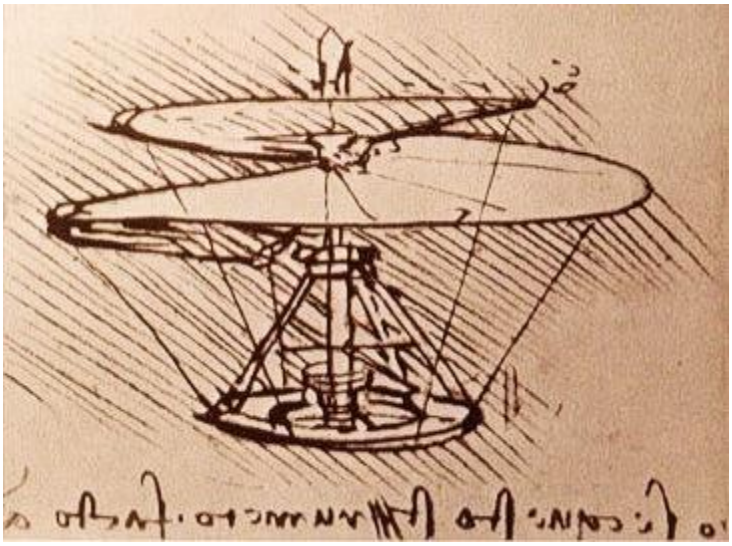
FACULTY OF SCIENCE AND TECHNOLOGY

BACHELOR'S PROGRAMME ADVANCED TECHNOLOGY

INFORMATION GUIDE 2019

UNIVERSITY OF TWENTE.

COLOPHON



Aerial screw by Leonardo da Vinci

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PREFACE

What is Advanced Technology?

Advanced Technology is a broad natural sciences and engineering programme which enables students to *explore* and *develop* their interests within this large domain. As such the programme attracts students with a broad interest like modern Leonardo da Vinci's. This is the reason for selecting one of his icon thoughts, the *helix pteron,* or aerial screw as the image on the previous page. It combines a visionary thought with a practical apparatus and knowledge from different disciplines.

Advanced Technology students first want to experience science and engineering before choosing between many interesting options. This not only facilitates to combine traditional disciplines and work in a multi-disciplinary fashion, but allows in a natural way to have a change of mind about the direction of your studies. In this manner Advanced Technology allows *you* to find *your* way in the wide range of possibilities in academic programmes.

This information guide intends to provide information for prospective students and others interested in the programme to answer this question. Therefore, it compiles general and detailed information about the curriculum and what to do before enrolment. The best idea about the programme is however given by our alumni and therefore we also included testimonials and descriptions of a few Bachelors assignments, the final 10-week project done by a student to show its maturity. The compilation of these assignments provides an excellent overview of the level attained by our students in very diverse directions. I am sure this booklet will answer some of your questions.

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1 THE ADVANCED TECHNOLOGY (AT) PROGRAMME

1.1 Why a programme Advanced Technology?

Advanced Technology is a unique, English-taught broad Bachelor's programme in natural sciences and engineering. It was established to meet the demand by students to have a broad education not limited by traditional discipline boundaries. This broad interest meets the requirements on future professionals: many of the professions that people have at this moment did not even exist 20 years ago. With this in mind it is impossible to predict what our students will be doing 20 years from now and what disciplinary knowledge is required. One thing is certain our students will probably work in a more complex and swiftly changing environment and their jobs might easily be less secure and less permanent than they are now. This is why we want to educate students to become entrepreneurial 'T-shaped professionals'. They know the depth of their field of study and can contribute to its development. They are also capable of stepping off the beaten tracks and have the skills to easily adapt new knowledge and apply this more broadly, in collaboration with other disciplines and society. The Advanced Technology programme at the University of Twente combines a bachelor's level in engineering and natural sciences with the required math and programming skills and insight in entrepreneurship and the impact of technology on society. This enables our students to be eligible for a wide range of masters especially in the engineering disciplines. These masters are both traditional disciplinary masters and masters on new emerging fields such as nanotechnology, mechatronics and sustainable energy.

1.2 The Twente Educational Model

Modular education

The University of Twente introduced in 2013 a modular education concept in which the bachelors programme is divided in twelve modules of each 10 weeks of full time study. Each module is 15 EC and integrates several theoretical courses and requires to apply this knowledge in practical's and projects. This integration implies that each module is centred around a specific theme such as Mechanics, Materials and System Engineering. The first two years (eight modules) represent the core of the programme. In the third year, students choose elective modules for broadening or deepening their knowledge, which also will make them eligible for the master's programme of their choice. This choice also means that each student has his/her own requirements for the third year, making each programme unique. The last module of the programme is devoted to the bachelor's assignment, a 10-week research or design assignment in one the research chairs at the University of Twente.

Modules allow flexibility in offering various teaching methods, such as inspiring lectures, practical's, tutorials, discussion platforms and review sessions or, for example, working full-time on one subject for several days and then switch to a different subject to work on full-time.

Project-based work

In order to encourage that students are involved in their own learning and that they study actively and nominally, it is of the utmost importance that the education offered is appealing. For that reason, the core of a module is shaped by a project: an activity that challenges students to independently gain and apply knowledge and skills. The size of a project is not predetermined.

