UNIVERSITY OF SOUTHERN DENMARK

Chapter 9
Programme specific part of the curriculum for

Bachelor (BSc) i teknisk videnskab (mekatronik)

Bachelor of Science (BSc) in Engineering (Mechatronics)

Curriculum 2012, Version 1.0

Applicable to students admitted September 2012 onwards

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

The mechatronics study programme provides a broad foundation of knowledge in the fields of mechanics, electronics and software. In addition, students also have the opportunity to specialise through the choice of elective courses from the MCI research groups in Nanotechnology, Embedded Systems or Dynamic Mechatronic Systems. The study programme focuses on product development. This primarily provides employment opportunities with companies that develop and sell mechatronic products. The broad foundation knowledge and particular specialised areas enable the mechatronics engineer to practise a variety of functions in the company. Typical job profiles are as follows:

- Development Engineer
- Project Manager
- Customer Advice
- Project Sales
- Training

Typically, mechatronics engineers will begin their careers as development engineers. Within a few years, they will have the opportunity to combine technical work with management functions. Engineers are often involved in cross-organisational development processes, as well as being involved in partnerships with external companies, both nationally and internationally. Alternatively, they may develop into specialists in particular technologies, or perhaps start their own business.

The bachelor programme in mechatronics provides an immediate opportunity to continue with an MSc (Eng) in mechatronics or a corresponding continuation study programme at the University of Southern Denmark (SDU) or another university.

§2 The competency description of the study programme

The aim of the study programme in mechatronics is to train a development engineer, with particular competencies in the fields of mechanics, electronics and software, including the interaction between technologies. The study programme provides qualifications for conducting, participating in and managing the development of mechatronic products.

Bachelors in Mechatronics from the University of Southern Denmark are distinguished by the following competencies:

- an ability to design and calculate mechanical structures;
- an ability to design and calculate electronic circuits;
- an ability to develop software for intelligent products;
- an ability to model mechatronic systems and implement these;
- an ability to make use of knowledge about technologies and theories for the development of new products;
- the possession of specialised knowledge within selected subjects, for example: Nanotechnology, Embedded Systems or Dynamic Mechatronic Systems;
- being trained in the completion of development projects alone and as a participant in teams; and
- being prepared to continue studying on a relevant Master of Science programme at SDU or other universities.

§3 The subject columns of the study programme

The competencies of the mechatronics engineer are built around students working on topics from five subject columns:

- the theoretical foundation in mathematical/physical modelling;
- dynamic conditions in mechatronic products – practical and theoretical;
- technologies, design and development;
- methods and personal learning; and
- specialisation.

The academic topics are interlinked during the individual semesters by semester themes. Throughout the course of study, students continually acquire the necessary academic knowledge, while at the same time gaining personal competencies. The columns include the following subjects and disciplines:

The theoretical foundation in mathematical/physical modelling

Consists principally of the academic fields: DYM, ESY, EPHYS, THER, CAE, with the following principal content:

DYM: Integration techniques; Differentiation techniques; Vectoral algebra; Matrices; Absolute speed and acceleration; Coordinate systems; Newton's laws; Work and energy; Momentum, angular momentum and their preservation.

ESY: Trigonometrical functions; Complex numbers; Differentiation/integration technique; Taylor series and L'Hôpital's rule; Electrical fields; Magnetic fields; Simple motors.

EPHYS: Laplace transformation; Fourier transformation; Z transformation.

THER: Principal theories of thermodynamics; Equation of energy; Equation of state; Momentum theorem; Equation of continuity; Open and closed systems; Circulatory processes; Flows in compressible and incompressible media; Momentum and forces caused by flows; 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.

Dynamic conditions in mechatronic products – practical and theoretical

Consists principally of the academic fields: CYB, MCCOE6, MCCOE5, MECH1, MECH2, with the following principal content:

CYB: Cybernetics; Dynamic feedback systems; Planning; Estimation; Applied mathematics; Computer simulation; Mathlab; Modelling; Mechatronics.

MCCOE5: 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.

MCCOE6: 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.

<u>Technologies, design and development</u>

Consists principally of the academic fields: DES, MAP, EMB1, EMB2, SAA, ELEC, PWE, MCAEM6, with the following principal 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; The 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: Numbering systems; Programming in C, including: simple data types, 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; Interrupts.

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.

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

MCAEM6: Electromagnetics focusing on the solution of various electrical engineering and physical problems.

