KVM, VMware Hyper-Z, Docker, OpenVZ, NAS, and SAN. It will examine modern operating data centre best practices. Syllabus: Introduction to Data Centers Structure of Data Centers Data Centers Networks Virtualization Technologies Management of Data Centers Data Centers Security Operation of Data Centers
Learning Outcomes	The students will: • Know and critical assess the latest achievements in the electronics engineering that correspond to the data centers. • Be able to apply knowledge that corresponds to the data centers subject, to develop new, innovative engineering ideas in solving non-standard computer engineering design problems. • Based on the knowledge of data centers, will be able to merge knowledge from different study fields, properly choose engineering equipment and software, will be able to deal with multiple engineering problems.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper. Assessments methods of students' formula: Formula for calculating the final grade G: $G = ND1 \times 0,2 + ND2 \times 0,2 + SE \times 0,4 + L \times 0,2$; where: NDi - ntn homework grade; SE - final exam grade; L - cumulative laboratory grade. Formula for calculating the laboratory grade L: $L = L1 \times 0.2 + L2 \times 0.2 + L3 \times 0.6$, where: L1 - grade for technical accomplishment of the task; L2 - grade for quality of the lab report; L3 - grade for efficiency of the lab report defense.
Literature	• Hwaiyu Geng. Data Center Handbook. Wiley, 2014 • Gary Lee. Cloud Networking: Understanding Cloud-based Data Center Networks. Morgan Kaufmann; 1 edition, 2014 • Thomas Erl. Cloud Computing: Concepts, Technology & Architecture (The Prentice Hall Service Technology Series from Thomas Erl). Prentice Hall, 2013 • Nayan B. Ruparelia. Cloud Computing. MIT Press, 2016 • Mr. Ray J Rafaels. Cloud Computing: From Beginning to End. CreateSpace Independent Publishing Platform, 2015

Course Title	**Hydropower and Biofuel**
Module ID	ELEIM17304/4EMINENT507
Responsible Lecturer	Prof. Dr. Audrius Grainys
University	Vilnius Gediminas Technical University
Semester	3
Relation to curriculum	Elective
Credit points (ECTS)	6
Teaching type	Lecture; Laboratory works; Individual or group projects; Case study.
Workload	Theory lectures: 28h; Laboratory works: 28h; Consultations: 2h; Independent work: 115h. Total number of working hours 160h.
Course description	Subject provides knowledge about the basic types of hydroelectric power plants, construction of hydropower stations, electrical and electronic devices and systems their design and operation. Syllabus: Fundamentals of hydroelectric power plants Hydroelectric power plants in Lithuania and abroad Types of hydroelectric system Parts of hydroelectric system Categories of turbines and how they are selected Hydroelectric power plants in the grid Power generation and transmission
Learning Outcomes	The students will: • Know and critical assess the latest achievements in the electrical engineering that correspond to the hydropower and biofuel technologies. • Be able to deal with multiply hydropower engineering problems through different study fields. • Be able to make engineering decisions when faced with multiple, uncertain and inaccurately defined engineering problems that corresponds to the hydropower and biofuel technologies. • Based on the knowledge of the hydropower and biofuel technologies, will be able to merge knowledge from different study fields, properly choose engineering equipment and software, will be able to deal with multiple engineering problems.
Assessment method	Writing or oral exam; Homeworks; Report and defense of laboratory works; Report of individual or group project/work/paper. An expression for an evaluation of a final mark G: Session and intermediate examinations using identical questions for the whole group, report. Final assessment grade G: $G = SE \times 0{,}4 + K \times 0{,}4 + R \times 0{,}2$, here SE - session examination; K - intermediate examination; R - report.
Literature	• Paul Breeze, Hydropower, 28th March 2018, Academic Press , https://www.sciencedirect.com/book/9780128129067/hydropower

	• David M. Clemen, 194 Pages/Hardcover/1999. • Hermann-Josef Wagner, Jyotirmay Mathur. Introduction to Hydro Energy Systems, Springer-Verlag Berlin Heidelberg, 2011.

Course Title	**Master Thesis**
Module ID	ELKRM17402/4EMINENT005
Responsible Lecturer	All professors of the department
University	Vilnius Gediminas Technical University
Semester	4
Relation to curriculum	Mandatory
Credit points (ECTS)	30
Teaching type	Individual or group projects
Workload	Independent work 800h. Total number of working hours 800h.
Course description	Completion of research planed on the preparatory phase in the research lab course in the 3rd semester, preparation of analysis of economic and environmental impact and human safety, preparation of final report and graphical material of Graduation Thesis, preparation presentation for Graduation Thesis defense and presentation during public defense. Abilities to thoroughly prepare graphical and textual documentation, to responsibly schedule own work and time, to be communicative working in a team and making oral presentation, are developed.
Learning Outcomes	The students will: • Be able to plan and carry out analytical, modelling and experimental studies of advanced sensor systems by applying new problem-solving methods and critically evaluate received data. • Know and understand the importance of commercial requirements. • Be able to effectively work independently and, in a team, be the leader of the team, will have very good knowledge on project management and business aspects, and will be able to know how to communicate with the engineering community. • Holistically understand the effects of engineering solutions on the society and the environment, will comply with professional ethics and understands of the responsibility for the engineering activities. • Know the organising principles and requirements of engineering activities related to the computer systems and embedded systems, will be able to assess the engineering activities in a sense of workplace safety, environmental, ethical, and commercial aspects.
Assessment method	The Master's Graduation Thesis is evaluated by defense committee. Evaluation is based on complexity of the Graduation Work task, quality of the technical report of Graduation Work, value of the research, created

	applications and models, evaluation of supervisor and reviewers, presentation and defense of the Graduation Thesis.
Literature	The literature is specified individually according to a specific problematic task.