Personal responsibility

With our Student-driven modules and open projects our students have the opportunity to take the reins themselves. Students are therefore expected to take on an active study and work attitude and reflect upon their work themselves. What do they have to pay more attention to and/or spend more time on, which activities do they have to complete to attain the learning objectives, which sources do they need,

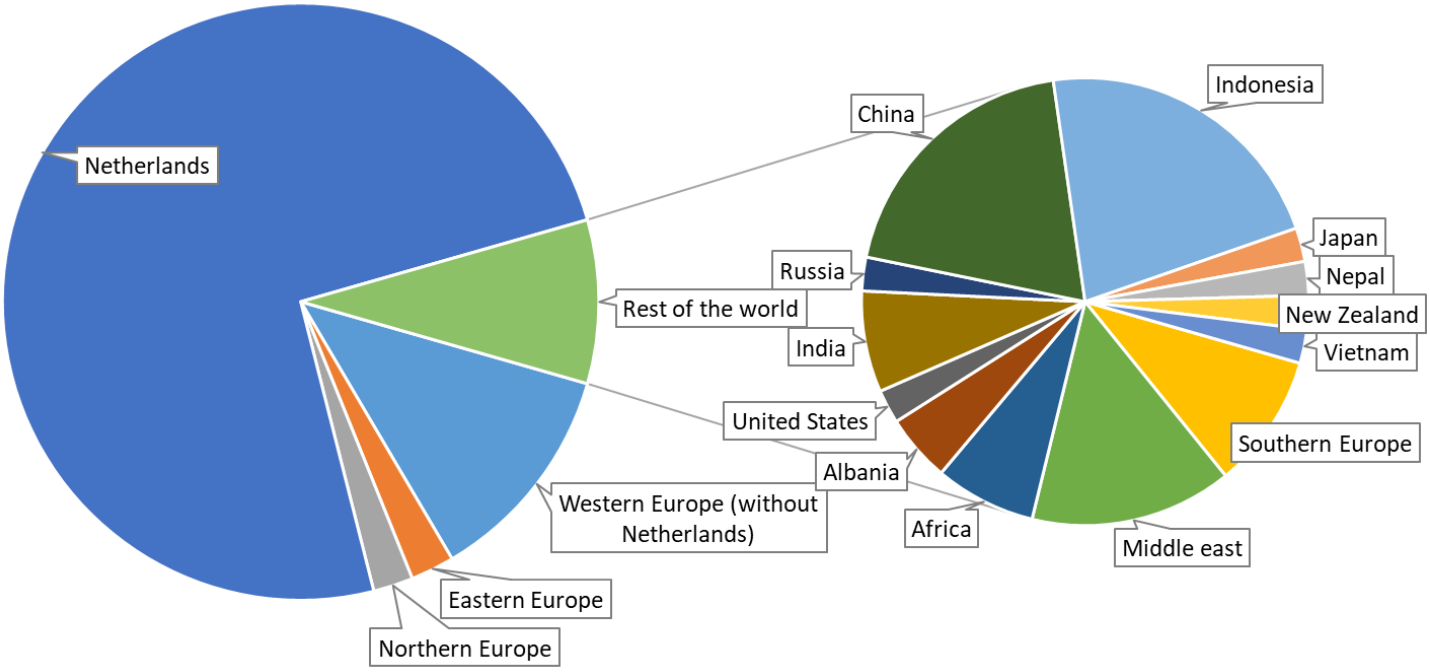
which role do they take on and in which setting do they perform their project assignment? Making these decisions and therefore being self-directed is something we want our students to learn. At the start of the programme the tutoring is intense while later on this gradually decreases.

Students learn together

Collaboration is a very important 21st century skill that our students will certainly need after completing their studies. For that reason, students work together frequently in a module. This applies to both the project and the other module units. Together the students have to ensure that in the end they all have sufficient knowledge of all aspects of the project or the assignment on which they have collaborated. This means that they can also be individually tested on the material.

1.3 An international programme

Advanced Technology is an English taught programme which has resulted in students that not only come from the Netherlands but also from countries such as Germany, Britain, Indonesia, South Africa and China. The only language requirement is English. Not only all our courses, but also all rules and regulations are in English. At this moment, the origin of almost 35% of our students is non-traditional Dutch. This makes that you will study alongside and collaborate with students of various nationalities which will give you the perfect preparation for the international labour market. You will learn to look at problems in a totally different way and solve problems together in an international team.



Overview of the countries AT students come from (based on enrolments 2012-2017).

