The Faculty of Engineering and Science
The Study Board for Mathematics, Physics and Nanotechnology

AALBORG UNIVERSITY
DENMARK

Curriculum for the Master's program in Nanomaterials and Nanophysics

Aalborg University
September 2017

Campus Aalborg

Preface

Pursuant to Act 261 of March 18, 2015 on Universities (the University Act) with subsequent changes, the following curriculum for the Master's program in Nanomaterials and Nanophysics is stipulated. The program also follows the Joint programme regulations and the Examination Policies and Procedures for The Technical Faculty of IT and Design, The Faculty of Engineering and Science, and The Faculty of Medicine.

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Chapter 1: Legal Basis of the Curriculum, etc.

1.1 Basis in ministerial orders

The Master's program in in Nanomaterials and Nanophysics is organised in accordance with the Ministry of Higher Education and Science's Ministerial Order no. 1328 of November 15, 2016 on Bachelor's and Master's Programs at Universities (the Ministerial Order of the Study Programs) and Ministerial Order no. 1062 of June 30, 2016 on University Examinations (the Examination Order) with subsequent changes. Further reference is made to Ministerial Order no. 258 of March 18, 2015 (the Admission Order) and Ministerial Order no. 114 of February 3, 2015 (the Grading Scale Order) with subsequent changes.

1.2 Faculty affiliation

The Master's program falls under the Faculty of Engineering and Science, Aalborg University.

1.3 Board of Studies affiliation

The Master's program falls under the Board of Studies for Mathematics, Physics, and Nanotechnology under the School of Science and Engineering.

1.4 Body of External Examiners

The Master's program is associated with the Body of External Examiners for Engineers (Ingeniørernes landsdækkende censorkorps (mat, fys, samf)).

Chapter 2: Admission, Degree Designation, Program Duration and Competence Profile

2.1 Admission

Applicants with a legal claim to admission (retskrav):
Applicants with the following degree are entitled to admission:

- Bachelor of Science (BSc) in Engineering (Nanotechnology with specialisation in Physics), Aalborg University

Applicants without legal claim to admission:

- Bachelor of Engineering in Nanotechnology, Aalborg University

2.2 Degree designation in Danish and English

The Master's program in in Nanomaterials and Nanophysics entitles the graduate to the designation civilingeniør, cand.polyt. (candidatus/candidate polytechnices) i nanomaterialer og nanofysik. The English designation is: Master of Science (MSc) in Engineering (Nanomaterials and Nanophysics).

2.3 The program's specification in ECTS credits

The Master's program is a 2-year, research-based, full-time study program. The program is set to 120 ECTS credits.

2.4 Competence profile on the diploma

The following competence profile will appear on the diploma:

> **A Candidatus graduate has the following compentency profile:**
> A graduate of the Master's program has competencies acquired through an educational program that has taken place in a research environment.
>
> The graduate of the Master's program can perform highly qualified functions on the labor market on the basis of the educational program. Moreover, the graduate has prerequisites for research (a Ph.D. program). Compared to the Bachelor's degree, the graduate of the Master's program has developed her/his academic knowledge and independence, so that the graduate can independently apply scientific theory and method in both an academic and occupational/professional context.

2.5 Competence profile of the program:

Students graduating with a Master's degree in Nanomaterials and Nanophysics have acquired the following knowledge, skills and competencies:

Knowledge	• within selected areas have knowledge that is based on the highest international research level, for instance in fields like solid state physics, optics, semiconductor physics, surfaces and interfaces, properties of materials and components on the nanoscale. • on a scientific level be able to understand and reflect over theory, methods and experiments within the mentioned areas
Skills	• can use basic scientific methods and tools within the field of physics and materials science • can be able to select appropriate theories, methods and tools to solve practical problems • can communicate research-based knowledge and discuss professional scientific problems both with peers and non-specialists
Competencies	• can manage work and development situations that are complex, unpredictable and require new solutions • can independently initiate and implement discipline-specific and interdisciplinary cooperation and assume professional responsibility • can independently take responsibility for own professional development and specialization

Chapter 3: Content and Organisation of the Program

The program is structured in modules and organised as a problem-based study. A module is a program element or a group of program elements, which aims to give students a set of professional skills within a fixed time frame specified in ECTS credits, and concluding with one or more examinations within specific exam periods that are defined in the curriculum.

