UNIVERSITY OF SOUTHERN DENMARK

Chapter 9
Curriculum Syllabus for

Diplomingeniør i Mekatronik
Bachelor of Engineering in Mechatronics
Study start 2009, Version 1.0

The curriculum is divided into general provisions (Chapters 1-8), a programme specific part (Chapter 9) and the module descriptions for the subjects studied for each programme. Students should familiarise themselves with all three parts in order to acquire a full overview of the rules that apply throughout the study programme.

1 Job Profiles

An engineer with a Bachelor of Engineering degree in Mechatronics has broad knowledge of mechanics, electronics and software. Furthermore, the students have the possibility of specialising in one of the profiles: Nanotechnology, Embedded Systems or Dynamic Mechatronic Systems. The study programme focuses on product development. The mechatronics engineer will typically find employment in companies which develop and sell mechatronic products. With broad general knowledge and special key competences the mechatronic engineer can occupy many different positions in the company. Typical job profiles include:

- Development engineer
- Project manager
- Consultant
- Project sales
- Teaching

The mechatronic engineer will typically start the career as development engineer and will, in the course of a few years, have the opportunity of combining the technical work with managerial work.

The mechatronic engineer often participates in development processes across organisations and is involved in collaboration with external companies, nationally and internationally. Alternatively, the mechatronic engineer can become a specialist within specific technologies or start up his/her own company.

2 Competency Description of the Study Programme

The aim of the Bachelor of Engineering study programme in Mechatronics is to educate a development engineer with competencies in mechanics, electronics and software including the interplay between the technologies. The study programmes qualifies the graduate engineer to carry out, participate in or lead the development of mechatronic products.

A Bachelor of Engineering in Mechatronics from the University of Southern Denmark is characterised by mastering the following competencies:

- the ability to design and calculate mechanical designs;
- the ability to design and calculate electronic circuits;
- the ability to develop software for intelligent products;
- the ability to participate in a company's development department independently and together with others;
- the ability to apply technological knowledge and theories for the development of new products;
- specialised knowledge within either of the profiles: Nanotechnology, Embedded Systems or Dynamic Mechatronic Systems;
- the ability to carry out development projects independently and in teams;
- the potential to become project manager for product development assignments.

3 Subject Columns of the Study Programme

The mechatronics engineer acquires the competencies by working with subject from the five subject columns:

- the theoretical basis in mathematical/physical modelling;
- dynamics in mechatronic products – practical and theortic;
- technologies and design;
- methods and personal learning;
- specialisation.

The technical subjects are interconnected by the semester themes of the semester concerned. The student continuously acquires the requisite technical knowledge and personal competencies during the study programme. Each column includes the following subjects and disciplines:

The theoretical foundation in mathematical/physical modelling:

Mainly comprises the units: DYM, ESY, EPHYS, THER, and CAE with the following main content:

DYM: Integration technique; differentiation technique; vector algebra; matrix algebra; absolute velocity and acceleration; coordinate systems; Newton's laws; work and energy; impulse and impulse momentum and maintaining these.

ESY: Trigonometric functions; complex numbers; differentiation and integration technique; Taylor series and L'Hôpital's rule; electrical fields; simple engines.

EPHYS: Laplace transform; Fourier transform; Z transform.

THER: theorems of thermodynamics; the energy equation; the state equation; the impulse theorem; the continuity equation; open and closed systems; circuit processes; flows in compressible and incompressible media; momentum and forces caused by flow; heat transmission.

CAE: Analysis of linear-, static- and heat transfer problems in axial, plane and three dimensional models. Finite element analysis using the ANSYS simulation tool.

Dymamics in mechatronic products – practical and theoretic:

Mainly comprises the units: CYB, COE1, COE2, MECH1, and MECH2 with the following main content:

CYB: Cybernetics; dynamic feedback systems; planning; estimation; applied mathematics; computer simulation; MATLAB; modelling; mechatronics.