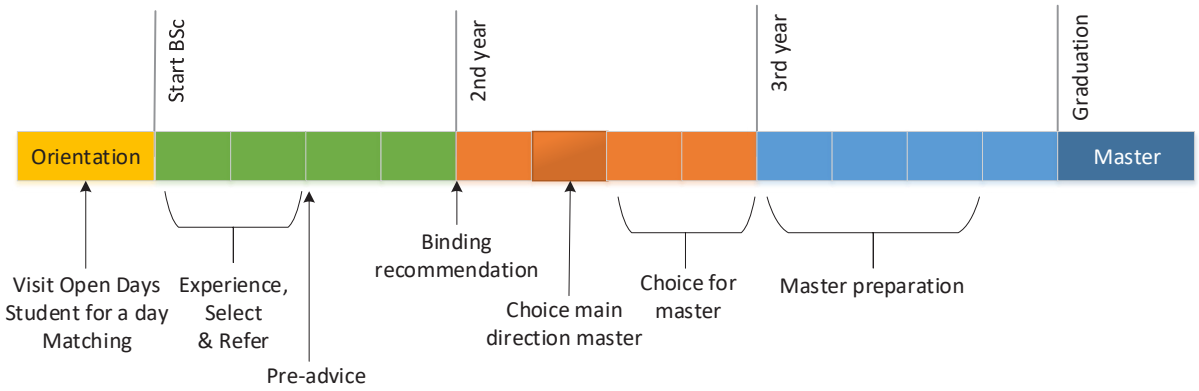
1.4 Student counselling

When you start university, you are expected to act responsibly and take care of your own business. However, especially when you have just started a bachelor's programme not everything speaks for itself. It can take a while for you to feel at home, and find your way around the university and its rules and regulations. Even later on during your studies you might feel that there are issues you would like to discuss, such as choosing your master, taking extra subjects etc. This is what the study advisor is here for.

Everything you discuss with the study advisor is confidential. Only if deemed necessary, and with your explicit permission, can the study advisor talk to other people about you. The study advisor is bound to the code of conduct of the LVSA (Dutch national association of study advisors).
Studying Advanced Technology at the University of Twente has a personal feel and an informal vibe. Our approachable teaching staff are always ready to answer your questions and your tutor or study advisor is always on hand to help you with any problems you might encounter.

1.5 Quick layout of the programme

The Advanced Technology programme is a three-year bachelor's programme. In the figure below a condensed view of activities by the programme is displayed, such as the binding recommendation after the first year and the various moments at which students shape their programme with their choices. The first year focuses on the first experience with the programme and the chance of success to succeed the programme. At the end of the first year, students already need to think about the direction they want to go. The second module of the second year is a module of choice, which is one out of the three main directions students go to: materials, transport and mechatronics.
The students' experience with their first choice will give them insight into the possible master's they would like to take. At the end of the second year, students need to know with which master's programme they would like to continue. The third year is characterized by the actual preparation for the master's programme of the students' choice.



Quick layout of the programme.

Matching

At the University of Twente we believe it is important for you to choose a programme that suits you, so that you will be able and motivated to complete your studies successfully. For this reason, we organize orientation and matching activities before you start. These allow you to really familiarize yourself with the programme of your choice, so that you will know for certain that it is a good fit for you.

Once you have signed up for the Advanced Technology programme, you will receive an e-mail with the link to a questionnaire that you need to fill in. After that you will receive a report and, based on your answers to the questions, our study advisor may ask you to come in for an interview. Another factor that we consider before making this decision is whether or not you have participated in our orientation activities, like the Bachelor's Open Days or our Student for a Day programme. If you have been invited for an interview, we will be in touch with you to arrange the details. The interview can also take place via the Internet or by phone.

Experience, Selection and Refer

One of the guiding pillars of the Twente Education Model is to help students realize as quickly as possible whether they have made the right choice. For that reason, the first two modules reflect the nature and content of the bachelor's programme and also focus on learning to learn. In addition, the students are

also given advice and guidance by the study advisor. In this manner students will be confronted with their motivation, attitude and capability. With this experience our students themselves, aided by the study advisor, will determine whether the programme actually fits them. For most students, this positive encounter will make them even more enthusiastic. However, some will experience a wrong choice and the study advisor will help to get them without delay to a more suitable place.

Binding Study Recommendation

At the end of the first year, students who have obtained less than 45 EC, will receive a negative binding recommendation and are not allowed to renew their enrolment for the programme. In general, this means that our students are required to successfully complete at least three of the four modules in the first year. This is the final selection by the programme and with two prior advices after module 1 and 2 a negative binding recommendation never comes as a surprise.

In case of personal circumstances known to the programme the ruling of Binding Study Recommendation can be adjusted to the actual capacity of the student. This means that if a student due to justifiable circumstances is not able to study during a quartile, this quartile will not be taken into account. The guideline is that a student should be able to complete at least 75% of the tasks he/she is capable to do. Personal circumstances can vary from sickness, family circumstance to being active as an athlete on a high level. All of these circumstances have to be known in advance to the programme. This allows to make a match of the programme to the abilities of the individual student as far as possible. It also serves to determine in advance what is required for passing the Binding Study recommendation.

Master choice and preparation

Advanced Technology students are not restricted in joining one direction of master's programme. An Advanced Technology diploma opens the world to a wide range of master's programmes. Students will think about possible master's programmes by already making a choice in the second year. They can make a choice in the materials, transport or mechatronics direction. The choice in the second year is the first encounter with a possible master direction. The experience with their first choice lets students become aware of their interests. This helps them in making the decision for a master's programme at the end of the second year and to prepare for the third year. In the third year, the students will take modules that meet the admission requirements of the chosen master's programme and actually become prepared to join the master's programme after graduation.

2 BEFORE JOINING THE PROGRAMME

2.1 Bachelor's open days

Twice a year (March and November), the University of Twente organizes Bachelor's Open Days. A visit to the Open Days will allow you to obtain information about the programmes offered by the University of Twente. You will receive information about the study programmes and can talk directly to the programme staff and students. More information about the Open Days can be found here: https://www.utwente.nl/en/opendays/bachelor/

2.2 Student for a day

A Student for a Day is an individual orientation day, during which you will be accompanied by a current student from the bachelor's programme you have selected for a whole day. You will experience what it is like to study at the University of Twente and in the chosen bachelor's programme. More information about the Student for a Day experience can be found here: https://www.utwente.nl/en/student-for-a-day/bachelor/

2.3 Admission requirements

The admission requirements for the Advanced Technology programme depend on the prior education you have succeeded.