The program is based on a combination of academic, problem-oriented and interdisciplinary approaches and organised based on the following work and evaluation methods that combine skills and reflection:

- lectures
- classroom instruction
- project work
- workshops
- exercises (individually and in groups)
- teacher feedback
- reflection
- portfolio work

All modules are assessed through individual grading according to the 7-point scale or Pass/Fail. All modules are assessed by external examination (external grading) or internal examination (internal grading or by assessment by the supervisor only).

Overview of the Master’s program in Nanomaterials and Nanophysics:

Semester		Code	Module	ECTS	Assessment	Exam
1		NFM1-1	Characterisation and Synthesis	15	7-point scale	Internal
		NFM1-2	Materials Chemistry	5	7-point scale	Internal
		NFM1-3	Synthesis and Characterisation	5	Pass/Fail	Internal
		NFM1-4	Semiconductors: Physics, Devices, and Engineering	5	7-point scale	Internal
2		NFM2-1	Functional Nanostructures	15	7-point scale	External
		NFM2-2	Optical Nanostructures and Materials	5	Pass/Fail	Internal
		NFM2-3	Computational Modelling for Physics and Engineering	5	Pass/fail	Internal
		NFM2-4	Physics and Chemistry of Surfaces	5	7-point scale	Internal
3	A or	NFM3-1	Advanced Applications of Nanotechnology	+15	Pass/fail	Internal
		Electives	Test and Validation	5	Pass/fail	Internal
			Reaction Engineering and Molecular Electronics	5	7-point scale	Internal
			Modern Physics	5	7-point scale	Internal
	B or		Study at another university*	30	Transfer of credits	Transfer of credits
	C or		Academic Internship*	30	7-point scale	Internal
	D		Long Master’s Thesis*	+30	7-point scale	External
4		NFM4-1	Master’s Thesis	30	7-point scale	External

The project on the 3rd semester can either be 15, 20, 25 or 30 ECTS, dependent on how many elective courses are chosen. The project on the 3rd semester can also be extended to become a Long Master’s Thesis which goes over 2 semesters and will thereby be equal to 60 ECTS. The Long Master’s thesis can also be combined with 2 or 3 elective courses, which means that a Long Master’s thesis can either be 45, 50, or 60 ECTS if no elective courses are chosen.

*Studying at another university (including universities abroad), an academic internship at a company, and a Long Master’s Thesis need to be approved by the board of studies.

3.0 Course in Problem Based Learning and Project Management at Aalborg University

Title: Problem based learning and project management (Problembaseret læring og projektledelse)
Objectives: The objective is to make newly started Master students coming from institutions other than AAU prepared to enter the problem based learning environment at AAU and manage study projects in close collaboration with peers.
Type of instruction: Three half day workshops centered around the individual student working with an individual challenge or curiosity in relation to using a PBL approach. Peer learning is also a hallmark, since the students will discuss and reflect their individual challenges/curiosities in a peer learning group.
Learning outcomes: After completion of the course the student should be able to **<u>Day 1:</u>** - describe and discuss the Aalborg PBL model based on the three key words: group work, project work, problem orientation - identify an initial individual challenge when using a PBL approach **<u>Day2:</u>** - develop and practice peer feedback skills - practice collaborative learning in a group - design a plan of action to deal with an initial individual PBL challenge or curiosity **<u>Day 3:</u>** - practice presentation skills - practice critical skills when giving feedback to peers - reflect on own and peer skills in relation to PBL practice
Exam format: Internal assessment during the course/class participation according to the rules in the Examination Policies and Procedures of Faculty of Engineering and Science, Aalborg University. In this case the assessment is primarily based on the oral performance during the course, which means that the student has to be active during the course time and participate in discussions. The course is an integrated part of the project for those not acquainted to the Aalborg PBL model, and is a precondition for participation in the project examination. In this way there will be no diploma for the course and it will not be visible on the academic transcripts.
Evaluation criteria: The criteria for the evaluation are specified in the Joint Programme Regulations.