COE1: Modelling of dynamic systems; model of DC-motor; transient analysis and frequency analysis; stability of closed loop systems; dimensioning of lead-lag- and PID-compensation; computer simulations with MATLAB.

COE2: state equations in analogue and digital form; state-space controller; controllability and observability; controller for reference input; Integral controller.

MECH1: Forces and couples; isolation of mechanical systems made up of one or more solids; dry friction; torsion of circular members; internal effects; design of beams for bending; kinematics and kinetics of rigid bodies: general equations of motion, translation, fixed-axis rotation, work, energy and power, impulse, momentum.

MECH2: Load diagrams; tension; bending; torsion; 3D loads; singularity functions; combined stress; Mohr's circle; static and dynamic load; endurance limits; Wöhler and Goodman diagrams; machine parts: shafts, bearings, springs.

Technologies and design:

Mainly comprises the units: DES, MAP, EMB1, EMB2, SAA, MCEEL and MCAEM2 with the following main content:

DES: Modelling with primitive solid elements; modelling with parametric solid elements; modelling with curves and sketches; 3D assembly modelling with solid components; design of technical drawings with section views and dimensions including tolerances; making technical drawings on the basis of a 3D assembly model; making an exploded view on the basis of a 3D assembly model; making a parts list on the basis of a 3D assembly model.

MAP: Concepts and data for the mechanical, electrical, magnetic, thermal, physical and durability properties of materials; coherence between the structures and the properties of metals and polymers; methods to improve the basic properties of materials including their strength; different methods for materials testing; modelling processes for metals and polymers; application of programs and databases for the systematic selection of materials and processes; work on tolerance indication and tolerance evaluation.

EMB1: Numerical systems; Programming in C including: simple types of data, control structures, functions, arrays, structs, pointers, bitwise operators, microcontroller systems

EMB2: Logic components; Boolean algebra; latches and flip-flops; state machines; microcontroller hardware; peripheral units; interrupt.

SAA: Sensor characterisation; Accuracy and error estimation; Basic understanding of semiconductor materials; Electromechanical-, thermal-, radiation- and electromagnetic transducers; Simple actuators.

ELEC: A/D and D/A converters; operational amplifiers; feedback; diodes; bipolar junction transistors; FET-transistors; transistor used as a switch; computer simulations; methods for EMC correct circuits.

MCEEL: Development of power electronics to drive actuators, motors, etc.

MCAEM2: Electromagnetics focusing on the solution of various electrical engineering and physical problems.

Methodology and Personal Learning:

Mainly comprises the units: SPRO1M, SPRO 2M, SPRO 3M, SPRO 4M and EXT5 with the following main content:

SPRO1M: The Mechatronic Development Process - An introduction to the discplines in mechatronics, coherens, interdisciplinarity and especially focussing on the development process. A mechatronic product is designed by applying the other technical knowledge gained during the semester.

SPRO2M: Build Mechatronics. The students build a mechatronic product which is able to move autonomously. The project is based on the other units of the semester..

SPRO3M: Develop Mechatronics. Focus is on the development of an intelligent and dynamic mechatronic product. Theory of Science is introduced.

SPRO4M: Mechatronics and the Environment. The semester project is based on the chosen specialisation (Nanotechnology, Dynamic Mechatronic Systems, Embedded Systems). Theory of science continues.

EXS5: Experts in Teams. The students design a product concept encompassing complex problems across academic disciplines. The project is described, presented and evaluated in English language and is carried out by students from different academic disciplines. Theory of science is completed.

Through the projects the personal and learning-related competencies are strengthened and developed, and at the same time the professional and technical competencies are learned in-depth and brought out in 'real' projects.

Personal competencies: commitment, initiative, responsibility, ethics, general education, the ability to put personal learning into perspective.

Learning related competencies: selection, collection, analysis and assessment of data, communicating results by applying modus operandi that require reflection, teamwork and independence.

Specialisation and Electives:

The competencies can be focused by choosing electives in fourth and fifth semester (15 ECTS) or by choosing one of the three specialisations: Nanotechnology, Embedded Systems or Dynamic Mechatronic Systems.