International Diploma

Students from outside the Netherlands should have a pre-university secondary education comparable to the Dutch VWO diploma, with as equivalent Mathematics, Physics and Chemistry subjects. The Dutch VWO diploma includes English and therefore from prospective students an English equivalent is expected. As the programme is taught entirely in English, a high level of English proficiency (CEFR, B2/C1 level; minimum IELTS score of 6.0, or equivalent) is also required. For more information, please contact our Admissions Office.

Are you an international student and is your secondary education not comparable to the Dutch VWO diploma? However, you would like to take Advanced Technology? The University of Twente and the Holland International Study Center offer you the possibility to take a preparation year after which you will be admissible to Advanced Technology. If the deficiency in Physics or Chemistry is small an admission on individual basis can be considered.

Dutch VWO diploma

You will be directly admitted to the Bachelor's programme in Advanced Technology if you possess a Dutch VWO diploma with a profile in Natuur & Techniek. You may also be eligible to start the programme with a profile in Natuur & Gezondheid, but only with the subjects Wiskunde B and Natuurkunde. Furthermore, you may be eligible to start the programme with another profile, but only with the subjects Wiskunde B, Scheikunde and Natuurkunde.

German Abitur

If you possess a German Abitur, you can gain admission to the programme if you have studied English, Mathematics and Physics to Abitur level. Please note it is not necessary to have taken these subjects as Leistungskurs. If the deficiency in Physics or Chemistry is small an admission on individual basis can be considered.

2.4 Apply for the AT programme

If you want to join the Advanced Technology programme you should enrol into the programme. The University of Twente applies different deadlines for application, depending on the programme, admission diploma, or type of student.

When should I enrol?

International students and Dutch students with an international degree

Information about the application deadlines can be found here:
https://www.utwente.nl/en/education/bachelor/application-enrolment/deadlines/

Dutch students with a Dutch pre-university degree

If you are a Dutch national with a Dutch pre-university degree and wish to start your studies on 1 September 2019, you can apply for a bachelor's programme via Studielink until 1 May 2019 if you want to participate in a matching activity. After this date, applying for the academic year 2019-2020 at the University of Twente is still possible for most of our programmes.

How should I enrol?

Students should use the Studielink to arrange their application for enrolment or re-enrolment at an institution of higher education in the Netherlands and to register with the DUO. It offers a single point of access for students to apply. If you want to study at the University of Twente, you have to use Studielink: https://app.studielink.nl/front-office/
After enrolment and admission, you will be invited for the matching procedure.

3 STUDY PROGRAMME

3.1 Programme learning outcomes

The programme is designed to achieve the programme learning outcomes. A graduate of the Advanced Technology Bachelor's programme has met the learning outcomes listed below, which are in accordance with the Meijers criteria, the common set of learning outcomes of engineering programmes at the 3 technical universities in the Netherlands.

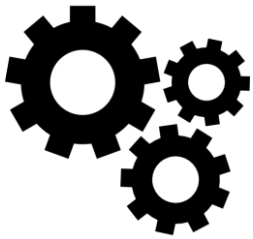
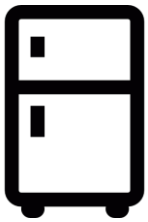
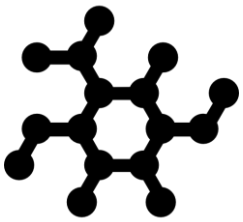
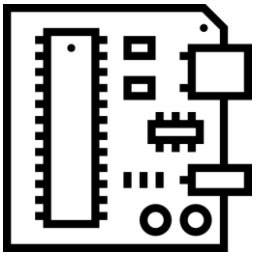
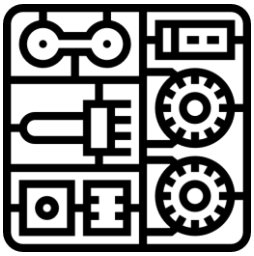
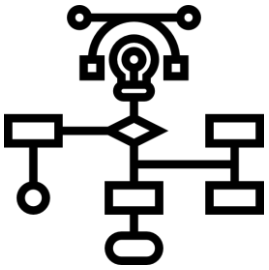
1. Domain knowledge & skills
   Can apply basic theoretical concepts, important methods and techniques in the fields listed below and has skills to increase and develop this through study:
   a. Elements from mechanical engineering, electrical engineering, physics, chemistry (Newtonian dynamics, Thermodynamics, Material Science, Mechatronic systems, electromagnetism, System Engineering)
   b. Mathematics and programming
   c. Innovation, business administration and development/trends of technology on a local and a global level)
   d. Analysis of impact of technology on a local and a global level
   e. Experimentation in the technical sciences.