<u>Methods and personal learning</u>

Consists principally of the academic fields: SPRO1M, SPRO2M, SPRO3M, SPRO4M, EXS5, with the following themes and principal content:

SPRO1M: The Mechatronic Development Process. An introduction to the Mechatronics disciplines: concept, interdisciplinarity and particular focus on the development process. A mechatronic product is designed by applying the other skills acquired during the semester.

SPRO2M: Build Mechatronics. A mechatronic product is built that is capable of autonomous movement. The other subjects of the semester are the academic basis for the project.

SPRO3M: Develop Mechatronics. The focus is on the development of an intelligent, dynamic mechatronic product. Science Theory is introduced.

SPRO4M: Mechatronics and the Environment. The project for the semester is based on the selected specialisation (Nanotechnology, Dynamic Mechatronic Systems, Embedded Control Systems). Continuation of Science Theory.

EXS5: Experts in Teams. Students design a product concept that involves complex problems across subject groups. The report on the project is given in English and is conducted by teams composed of students from a number of different branches. Completion of Science Theory.

The projects enhance and develop personal and learning competencies, while at the same time the academic competencies are learned in depth and brought to maturity in "real" projects.

Personal competencies: Commitment, Initiative, Responsibility, Ethics, Establishment, Ability to put personal learning into perspective.

Learning competencies: Selection, collection, analysis and assessment of data material; Communication of working results using approaches that require reflection, cooperation and independence.

Specialisation and electives

Focusing of competencies may be done either by choosing electives in the fourth, fifth and sixth semesters (20 ECTS points in total). The courses will be in the domain of the MCI research, -e.g.: Nanotechnology, Embedded Control Systems or Dynamic Mechatronic Systems.

§4 Semester themes

Semester	SEMESTER THEMES
6.	**Bachelor Project**
5.	**Experts in teams**
4.	**Construct Mechatronics**
3.	**Develop Mechatronics**
2.	**Build Mechatronics**
1.	**Discover Mechatronics**

§5 Semester modules

<table>
<tr><td>Semester</td><td colspan="30">STRUCTURE</td></tr>
<tr><td>6.</td><td colspan="15">NABPRO1
Bachelor Project</td><td colspan="5">MCCOE6
Control Engi-neering 6</td><td colspan="5">MCAEM6
Applied Elec-tromagnetics</td><td colspan="5">Elective</td></tr>
<tr><td>5.</td><td colspan="15">EXS5
Experts in Teams</td><td colspan="5">MMCOE5
Control Engi-neering 5</td><td colspan="5">Elective</td><td colspan="5">Elective</td></tr>
<tr><td>4.</td><td colspan="15">MCCOM4
Construct Mechatronics</td><td colspan="5">MCCAE4
Computer Ai-ded Enginee-ring</td><td colspan="5">MCTHER4
Thermody-namics</td><td colspan="5">Elective</td></tr>
<tr><td>3.</td><td colspan="20">IMDIM3M
Develop Intelligent Dynamic Mechatronic Systems</td><td colspan="10">IMDYN3M
Dynamic Systems</td></tr>
<tr><td>2.</td><td colspan="20">IMBMM2M
Build Mechatronic Products that can Move</td><td colspan="10">IMBAM2M
Basic Mechatronics</td></tr>
<tr><td>1.</td><td colspan="30">IMMDP1M
The Mechatronic Development Process</td></tr>
<tr><td>ECTS points</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr>
</table>

§6 Description of first semester

SEMESTER THEME

The theme for the first semester is 'The Mechatronic Development Process'.

VALUE ARGUMENTATION

It is important for new students to gain an insight into what mechatronics is, as well as an understanding of how the development of mechatronic products may proceed, as this will later enable them to understand and make use of the more complex concepts and skills required for the development of mechatronic products.

During the project work this semester, students will experiment with the design of a small mechatronic product and will be guided through all the phases of the development process. This will enable students to gain a general knowledge of the individual disciplines, the interdisciplinary nature of the work, and the process involved, thus providing them with an overview of what mechatronics is. The project is supported by the semester courses in mechanical design, materials and processes, and embedded systems, as well as the associated physics/mathematics.