Nanotechnology.

Comprises the units: MCWAQ, MCOPS, MCCLM with the following main content::

MCWAQ: Electromagnetic waves and quantum mechanics.

MCOPS: Optics and Photonics Sensors.

MCCLM: Microfabrication techniques and processes.

Embedded Control Systems

Comprises the units: MCRTOS, MCPLD and MCADP with the following main content:

MCRTOS: Real-time kernels and operating systems: functions and subsystems – task management, time management, event management, synchronization and communication, etc.; embedded system design using kernels

PMCLD: Programmable logic circuits; field-programmable gate arrays (FPGA's); hardware design languages (e.g. VHDL); FPGA-based hardware design tools and environments.

MCADP: Advanced Programming: Inheritance, Polymorphism, Templates, Exceptions, Graphical User Interface, Interface to a SQL-database.

Dynamic Mechatronic Systems

Comprises the units: MCACT, MCMEV and MCARI with the following main content:

MCACT: The main topic is the DC motor and the control of the motor which includes: Motor Physics, controller types, control of speed, torque and position, feedback systems, 1, 2 and 4 quadrant operations, energy handling. Other actuator and controller types will be studied with the DC motor as frame of reference. This includes: stepper motors, AC motors, linear motors, voice coil, piezo actuators, electro active polymers.

MCMEV: Vibration and time response for mechanical components; the harmonic oscillator (damped and undamped oscillations); vibrations of strings, bars, membranes, and plates; introduction to nonlinear mechanical vibrations.

MCARI: Introduction to knowledge-based intelligent systems, rule-based expert systems, uncertainty management in rule-based expert systems, fuzzy expert systems, artificial neural networks, hybrid intelligent systems

4 Semester themes

Semester	SEMESTER THEMES
7.	**Final Project**
6.	**Internship**
5.	**Experts in teams**
4.	**Mechatronics and the Environment**
3.	**Develop Mechatronics**
2.	**Build Mechatronics**
1.	**Discover Mechatronics**

5 Semester modules

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6 Description of the first semester

SEMESTER THEME

First semester: ”The Mechatronic Development Process”

VALUE ARGUMENTATION

It is important for new students to gain an understanding of what mechatronics is and an understanding of how mechatronic products can be developed. This will enable them to understand and utilise the complex correlations between disciplines and the technical knowledge necessary for developing mechatronic products.

During the semester project the students experiment with developing a small mechatronic product and the students are led through all phases of the development process. In doing so, the student gain general knowledge about individual subjects, interdisciplinarity and process, thus gaining an overview of what mechtronics is. The project is underpinned by the semester courses in mechanical design, materials and processes, embedded systems and the supporting mathematics and physics.

COMPETENCE GOALS

The student should learn to:

- Explain and use a structured product development model divided into phases to develop a mechatronic product from idea, concept, sketching, choise of materials/process to making a prototype;
- design and have mechanical elements developed using CAD modelling;
- Develop software able to receive input from the surroundings, process the input and respond back to the surroundings using an existing hardware platform;
- Understand the mathematics and physics of simple mechanical systems.

SEMESTER STRUCTURE

IMMDP1M – The Mechatronic Development Process (30 ECTS points)

The module is mandatory and constitutes the first-year examination.

CONTEXT

The semester consists of one module: IMMDP1M (The Mechatronic development process). The module includes a semester project with the same title as the semester theme, as well as four units to underpin the project. Overall, this constitutes an introduction to the concept of mechatronics and the underpinning central subject knowledge. The four units are: DES (mechanical design); MAP1 (materials and processes); EMB1 (embedded hardware/software); DYM (mathematics/physics (dynamic systems)).

7 Module descriptions for the 1st Semester

Module descriptions for BEng in Mechatronics, applicable for first semester students enrolled in September 2009, is available in the Course Database under Course Descriptions autumn 2009.

8 Description of the second semester

SEMESTER THEME

The theme for the second semester is 'Build Mechatronics'.