3.1. Description of modules for 1st semester, NFM1

3.1.1. Project module on 1st semester, NFM1

Title: Characterisation and Synthesis/Karakterisering og syntese.

As part of the project a workshop within some selected topic of physics will be carried out. It will be obligatory for all students and should be considered as a repetition within these areas. The workshop consists of lectures and has an individual continuous evaluation based on exercises given through the lectures.

Workshop will cover:

Knowledge within the following areas:

Quantum mechanics: The general concepts and methods of quantum mechanics covering subjects like: Operators, wave functions and eigenvalues. The Schrödinger equation. position, momentum, energy and angular momentum in quantum mechanics.

Solid State Physics: Crystal structure, diffraction and reciprocal lattice, vibrations and phonons, electronic band structure.

Optics: Geometrical optics (ray tracing, imaging and aberrations) and physical optics (polarization, interference and diffraction).

Skills in:

Basic quantum mechanics, solid state physics and optics.

Competencies:

The student will be able to use the described theories and methods to understand and solve problems within the described areas of quantum mechanics, solid state physics and optics. Furthermore it will enable them to better follow the courses in the Master Program of nanomaterials and nanophysics.

Project:

Objectives: This project module will give the student experience with advanced methods for synthesis and characterisation of nanostructures and nanomaterials.

Students who pass this module develop:

Knowledge on

- Methods for creation of nanostructures
- Methods for characterisation of nanostructures

Skills in

- Optical spectroscopy on nanostructures
- Nanolithography

- Advanced microscopy (e.g. SEM, AFM)

Competencies

- Application of advanced methods for creation of small structures based on lithography and/or self-organising systems
- Application of various techniques for studying the fundamental properties of nanostructures like, e.g., size, shape, and electronic properties

Exam format: Since the workshop is an integrated part of the project it is obligatory for all students to participate. A successful participation in the workshop is a precondition for participation in the project examination. The project exam comprises of an oral evaluation based on a project report.

Evaluation criteria: Are stated in the Joint Programme Regulations.

3.1.2. Course modules on 1st semester, NFM1

NFM1-2: Course module Materials Chemistry/Materialekemi

Prerequisites:	The module builds on knowledge in the area of Inorganic Chemistry and Physical Chemistry.
Aim:	The purposes of the course are to introduce both fundamental chemical principles of materials and nanomaterials, and main methods for developing, optimising, post-treating and characterising materials regarding different physical and chemical performances. The focus will be placed on the relation between chemical composition, structure and properties. The two courses will introduce the current status of materials and nanomaterials technologies.
Learning outcomes:	After the course the students should be able to: Knowledge • Understand the fundamental principles of materials chemistry • Understand different application areas of materials and to optimize the production process of materials Skills • Prepare, characterize and modify materials to reach the target properties by using the materials chemistry knowledge and laboratory facilities • Design, synthesize, and produce nanostructured materials with given properties. • Characterize conventional materials and nano-materials
Content:	Materials chemistry focuses on the fundamental principles and applications of both conventional and advanced inorganic materials. The course is divided into the following two parts. 1. General inorganic materials chemistry: • Glass chemistry • Ceramic chemistry • Metal chemistry • Cement chemistry • Characterisation of inorganic materials 2. Nanomaterials chemistry • Thin films • Nano-crystals and –particles • Carbon nanotubes and other inorganic nanotubes • Mesoporous materials • Nano wires • Production of polymer nanomaterials • Nano-structured polymer
Exam format:	Individual oral evaluation.
Evaluation criteria:	Are stated in the Joint Programme Regulations.

NFM1-3: Course module Synthesis and Characterisation/Syntese og karakterisering.

Prerequisites: The module builds on knowledge in the area of Electronic Structures of Solids and Nanofabrication.