   A detailed list of this domain knowledge is presented in table 1.
2. Research & Design
   a. is able to apply the most important scientific research method
   b. is able to apply the most important scientific design methods and is able to divide a design problem in different sub problems.
3. Organize
   Is able to organize work both independently and as a member of an international project group. In project work able to define separate problems for team members, to assure the interconnection between these entities and to implement a timeline.
4. Report & Presentation
   Is capable of communicating on technical-scientific issues both in writing and orally in a clear, concise and professional manner.
5. Problem solving
   Is capable of analysing, modelling, interpreting and solving technical-scientific problems with an academic approach, i.e., formulating a problem definition, selecting scientific information and processing it, conducting research and critically evaluating the subsequent results, and of formulating conclusions.
6. Personal Development
   Is able to recognize personal strengths and weaknesses as well as personal interests that are necessary to opt for either a follow-on study, in particular an academic master's programme which requires a high level of autonomy or a job in the labour market.

Table 1: Domain knowledge and skills

MECHANICS	THERMODYNAMICS
▪ Newton's law ▪ Static equilibrium ▪ Equations of motion ▪ Mechanical rotation, torque and momentum ▪ Conservation of linear momentum, angular momentum and energy, ▪ Elasticity	▪ Phase diagrams, ideal and non-ideal gas models ▪ First and second law of Thermodynamics ▪ Heat capacity and heat conductivity ▪ Cyclic thermodynamic processes ▪ Maxwell relations and interpretation of Energy, Enthalpy, Helmholtz and Gibbs free energy
ELECTROMAGNETISM	**MATERIALS**
▪ Electrostatics (electric field, Coulomb's Law, superposition of fields from charges and charge distributions, Gauss's Law, electrostatic potential, dipole, equations of Laplace and Poisson, dielectrics, electrostatic analogues) ▪ Magnetostatics, (magnetic field, Ampere's Law, Law of Biot and Savart, vector potential, current and current density, magnetic dipole, energy density) ▪ Electrodynamics (induction, plane waves in free space, radiation, interference, polarization, resonance in cavities, waveguides, transmission lines, phase and group velocity, pointing vector, reflection and diffraction)	▪ Historic perspective of quantum mechanics ▪ Use Schrödinger's equation to solve elementary problems like particle in a box and the hydrogen atom. ▪ Structure on molecular, microscopic and macroscopic level of material classes ▪ Understand the relation between properties and the underlying structure ▪ Identification of basic chemical structures and functional groups and their reactivity ▪ Diffusion processes in solids ▪ Binary phase diagrams, phase transition and relation to microstructure ▪ Qualitative understanding of electrical and magnetic properties ▪ Relation between properties, structure/composition and synthesis ▪ Basics of various techniques used for material (film deposition) synthesis
MODELLING	**MATHEMATICS**
▪ Use conservation laws and continuity to model mechanical, electrical and thermodynamic (mixed) systems in a set of differential equations with a lumped system approach. ▪ Mathematical description of a distributed system. ▪ Analysis of mathematical models and derivation of analytical or simulated solutions ▪ Design of a control loop for a system and choice of elementary feedback controllers ▪ Define a system that is viable from various perspectives (user, developer, producer, etc.) ▪ Translate stakeholder requirements into a consistent set of "System Performance Specs" ▪ Make a system design (breakdown the system into modules; make budgets, linking system performance to module performance design of at least one sub-system; make an integration & test plan; make a risk assessment)	▪ Formal logic and proving techniques such as induction principle ▪ Solving linear differential equations ▪ Continuity and differentiability ▪ Functions of multiple variables ▪ Integration of functions with standard methods ▪ Power series, Taylor expansion and linearization ▪ Vectors, matrices and linear transformations ▪ Eigenvalues and eigenvectors of matrices ▪ Multivariate calculus ▪ Fourier, Laplace and z-transform and their applications ▪ Analysis of stochastic signals with momentum analysis and correlation techniques ▪ Theorems of Gauss and Stokes ▪ Gradient, divergence and rotation of a vector field
PROGRAMMING AND SOFTWARE SKILLS	**INNOVATION, BUSINESS ADMINISTRATION AND DEVELOPMENT/TRENDS OF TECHNOLOGY**
▪ Creating and validating a computer program in Matlab ▪ Use Matlab tools like Simulink and digital filter design tools. ▪ Creating a technical drawing in Solidworks ▪ Use COMSOL to set-up and validate a Finite Element problem	▪ Business models and their constituting elements. ▪ Business development in relation to external environment ▪ Innovation as a processes of knowledge production ▪ Trend analysis, Delphi method, forecasting, backcasting; road mapping
ANALYSING TECHNOLOGY IN SOCIETAL CONTEXT	**EXPERIMENTATION**
▪ Understanding of technology as a social phenomenon. ▪ Social contexts in which technologies emerge and the social consequences of new technologies.	▪ Learning basic skills for setting up and conducting experimental work, including safety, and error handling. ▪ Familiar with design, realization and analysis of electrical circuits and signal analysis.

3.2 Programme overview

	QUARTILE 1	QUARTILE 2	QUARTILE 3	QUARTILE 4
FIRST YEAR	MECHANICS 	THERMODYNAMICS 	FUNDAMENTALS OF MATERIALS 	DYNAMICS 
SECOND YEAR	SIGNALS, MODELS AND SYSTEMS 	CHOICE 	FIELDS AND WAVES 	BUSINESS & SOCIETY 
THIRD YEAR	MASTER PREPARATION 			BACHELOR ASSIGNMENT 

Icons obtained from www.flaticon.com

3.3 The first year

MODULE 1	First year	15.0 EC
Mechanics	First quartile	Dr. H.K. Hemmes

The Mechanics module provides a first encounter with the world of engineering. Students learn to capture salient details of classical mechanics/dynamic systems in simple models.
The content of the module is based on mechanics (movement, Newton's laws, statics) and first and second order systems.