VALUE ARGUMENTATION

In relation to the development of mechatronic products, it is important for students to have both a command of the system in general and knowledge of the system components and their interaction. This semester introduces thinking about the system and builds up experience in the modelling of systems with feedback. In addition, students learn how to design electronic and mechanical elements, as well as how to manufacture and apply them. This application takes the form of a semester project in which the theme of the semester is central: the construction of a mechatronic product that can move. The project is backed up by the other academic fields of the semester, which provide an insight into the technology and the physical/mathematical foundation.

COMPETENCE GOALS

Students will be able to:

- design and have mechanical components manufactured;
- build digital electronics;
- integrate electronics, mechanics and software into an overall functioning system; and
- describe the kinematics of a system and produce simple mathematical models of systems with feedback.

SEMESTER STRUCTURE

IMBMM2M – Build Mechatronic Products that can Move (20 ECTS points)
IMBAM2M – Basic Mechatronics (10 ECTS points)

Both modules are mandatory.

CONTEXT

The semester includes two modules: IMBMM2M (Build Mechatronic Products that can Move) and IMBAM2M (Basic Mechatronics). IMBMM2M focuses particularly on the theme of the semester, as in semester project SPRO2M a mechatronic system is to be built that can move. The two associated academic fields, CYB and EMB2, provide an insight into the modelling of systems with feedback and the design of digital electronics. On the basis of the competencies attained in the first semester, students will thus be able to build a complete system. Module IMBAM2M (Basic Mechatronics) provides the background to the semester, particularly the theoretical angle in terms of the associated mechanics, mathematics and physics.

9 Module descriptions for second semester

The module descriptions for the BEng in Mechatronics, applicable for second semester students enrolled in September 2009, are available in the Course Database under Course Descriptions, spring 2010.

10 Description of the third semester

SEMESTER THEME

Develop Mechatronics

VALUE ARGUMENTATION

Over the first two semesters, students will have attained a fundamental knowledge of mechatronics and mechatronics development, and learned how to design mechanics and digital electronics. In this semester, it is important for students to attain a greater understanding of the whole concept and gain a more professional approach to the development of products. This is achieved by teaching students about analogue electronics, actuators and sensors, and dynamic systems. A project is completed in which students' development efforts are focused on the application of actuators and sensors, the design of electronics and the specification and production of mechanics, thus enabling the development of a complete mechatronic system. Students gain an insight into the interaction between the various skills, including the dynamic conditions within systems:

- students gain an insight into, and understanding of, the interaction between mechanics and electronics;
- students are able to understand and model dynamic problems in connection with mechatronic systems;
- students can specify, design and develop mechatronic products, in which a mechanical system is regulated by an analogue electronic system; and
- students have a command of the physics that forms the basis of selected transducers and actuators.

COMPETENCE GOALS

In the third semester, students attain the following academic competencies:

- the ability to analyse, specify and design passive and active analogue electronic circuits;
- an understanding of the physical basic principles in actuators and sensors, and an ability to use these as components in the development of mechatronic systems;
- an insight into, and understanding of, the interaction between mechanics and electronics;
- the ability to understand and model dynamic problems in connection with mechatronic systems;
- the ability to specify, design and develop mechatronic products, in which a mechanical system is regulated by an analogue electronic system that is central to the functionality; and
- the ability to integrate mechanics, electronics and software into a functioning mechatronic system.

SEMESTER STRUCTURE

IMDIM3M – Develop Intelligent Dynamic Mechatronic Systems (20 ECTS points)
IMDYN3M – Dynamic systems (10 ECTS points)

Both modules are mandatory.

CONTEXT

The semester consists of two modules, IMDIM3M (Develop Intelligent Dynamic Mechatronic Systems) and IMDYN3M (Dynamic systems). In IMDIM3M, students complete a semester project that deals with

the development of an intelligent mechatronic system, in which the electronics and software must be developed, while the mechanics must be designed, specified and manufactured externally. The accompanying teaching deals in particular with the development of electronics as well as sensors and actuators. In IMDYN3M, the focus is on the theoretical aspect of dynamic systems and the modelling of electrotechnical systems.