Aim: Students completing the module will obtain:

Knowledge within the following areas:

- Optical characterisation techniques
- Ellipsometry
- Photo luminescense
- Electron microscopy
- Electron beam writing
- Thin film deposition
- Reactive ion etching
- Fucused ion beam lithography
- Atomic force microscopy

Skills that enables them to:

- Apply basic experimental techniques for geometrical characterisation of nanostructures
- Synthesise and characterise thin film
- Produce surface structures using particle beam lithography

Competencies:

- Be able to design fabrication processes for nano-scale components
- Be able to produce simple components
- Be able to analyse results and compare to basic limitations

Type of instruction: Lectures combined with theoretical and practical exercises.

Exam format: Individual continuous evaluation based on exercises given through the course.

Evaluation criteria: Are stated in the Joint Programme Regulations.

NFM1-4: Course module Semiconductors: Physics, Devices, and Engineering/Halvledere: fysik, komponenter og teknologi

Prerequisites: The module is built on knowledge obtained in Solid State Physics and Basic Quantum Mechanics

Objective: To provide an understanding of semiconductor properties, principles of operation of important semiconductor components as well as knowledge about methods of synthesis of semiconductor materials and basic technologies towards device fabrication

Knowledge: about

- Crystalline structure and specific properties of semiconductors
- Electronic band structure of semiconductors, both intrinsic and doped onces, as well as statistics and dynamics of charge carriers
- Characteristics of basic components including pn junctions, bipolar transistors, metal-oxide-semiconductor components and devices for power electronics
- Basic methods and technologies for fabrication of semiconductor devices

Skills: The student should be able:

- to explain and use theory and methods describing properties of semiconductors, including crystal structure, electronic characteristics of intrinsic and doped semiconductors as well as statistics and dynamics of charge carriers
- to explain properties and characteristics of basic semiconductor-based components as well as technologies used for fabrication of semiconductor devices.

Competencies: The student should develop and strengthen the knowledge about properties of semiconductors as well as basic principles and technologies behind the semiconductor-based devices. The student should be able to give reasons and arguments based on the concepts of semiconductor physics and technology.

Type of instruction: Lectures with exercises.

Exam format: Individual written or oral graded evaluation.

Evaluation criteria: Are stated in the Joint Programme Regulations.

3.2. Description of modules for 2nd semester, NFM2

3.2.1. Project module on 2nd semester, NFM2

Title: Functional Nanostructures/Funktionelle nanostrukturer.

Prerequisites: The module builds on knowledge obtained from project on NFM1.

Objectives: This project module will give the student experience with advanced methods for creation of functional nanostructures. In addition, possible applications of the created nanostructures will be investigated.

Students who pass this module develop:

Knowledge on:

- Methods for creation of functional nanostructures
- Applications of functional nanostructures

Skills in:

- Characterisation of functional nanostructures
- Theoretical description of the properties of functional nanostructures

Competencies:

- Through application of micro- and macroscopic modelling the student will be able to describe the properties and functionality of nanostructures.
- Applications of the properties of the designed nanostructures for adding special functions to macroscopic components

Exam format: Oral evaluation based on project report.

Evaluation criteria: Are stated in the Joint Programme Regulations.

3.2.2. Course modules on 2nd semester, NFM2

NFM2-2: Course module Optical Nanostructures and Materials/Optisk nanostrukturer og materialer.

Prerequisites: The module builds on knowledge in the area of Electromagnetism, and Optics and Spectroscopy.

Aim: The student must obtain knowledge about optical nanostructures and components, optical microscopy techniques for nanostructures, propagation, scattering and absorption of light in nanostructures, the optical response of nanomaterials, and the related theory and theoretical methods. Students completing the module will obtain

Knowledge: Knowledge within the following areas

- Optical nanostructures and components
- Optical microscopy techniques for nano- and microstructures including the physical limitations to the resolution of the microscopies
- Theoretical methods for the optics of nanostructures including the modeling of electromagnetic fields in nanostructures, the scattering of light by nanostructures, and propagation and absorption of light in nanostructures.
- Optical response of nanomaterials including effects due to electronic quantization in nanoscale structures

Skills: The student must be able to apply the knowledge in above mentioned areas for solving problems including modeling of the optics of nanostructures on a computer.