Calculus 1

The calculus 1 part includes: functions, differentiation, 1st and 2nd order differential equations, complex numbers, logic, proof, and vectors. Differential equations are the core of mathematics that is used in the rest of this module (mechanics, dynamical systems).

Mechanics

The engineering portion of the module encompasses classical dynamics and statics. The concept of Free Body Diagrams will be introduced in order to analyse both static and dynamical systems. Dynamics is treated starting from velocity and acceleration, moving towards Newton's laws in both the translational and rotational domains. Mechanical second order systems (mass, spring, damper) are included.

Laboratory Practice

In the experiments issues are introduced such as formulating a hypothesis, translate a problem into measurable quantities, carefully planning an experiment, etc. In conducting the experiments, a selection of technical methods and experimental skills are learned. In many of the experiments the computer is used for data acquisition, processing and/or analysis. By structured documentation of the work in a lab journal, a systematic approach towards experimental research is developed. Other topics encountered are error analysis and programming skills using Matlab software.

Project

This module contains a project with a study load of about 3 EC. The project is not supposed to be an illustration of the subjects of the other parts, but rather an integration and a means to learn the various subjects (i.e. project lead learning (PLL)). Rather than being separate parts, the intent is to have coherence between the various subjects. To this end the project integrates mathematics and mechanics and forms the playground for achieving a deeper understanding of the subjects as well as developing the academic skills.
In the project students will choose a research question related to a relevant dynamical system from a list of in total 15 descriptions. They all are related to the Mechanics and Calculus 1 parts of the module, but go much deeper. The project starts with a problem analysis, contains a (mathematical) modelling step and the final answer obtained by solving this mathematical model must also be validated by an experiment.

Workshops

There are 8 workshops on skills, all designated to support the main subjects of the module. At the same time these skills are also relevant for the rest of the curriculum.

- 'Math refreshers'. Reviews all Dutch secondary school topics (algebra, differentiation, integration). Support for Calculus 1 and Mechanics.
- 'Mathematica'. Introduction to Mathematica for solving mathematical problems. Support for Calculus 1 and Mechanics.
- 'Information and Literature Skills'. On finding, assessing, using and referencing scientific information sources. Support for Laboratory Practice and Project.
- 'Effective meetings'. Support for Project.

- 'LATEX'. Introduction to the text editor environment. Support for Project and Mechanics.
- 'Simulation'. Solving Differential Equations with Mathematica. Support for Project.
- 'Academic writing'. Support for Laboratory Practice and Project.
- 'Presentation skills'. Support for Project.

MODULE 2	First year	15.0 EC
Thermodynamics	Second quartile	Prof.dr.ir. H.J.M. ter Brake

Thermodynamics

In daily live we are familiar with systems that contain many, many particles. To boil a small kettle of water you will need to heat up some 10^25 water molecules. In order to describe the behaviour of such a multi-particle system, it is impossible to consider that of each individual particle (microscopic approach). Therefore, the system is considered macroscopically: the system is considered as a whole, e.g., its thermal conductivity or its heat capacity. Usually, these properties do not depend on the microscopic details of the system. For instance, a gas will always expand when it is fills a larger volume, but the reverse process will never occur spontaneously. This kind of behaviour and the underlying principles are considered in thermodynamics. Linking this module component to the project case, thermodynamic cycles will be considered such as engines and heat pumps. Here, the first and second laws of thermodynamics are of crucial importance (respectively dealing with conservation of energy and increasing entropy).

Calculus 2

The Calculus 2 course is divided into four parts:

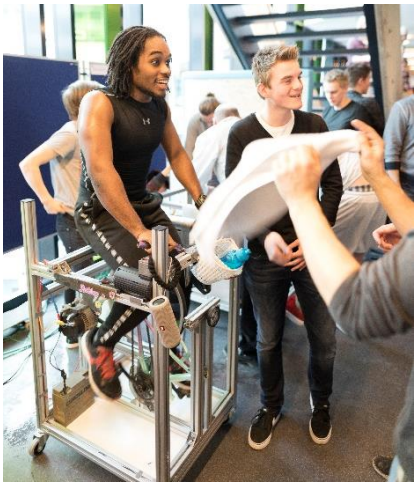
1. Integration theory. The integral of a function is presented and several integration techniques are illustrated.
2. Power series and Taylor series. A short introduction into power series is given, with the Taylor series as its main application.
3. Functions of several variables, vector valued functions. This allows to describe variables depending on 3D position in space and time.
4. Partial Differentiation. Functions that depend on several variables will have a derivative depending on which variable is chosen to vary.

Laboratory practice

In the practical experiments issues are introduced such as formulating hypotheses, translate a problem into measurable variables, carefully planning an experiment, etc., In conducting the experiments, a number of technical methods and experimental skills are taught. In many of the experiments the computer is used for data processing and analysis. By documenting the work in a structured log book, a systematic research approach is developed. Further topics are error analysis, statistical analysis of data, basic programming skills and processing experimental results using Matlab software.