COMPETENCE GOALS

Students will be able to:

- explain and use a structured, phased product development module for the development of a mechatronic product from idea, concept, outline, choice of materials/process through to prototype manufacture;
- design, and have manufactured, mechanical elements based in CAD;
- write software that is able to register input from the surroundings, process this and send control information back to the environment using an existing hardware platform; and
- understand the mathematical and physical basis 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 includes one module: IMMDP1M (The Mechatronic Development Process). The module contains a semester project of the same title as the semester theme, as well as four supporting academic fields. Overall, this forms an introduction to the concept of mechatronics and its associated core skills. The four academic fields are: DES: Mechanical Design; MAP1: Materials and Processes; EMB1: Embedded Hardware/Software; and DYM: Mathematics/Physics (dynamic systems).

§7 Description of 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.

§8 Description of 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.

§9 Description of fourth semester

SEMESTER THEME

Construct Mechatronics

VALUE ARGUMENTATION

In the fourth semester, the focus is on students being able to apply their knowledge of the development process of mechatronic products combined with the ability to construct power circuits and validate the quality of the constructed mechatronic system. The third semester is consolidated by the introduction of Power Electronics, Thermodynamics and Computer Aided Engineering, which form a significant theoretical foundation for the development of advanced mechatronic systems. Students also choose an elective, course. This semester 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 ability to construct power electronic circuits and understand control of power circuits;
- the ability to validate solutions with respect to production quality, tolerances and life time estimates;
- theoretical ballast in thermodynamic conditions in connection with mechatronic systems; and
- Specialisation through the choice of an elective course, for instance:
    - Electromagnetic waves; or
    - Development of object-oriented programs for embedded systems; or
    - AC and DC motors and their application as actuators.

SEMESTER STRUCTURE

MCCOM4 – Construct Mechatronics (15 ECTS points)
MCCAE4 – Computer Aided Engineering (5 ECTS points)
MCTHER4 – Thermodynamics (5 ECTS points)

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

CONTEXT

The semester consists of three mandatory modules, MCCOM4 (Construct Mechatronics), MCCAE4 (Computer Aided Engineering) and MCTHER4 (Thermodynamics). In addition, students must choose an elective course. MCCOM4 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. The module includes teaching in main topics of power electronics. In MCCAE4 and MCTHER4, teaching is provided in Thermodynamics and Computer Aided Engineering – a necessary theoretical foundation that will support the development of advanced mechatronic products.

§10 Description of 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 mechatronic systems, including the particular focus on control systems. 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 control system in the context of a mechatronic product;
- 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 of two elective courses, for example:
  - Optics and Sensor Technology;
  - Clean Room Manufacture;
  - The application of real-time operating systems;
  - The modelling of digital systems using VHDL;
  - Mechanical vibrations..

SEMESTER STRUCTURE

EXS5 – Experts in Teams and Science Theory (15 ECTS points)

MCCOE5 – 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 MCCOE5 (Control Engineering) is worth 5 ECTS points. In addition, specialisation via two electives or profile subjects, each worth 5 ECTS points. MCCOE5 contains basic control technology. Students complete a project that includes an inter-disciplinary 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.

§11 Description of sixth semester

SEMESTER THEME

The theme of the sixth semester is the Bachelor project.

VALUE ARGUMENTATION

The focus of the semester is on students demonstrating an overall view, independence and mastering of the core skills taught in the study programme. This is documented in the Bachelor project. The semester is supplemented by two advanced modules: MCCOE6 (control Engineering) and MCAEM6 (Applied Electromagnetics) as well as an elective course. This provides students with theoretical insight that can be applied to the bachelor project and is a prerequisite for any further studies.

COMPETENCE GOALS

Students gain:

- The application of control theory for solutions in mechatronic products;
- knowledge of numerical methods for the resolution of electrophysical problems;
- Specialized knowledge through the selection of an elective course from one of the areas: Nanotechnology, Embedded Control Systems or Dynamic Mechatronic Systems; and
- the ability to complete a Bachelor project by making use of the core skills taught in the study programme.

SEMESTER STRUCTURE

NABPRO1 – Bachelor project (15 ECTS points)
MCCOE6 – Control Engineering (5 ECTS points)
MCAEM6 – Applied Electromagnetics (5 ECTS points)

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

CONTEXT

The semester consists of three modules, a Bachelor project worth 15 ECTS points, MCCOE6 (Control Engineering) worth 5 ECTS points and MCAEM6 (Applied Electromagnetics) worth 5 ECTS points, as well as an elective subject worth 5 ECTS points.

§12 External examiners and Academic Study Board

The study programme falls under the jurisdiction of the Academic Study Board of the Faculty of Engineering and the Engineering Study Programmes' nationwide external examiners.

§13 Entry into force and amendments

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 2012 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 13 April 2012 (Version 1.0).