Competencies: Based on given information the student must be able to discuss and argument using concepts from the field of optical nanostructures and materials.

Type of instruction: Lectures combined with theoretical exercises

Examination form: Individual written or oral evaluation, graded.

Evaluation criteria: Are stated in the Joint Programme Regulations.

NFM2-3: Course module Computational Modelling for Physics and Engineering / Numerisk modellering i fysik og ingeniørvidenskab

Prerequisites: The module builds on a solid background in either Physics or an Engineering discipline. The type of computational problems used as examples in the course will be selected according to the background of the participants.

Aim: The student must obtain knowledge about common numerical methods for modeling of problems in physics and engineering, and be able to use the methods for computational modeling. The latter includes the construction and usage of computer programs in Matlab based on the numerical methods, and the usage of commercial software packages. Students completing the module will obtain

Knowledge: Knowledge within the following areas

- Common numerical methods in physics including but not limited to: Finite-Difference-Time-Domain (FDTD) method, Finite-Difference-Methods in the frequency domain, The Fourier Modal Method (FMM), The Finite Element Method (FEM), and Greens Function Integral Equation Methods (GFIEM).
- Construction of computer programs in Matlab for numerical modeling of physics and engineering problems.
- Commercial software packages for computational modeling.

Skills: The student must be able to judge which numerical method from a range of methods is most suitable for a specific problem in physics or engineering. The student must be able to carry out computational modeling for physics and engineering by constructing and using his / her own programs in Matlab based on common numerical methods, and by using commercial software packages.

Competencies: The student will gain insight into numerical methods for computational modeling in physics and engineering, and will gain experience in using the methods. This will serve as a foundation based on which the student will be able to choose and use appropriate numerical methods for specific problems in physics and engineering, including constructing and using numerical programs in matlab and using commercial software packages.

Type of instruction: Lectures combined with theoretical exercises

Examination form: Evaluation of report on a specific computational modeling study carried out during the semester, passed / not-passed.

Evaluation criteria: Are stated in the Joint Programme Regulations.

NFM2-4: Course module Physics and Chemistry of Surfaces / Overfladefysik og -kemi

Prerequisites: The module is built on knowledge in Solid State Physics, Basic and Physical Chemistry

Objectives: Aim of the course is to provide knowledge about specific aspects as well as physical and chemical phenomena occurring at surfaces and interfaces.

Knowledge should be acquired within the following topics:

- Structure of crystalline surfaces as well as the methods and techniques for their preparation and characterisation;
- basic thermodynamics and kinetics of surface processes including phenomena of surface tension and adsorption/desorption;
- major interaction forces near the interfaces including van der Waals and double-layer forces;
- physi- and chemi-sorption at surfaces and catalysis;
- structure of interfaces, wetting theory, hydrophobicity, membranes and growth of thin films;
- electronic structure of surfaces, electric and magnetic phenomena at surfaces and interfaces;

Skills: The student will become skilled in solving problems within the topics listed above and will be able to apply theories and methods of surface physics and chemistry.

Competencies: that are acquired develop and strengthen the knowledge and understanding of theory and methods in surface science, as well as their applications. Based on the skills acquired in this module the student should be able to reflect on and discuss topics from surface science.

Type of instruction: Lectures supported by problem solving classes.

Exam format: Individual oral or written evaluation.

Evaluation criteria: Are stated in the Joint Programme Regulations.

3.3. Description of modules for 3rd semester, NFM3

3.3.1. Project module on 3rd semester, NFM3

The project on the 3rd semester can either be a normal semester project of up to 30 ECTS or can be combined with the Master's thesis to a **Long Master's Thesis**. In case of a separate project, the scope of the project can vary between 15, 20, 25, and 30 ECTS dependent on how many elective courses are chosen by the student. A Long Master's Thesis can also vary between 45, 50, and 60 ECTS dependent on how many elective courses are taken by the student.