11 Module descriptions for the 3rd Semester

Module descriptions for B.Eng in Mechatronics, applicable for first semester students enrolled in September 2009, is available in the Course Database under Course Descriptions autumn 2010.

12 Description of the fourth semester

SEMESTER THEME

Mechatronics and the Environment

VALUE ARGUMENTATION

In the fourth semester, the focus is on students being able to apply their knowledge of the development of mechatronic products with regard to the environment/users. The third semester is consolidated by the introduction of Regulation Technology, Thermodynamics and Computer Aided Engineering, which form a significant theoretical foundation for the development of advanced mechatronic systems. Students also choose an elective, or select one of three profiles (Nanotechnology, Embedded Control Systems, Dynamic Mechatronic Systems). This results in a general specialisation in the field of mechatronics and initiates a profiling that may continue with actual specialisation at graduate engineer level.

COMPETENCE GOALS

In the fourth semester, students attain the following academic competencies:

- the ability to model and implement a mechatronic system or product while taking into account the context of which it forms part;
- the ability to use element analysis to solve simple plane, axial and spatial structures;
- the application of regulation technology solutions in mechatronic products in theory and practice;
- theoretical ballast in thermodynamic conditions in connection with mechatronic systems; and
- Specialisation within the selected profile – either:
    - Basic knowledge about Nanotechnology; or:
    - Basic knowledge of the development of object-oriented programs for embedded systems; or
    - Basic knowledge about DC motors and their application as actuators.

SEMESTER STRUCTURE

IMMEN4MC – Mechatronics and the Environment (10 ECTS points)
IMADM4MC – Advanced Mechatronics (15 ECTS points)

The above modules are mandatory. In addition, an elective or profile course equivalent to 5 ECTS points.

CONTEXT

The semester consists of two mandatory modules, IMMEN4MC (Mechatronics and the Environment) and IMADM4MC (Advanced Mechatronics). In addition, students must choose an elective or a profile course within one of three profiles (Nanotechnology, Embedded Systems, Dynamic Mechatronic Systems). IMMEN4MC consists of a semester project in which a mechatronic product must be developed that makes use of the profile subject and the other skills learnt during the semester. In IMADM4MC, teaching is provided in Thermodynamics, Regulation Technology and Computer Aided Engineering – a necessary theoretical foundation that will allow the development of advanced mechatronic products.

13 Module descriptions for the 4th Semester

Module descriptions for B.Eng in Mechatronics, applicable for fourth semester students enrolled in September 2009, is available in the Course Database under Course Descriptions spring 2011.

14 Description of the fifth semester

SEMESTER THEME

Experts in Teams

VALUE ARGUMENTATION

The purpose of the theme is as follows:

Students will gain knowledge of and the ability to develop complex (dynamic) mechatronic systems, where the particular focus is on major demands on control and regulation. Students will also gain experience of the completion of project work in a context of 'innovation and enterprise'. The work of the project is organised into a virtual company, and students must complete all phases of development from the idea to the manufacture of a fully functioning prototype, taking into account finance, external suppliers, etc. In addition, the semester includes two electives, in which students can consolidate their chosen profile from the fourth semester and thus become specialists, or become 'experts on the team'.

COMPETENCE GOALS

In the fifth semester, students attain the following academic competencies:

- the ability to model a regulation system;
- the ability to design a digital pole-placement regulator;
- experience of project management, the construction of the required organisation and financial management of a project;
- knowledge of how to collaborate on a major project requiring different skills;
- the ability to understand their own roles in the work of the project;
- an understanding of the philosophical aspects of science; and
- the attainment of further specialisation within one of the chosen profiles:
    - Nanotechnology: Optics, Sensor Technology and Clean Room Manufacture.
    - Embedded Control Systems: The application of real-time operating systems and the modelling of digital systems using VHDL;
    - Dynamic Mechatronic Systems: Mechanical vibrations and artificial intelligence.