Project

The project aims at applying the material taught in Thermodynamics in a practical case. The students get an assignment like the design and realization of a human powered fridge. This has to be completed in groups of typically 8 students in the short period of only 10 weeks of the module. Apart from thermodynamics also systematic design plays a crucial role in this assignment. At the start of the module two lectures are given on systematic design. It should be applied in the project and is assessed as part of the project. In the last two weeks of the module, the project is closed by a report, a presentation fair, and an oral elucidation on the report.




Students demonstrating their human powered cooling device.

MODULE 3	First year	15.0 EC
Fundamentals of Materials	Third quartile	Prof.dr.ir. G. Koster

In this module matter and materials are the central themes: from fundamental quantum matter that which properties are ruled by the laws of quantum mechanics, to atoms, bonds between atoms, to larger microscopic and macroscopic structures with mechanical and electrical properties that are used everywhere in our society.

In Quantum Matter an introduction to quantum mechanics and elementary particles and systems is given. This is followed by Structure and Properties of Materials, in which the structure of materials is described and discussed, from individual atoms, to unit cells, to microstructures on larger mesoscopic and macroscopic length scales. The main mechanical and electrical properties that emerge from this microstructure is also discussed. Because of the importance of polymers and organic materials for many advanced technologies, their properties and synthesis are discussed in a separate block of lectures entitled Organic Chemistry for Molecular Materials. In the Project Materials for Energy all gained knowledge from the theoretical lecture series is applied in a literature survey on a materials-related topic in the field of energy harvesting, production, storage, or a closely related area. Analysing Technology in Societal Context aims to increase understanding of technology as social phenomenon. The course will examine critically the social contexts in which technologies emerge and the social consequences of new technologies. Mathematics C1 completes the module.

Materials

Quantum Matter

The basic elements of quantum mechanics will be introduced using a series of examples from modern physics. The following topics will be addressed: duality of particles, diffraction, photo-electric effect, uncertainty relation of Heisenberg, Schrödinger equation, quantum mechanical particle in a box, atoms and molecules, free electron model, band theory of solids, semiconductors and superconductors.

Structure and properties of materials

The 3 main classes of materials are discussed in this part of the module: metals, polymers, and inorganic materials such as ceramics and glass. The structure of these classes of materials are described on various length scales, going from atoms and atomic bonds, via microscopic, to macroscopic objects. The mechanical and electrical properties of materials are described and explained from the underlying structure on different length scales. This block ends with a discussion of metals and semiconductors.

Organic Chemistry for Molecular Materials

In this part of the module we will try to understand and rationalize the properties and the reactivity of organic materials and molecules, i.e. compounds that contain carbon atoms. Although organic

chemistry is literally defined as the study of compounds that contain carbon atoms, its true essence is actually the study of electrons. Throughout this course, we will study the behavioural pattern of electrons, enabling us to predict, and even control, the outcome of chemical reactions. The structure and synthesis of some polymers will be discussed also.

Project Materials for Energy

The students carry out a literature survey on a given material science topic in the area of energy applications. They receive instruction on literature analysis using databases and search strategy, and get feedback by an information specialist in their search strategy. The essay is written in small groups of students, and each group has a contact person (staff member) who is familiar with the subject. The final essay is assessed based on contents and search strategy used. Secondly, all groups make a poster on which the topic of the essay is presented. The posters are presented at a poster session.

Vector Calculus

Vectors are used to describe phenomena in more than one dimension, not only the value but also the direction of a force or a flow is important. Vector calculus shows how to work mathematically in a world with more than one dimension. This includes integration in 2 and 3 dimensions, vector fields, integration along a curve, surface integrals, the definition of gradient, divergence and curl and the theorems of Gauss and Stokes and its use in describing flow systems and electromagnetism.

Analysing Technology in Society

In this course, students will learn various concepts to analyse techno-social innovations. Examples of current debates and controversies on technologies will show how the use of specific theoretical approaches and models enables them to recognize and develop possibilities for management of innovation processes.

The course aims to increase understanding of technology as social phenomenon. The course will examine critically the social contexts in which technologies emerge and the social consequences of new technologies. Students will gain knowledge of concepts and approaches introduced to analyse technologies in social contexts, including technological regimes and transitions, risks and responsibility issues, and technology assessment.

MODULE 4	First year	15.0 EC
Dynamics	Fourth quartile	Dr.ir. H. Wormeester

In Module 4 “Dynamics” you will design, build, test, and analyse a working accelerometer! This could be a pedometer, a seismometer, an inclinometer, etc. - the scope is up to you and your project team - and the rest of the module is designed to help you accomplish this central goal.

Dynamical Systems

In the `Dynamical Systems' part, the students will learn how to model dynamic systems with an emphasis on mechanical and electrical systems as a set of coupled differential equations. This modelling requires the identification of energy storing and dissipating elements and the application of conservation and continuity rules. The analysis of the resulting mathematical equations tells how the system will behave and how fast it will show a response. This method of analysis couples the behaviour in the time and the frequency domain and students will have to learn to think in both time and frequency response. The toolbox for this is the analysis of ordinary linear differential equations (which was already treated in the first module) and the Laplace transform to make the translation from time domain to frequency domain. Special attention is given to the identification of (the value of) system components by observing the stationary behaviour (in which nothing changes, so all time derivatives are zero) and the dynamic response. The generalization will show that all linear systems can be classified as a sequence of first and second order systems, with the latter one being able to show oscillating behaviour. The mathematical description of a system as a set of coupled first order differential equations allows to use the power of linear algebra to write the model in a matrix notation, the State model. This link with the linear algebra

part of the module allows to expand the system modelling to a more generic approach which enables to solve Multi Input Multi Output (MIMO) systems.