Students on the 3rd semester have also the possibility to study at another Danish or international university (**go abroad**), as well as they can spend the semester at a company performing an **academic internship**.

Studying at another university (including universities abroad), an academic internship at a company, and a Long Master's Thesis need to be approved by the board of studies.

Title: Advanced Applications of Nanotechnology/Avancerede anvendelser af nanoteknologi.

Prerequisites: The module builds on knowledge obtained from the project on NFM2.

If the project is less than 30 ECTS the workload of the project is reduced in accordance to the number of ECTS.

Objectives: This project module will give the student experience with independently applying nanotechnology within a chosen technological area.

Students who pass this module develop:

Knowledge on:

- Advanced applications of nanotechnology for solving technological problems.

Skills in:

- Applied aspects of nanotechnology.

Competencies:

- Given a problematic technological issue the student can use different tools from nanotechnology to find solutions to the actual problem.

Exam format: Oral evaluation based on project report.

Evaluation criteria: Are stated in the Joint Programme Regulations.

Title: Academic Internship / Projektorienteret forløb i en virksomhed

Prerequisites: This module is based on knowledge obtained on the 1st and 2nd Semester of the MSc in Physics Programme.

Objective: Upon completion of the module (project or academic internship), the student can:

Knowledge

- Discuss the subject matter of the project specified within the area of the study programme

Skills

- Solve complex problems using theory and concepts within physics
- Evaluate and choose among potentially relevant theories, concepts and methodologies applied to solve problem within physics.
- Evaluate the relevance and limitations of the theories, concepts, methods and tools actually applied in the project
- Account for any choices made during the problem analysis and solution development
- Develop solution alternatives and evaluate the consequences of solution alternatives and make a well-informed choice based on that
- Plan, execute and report an extensive individual research project within an agreed time frame
- Write a well-structured project report, which meets all the usual requirements of an academic work, including:
    - Empirical background
    - Research problem/project objective
    - Relevant theory
    - Research design:
    - Presentation of data
    - Presentation and discussion of findings
    - Evaluation of the project; i.e., findings, methods and, if relevant, considerations regarding the limitations and generalizability of the study.
    - specific for internship: a personal reflection is required, a reflection on: how was it to work alone, full-time in a company, and, if applicable, in a different country with a different culture, language, industrial structure, etc.

Competences

- Analyze and solve an actual problem of industrial relevance through application of systematic research and development processes, including advanced analytical, experimental, and/or numerical methods and models.
- Work together with an organization and identify problems and finally develop solutions.

- Operationalize theoretical contributions in a practical setting
- Compare and critically evaluate the results of the project in relation to existing knowledge and accepted theories within the subject area
- Communicate a balanced view of the results and conclusions of the project in well-organized written and oral presentation

Organization: The student is included in the company's daily work and carry out independent project work on an industrial problem relevant for the company. Concurrent to the work in the company, the student makes a project report, which is evaluated after the ending of the internship.

Exam Format: Oral examination based on a written report

Evaluation criteria: As stated in the Joint Programme Regulations.

3.3.2 Electives on 3rd semester, NFM3

Test and Validation/Test og validering

Recommended placement	MSc programme 3rd semester
Prerequisites	The module builds upon knowledge obtained in the modules *Applied Statistics* and *Probability Theory*
Duration	5 ECTS
Aim	The aim of the course is to enable participants to apply generic and elementary as well as specific, advanced methods to planning, execution and validation of experiments and tests, thereby to verify the validity of model-based results against experimental results and vice versa. Due to the stochastic nature of principal parameters (model input data, test equipment precision etc.) verification will relate heavily (although not exclusively) on statistical and probabilistic methodologies. In continuation hereof, the course aims to introduce central validation concepts and criteria as applied in contemporary industry standards.
Objectives	Upon completion of the course, the student should be able to *Knowledge* • Understand methodology for design of experiments and test series and for reduction of ambiguity of experimental results, and for comparability with model predictions • Explain elementary and advanced quantification tools, and their application to validation between model and experiment data • Account for common contemporary methods and relevant specific industry standards • Understand processing methods for analog and digital data (continuous vs. discrete) *Skills* • scrutinize a non-trivial physical systems for appropriate experimental study