SEMESTER STRUCTURE

EXS5 – Experts in Teams and Science Theory (15 ECTS points)
IMCOE5 – Control Engineering 5 (5 ECTS points)

The above modules are mandatory. In addition, two elective or profile courses equivalent to 10 ECTS points.

CONTEXT

The semester consists of two mandatory modules, EXS5 (Experts in Teams and Science Theory) for 15 ECTS points, of which Science Theory constitutes 3 ECTS points and IMCOE5 (Control Engineering) is worth 5 ECTS points. In addition, specialisation via two electives or profile subjects, each worth 5 ECTS points. IMCOE5 contains advanced regulation technology. Students complete a project that includes an interdisciplinary problem. Engineering methodology forms an integral part of the project work, and particular emphasis is placed on project management, organisation and roles on the project. There is a

focus on the application of the methods of research and science theory in the resolution of new problems.

15 Module descriptions for the 5th Semester

Module descriptions for B.Eng in Mechatronics, applicable for fifth semester students enrolled in September 2009, is available in the Course Database under Course Descriptions autumn 2011.

16 Description of the sixth semester

SEMESTER THEME

Internship.

Focus is put on practical training of core competencies and an advanced business understanding.

VALUE ARGUMENTATION

The students' abilities are improved by taking part in the company's projects; and thus train the acquired theory and project procedures. Co-operation and networking with industrial companies open doors for finding a final project and maybe also the first job.

COMPETENCE GOALS

To expand on the students' business understanding, develop their creativity, independence and interpersonal skills; and to provide students with more of the following competencies:

- Ability to transform the theoretical core areas of the programme into practical and feasible projects.
- Competency requiring that new knowledge is acquired to carry through projects.
- Comprehension of a company's organisational, economic, social and work-related conditions.
- Knowledge of a company's social and executive environment (communication and co-operation among employees at different level; as well as rules and clerical routines).
- Skills in presenting working results both orally and in writing; in forums of different level.

SEMESTER STRUCTURE

IMINGPR – Industrial Engineering Training (30 ECTS)

The module is mandatory.

17 Module descriptions for the 6th Semester

Module descriptions for B.Eng in Mechatronics, applicable for sixth semester students enrolled in September 2009, is available in the Course Database under Course Descriptions spring 2012.

18 Description of the seventh semester

SEMESTER THEME

Final Project.

Focus is put on problem-based project work linked up to the principal subjects of the programme.

VALUE ARGUMENTATION

The final project must reveal an independent, experimental or theoretical discussion of a practical problem linked up to the principal subjects of the programme. The student is trained in professional problem-solving in co-operation with an internal supervisor and an external supervisor from industry.

COMPETENCE GOALS

The final project must demonstrate the student's ability to independently describe, analyse and build up solutions for practical engineering problems. The student must prove skills in: translating technical research results; and scientific and technical knowledge into practical application by means of development tasks and solving technical problems having a critical and reflective approach to experiences from the internship.

Critically acquiring new knowledge within relevant engineering areas and hereby independently solve engineering problems drawing in social, economic, environmental- and working consequences when solving technical problems attending executive- and co-operative relations with people of different educational and cultural background putting into perspective the project's results to a broader target group.

SEMESTER STRUCTURE

IMPROJ – Final Project (30 ECTS).

The module is mandatory.

19 Module descriptions for the 7th Semester

Module descriptions for B.Eng in Mechatronics, applicable for seventh semester students enrolled in September 2009, is available in the Course Database under Course Descriptions autumn 2012.

20 Entry into force and changes

1. Approved by the Academic Study Board of the Faculty of Engineering and the Director of Studies on behalf of the Dean of the Faculty of Engineering on 20 August 2008.

2. Study start september 2009 approved by the Academic Study Board of the Faculty of Engineering and Director of Studies on behalf of the Dean of the Faculty of Engineering on 15th December 2011 (Version 1.0).