	• isolate principal measurable parameters • design an experiment matrix for systematic variation of parameters • perform a probabilistic study of the experimental data in order to quantify the influence of individual parameters • scrutinize a model (analytical or numerical) for comparison with an appropriate experimental study • isolate principal input parameters and their known or assumed statistical variations • perform a probabilistic study of the model in order to quantify the level of confidence • account for the level of coherence between test results and model predictions • Identify invalid data (outliers) • account for common errors and limitations in the processing of model data or experimentally obtained data *Competencies* • undertake experiment planning and execution for refinement and validation (or rejection) of model-based predictions of phenomena within their principal line of study.
Assessment	Oral examination based on submitted written assignment
Grading	Passed/Not passed
Evaluation criteria	Cf. Joint Programme Regulations

Reaction Engineering and Molecular Electronics/ Engineering af reaktioner og molekylær elektronik

Prerequisites: The module builds on knowledge in the area of Physical Chemistry, Inorganic and Organic Chemistry, Lab-on-a-Chip, basic Quantum Mechanics, and Microbiology.

Objective: Students who complete the module:

Knowledge:

- Must acquire knowledge about basic design principles and modeling of chemical, biochemical, and biotechnological reactors
- Must acquire knowledge about micro-reactors and their application in biotechnology
- Must acquire knowledge on the underlying principles and the current state of molecular electronics

Skills:

- Must be able to apply the acquired knowledge to the design and performance evaluation of batch and continuous flow reactors
- Must be able to model chemical and biochemical reactors using COMSOL and other mathematical modeling software

Competencies:

- Must have working knowledge and basic skills for designing, modeling and evaluating of chemical, biochemical, and biotechnological reactors

- Must acquire an overview of the current progress in the area of molecular electronics

Type of instruction: Lectures and exercises.

Exam format: Individual oral evaluation.

Evaluation criteria: Besides the evaluation criteria stated in the Joint programme regulations, the grade requires participation in presentations and discussions of research papers and completion of an assignment.

Modern Physics/Moderne fysik

Prerequisite: The module builds on knowledge in the area of mechanical physics, electromagnetism, and basic quantum mechanics.

Objectives: students who complete the module

Knowledge:
- Should have knowledge about fundamental concepts and theories related to nuclear physics, including the structure of atomic nuclei, nuclear reactions (fission and fusion), as well as radioactivity.
- Should have knowledge about fundamental concepts and theories related to particle physics.
- Should have knowledge about fundamental concepts and theories related to the special theory of relativity.

Skills:
- Should be able to explain concepts and theories related to the description of nuclear physics.
- Should be able to explain concepts and theories related to the description of particle physics.
- Should be able to explain concepts and theories related to the description of the theory of the special relativity.

Competencies:
- Should from the given prerequisites be able to reason and argue using concepts from modern physics and be able to use them on simple model systems.
- Should be able to develop and strengthen knowledge about, as well as, understanding- and application of theories and methods from modern physics within other areas or topics.

Motivation: Nuclear physics constitutes the foundation for understanding important and societally relevant phenomena like nuclear fission, fusion and radioactivity. In addition, the theory of relativity represent (together with quantum mechanics) key parts of the new paradigm for physics established in the 1900s by replacing the absolute perception of time and space of classical physics with the principle of relativity.

Type of instruction: Lectures and exercises.

Exam format: Individual oral evaluation.

Evaluation criteria: Are stated in the Joint Programme Regulations.

3.4. Description of modules for 4th semester, NFM4

3.4.1 Project module on 4th semester, NFM4

Title: Master's Thesis/Kandidatspeciale

The student has the possibility to write a Long Master's Thesis (over 2 semesters), if the thesis is of experimental character. A Long Master's Thesis can be chosen as either 45, 50, or 60 ECTS. If choosing to do a Long Master's Thesis, the amount of experimental work must reflect the allotted ECTS.

Objectives: The Master's thesis should be approved by the Board of Studies. It will be done as problem based project work, where the student will develop:

Knowledge on:

- Either specialist information on one or a few chosen elements of the relevant topic.
- Or broader insight in the topic with regards to theory, methodology, key elements and their mutual contextual relations.
- Or competencies that, in a relevant way, support and expand the actual competence profile of the student.

Skills in:

- Applying nanotechnology.

Competencies:

- Identifying, formulating and analysing actual problems using independent, systematic and critical thinking.
- Relating a problem to the scientific area in question and justify the choices made with regards to the problem definition in a relevant way.
- Independently making and justifying the choice of scientific theoretical and/or experimental methods.
- The ability to independently apply critical thinking to evaluate both the chosen theory and methodology, as well as to evaluate the analysis, results and conclusions of the project both during and at the end of the project.
- Presenting relevant academic and professional aspects of the project work in a clear and systematic way.

Exam format: Oral evaluation based on project report.

Evaluation criteria: Are stated in the Joint Programme Regulations.

Chapter 4: Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of The Faculty of Engineering and Science and enters into force as of 1st of September 2017.

Students who wish to complete their studies under the previous curriculum from 2016 must conclude their education by the summer examination period 2018 at the latest, since examinations under the previous curriculum are not offered after this time.

Chapter 5: Other Provisions

5.1 Rules concerning written work, including the Master's thesis

In the assessment of all written work, regardless of the language it is written in, weight is also given to the student's spelling and formulation ability, in addition to the academic content. Orthographic and grammatical correctness as well as stylistic proficiency are taken as a basis for the evaluation of language performance. Language performance must always be included as an independent dimension of the total evaluation. However, no examination can be assessed as 'Pass' on the basis of language performance alone; similarly, an examination normally cannot be assessed as 'Fail' on the basis of poor language performance alone.
The Board of Studies can grant exemption from this in special cases (e.g., dyslexia or a native language other than Danish).

The Master's thesis must include an English summary.[1] If the project is written in English, the summary must be in Danish.[2] The summary must be at least 1 page and not more than 2 pages. The summary is included in the evaluation of the project as a whole.

5.2 Rules concerning credit transfer (merit), including the possibility for choice of modules that are part of another program at a university in Denmark or abroad

In the individual case, the Board of Studies can approve successfully completed (passed) program elements from other Master's programs in lieu of program elements in this program (credit transfer). The Board of Studies can also approve successfully completed (passed) program elements from another Danish program or a program outside of Denmark at the same level in lieu of program elements within this curriculum. Decisions on credit transfer are made by the Board of Studies based on an academic assessment. See the Joint programme regulations for the rules on credit transfer.

5.3 Rules for examinations

The rules for examinations are stated in the Examination Policies and Procedures published by The Technical Faculty of IT and Design, The Faculty of Engineering and Science, and The Faculty of Medicine on their website.

5.4 Exemption

In exceptional circumstances, the Board of Studies study can grant exemption from those parts of the curriculum that are not stipulated by law or ministerial order. Exemption regarding an examination applies to the immediate examination.

[1] Or another foreign language (upon approval from the Board of Studies.
[2] The Board of Studies can grant exemption from this.

5.5 Rules and Requirements concerning the Reading of Texts in Foreign Languages and a Statement of the Foreign Language Knowledge

At programmes that are taught in Danish, it is assumed that the student can read academic texts in modern Danish, Norwegian, Swedish, and English and use reference works, etc., in other European languages. At programmes taught in English, it is assumed that the student can read academic texts and use reference works, etc., in English.

5.6 Additional information

The current version of the curriculum is published on the Board of Studies' website, including more detailed information about the program, including exams.

Bemærkninger: Studieordningen er revideret ift. retskravs- og adgangsgivende uddannelser i juni 2018