Project Accelerometer

In the project `Accelerometer', an acceleration sensor is used to study a mass-spring-damper system. The students design and realize their own accelerometer system. The knowledge from Dynamical Systems is needed for mathematical modeling and analysis of the system. Moreover the analysis allows to tune system parameter to achieve a desired response of the accelerometer, i.e. the frequency range it should cover and the shape of time response. Besides analytical calculations, numerical simulations will help to validate the design. The actual performance will be measured to compare with the desired response. The knowledge from Instrumentation is used to realize the electronic readout of the accelerometer system.

Instrumentation

The main objective of the `Instrumentation' course is to familiarise the students in a hands-on fashion with the basics of analogue electronics and signal processing. You will gain hands-on experience of building and optimising electrical circuits and instruments in the instrumentation laboratory. This is accompanied by an introduction to the analysis of electrical networks, the properties of the basic electrical components such as diodes and transistors and the design of electrical circuits. Starting off with very basic circuitry, providing a rather poor system performance, the students will gradually improve and extend their circuits and at the end they will be able to realise and understand a fully-fledged detection circuit for the accelerometer project.

Linear Algebra

The ‘Linear Algebra’ part introduces the description of linear systems by using a matrix. The basic operations of vectors and matrices, such as addition, multiplication, inverse and transpose will be treated. Linear systems are examined where the number of equations equals the number of unknowns. Here the concepts of invertibility and diagonalizability of a square matrix play an important role. Much emphasis is laid on the relations among the various concepts. The application of matrices to evaluate the evolution of dynamical systems (eigenvectors and eigenvalues) and to describe linear transformations is given.

The instrumentation laboratory.

3.4 The second year

When you received a positive binding recommendation advice, you are allowed to enter the second year. Just like the first year, the second year consists out of 4 modules. Different from the first year is the choice you have in the second quartile.

MODULE 5	Second year	15.0 EC
Signals, Models & Systems	First quartile	Dr.ir. H. Wormeester

Signals

The understanding and ability to manipulate signals requires the study of their frequency content as obtained from Fourier Analysis. Continuous Fourier Transform and its properties is introduced including convolution and modulation. With Discrete Fourier Transform digital signals can be analyzed. Digital Filtering and the z-transform are introduced as an introduction to Digital Signal Processing with emphasis on digital filtering. The application of the theory is done with an AM modulation experiment and the digital clean up of a measured ECG signal.

Models

The modelling of simple thermal systems and a generalization of the modelling of physical systems is introduced as well as the linearization of non-linear systems. After this introduction the three main topics of the modelling part are dealt with: a) Mixed systems combining components from different physical domains, b) Stability and Control of systems and c) Distributed systems. These topics are accompanied with 4 practicals: 1) Characterization of an electro-motor, 2) The design of a feedback for a motor-generator pair, 3) The non-uniform heating of a rod and 4) The heat transfer in a flow experiment.

Project SMS

In the project students have to demonstrate the ability to model a system of their choice and use signal analysis to characterize the performance or to control this system. The report includes a video of the project.

Elective

Engineering Solid Mechanics

The first part of this course covers how the stiffness and strength of a structure consisting of different members such as bars, beams and shafts can be determined. Stiffness describes the relationship between loads and deflections of a structure and strength refers to stresses and strains occurring in the material.

In the second part of the course the linear elastic theory (Hook's Law) is discussed and extended towards more complex 3D situations (principle stresses, etc.). Finally, theories of failure will be discussed.

Programming in Engineering

Computations are omnipresent in complex engineering problems in solid mechanics, fluid mechanics, civil and process engineering. Many problems are resolved with the aid of computers and dedicated programs today. Therefore, it is really important for an engineer to be familiar with computers and programming languages. In this course, you will learn how to translate problems into algorithms and how to implement the algorithm into a computer language. We will focus on implementation in two widely used programming languages: MATLAB and C++. You will learn how to write, compile, and execute small programs in each language. We teach you how to write structured reusable code (object-oriented programming in C++) and how to visualize your solutions (in MATLAB). Further, we teach how to better understand, analyze, optimise, and debug code. The course consists of lectures as well as lots of practical exercises. The course is divided into two sections, C++ and MATLAB. At the end of each section, you will be asked to solve a final assignment (at home), and attend an oral exam. The course is

complemented with an extension on the implementation on solving ODE's and the communication with an electronics platform as an Arduino and Raspberry Pi.

Classical Mechanics

We will study motion and the cause of motion not only from Newton's perspective (using the concept of Force) but we will also consider the approach of Lagrange and Hamilton. Using this newly gained knowledge, we will study the behaviour of particles in a central force field, harmonic and anharmonic oscillations, coupled oscillations and normal mode analysis, as well as the motion of a symmetric top.
We derive and use Euler, Lagrange, and Hamilton formalisms. We investigate conservation and central forces (including planetary motion) and the study systems of particles and collisions. Next, we investigate rotations and inertia before moving to coupled oscillations and forced and damped motions.

MODULE 6A (CHOICE)	Second year	15.0 EC
Materials Science and Engineering	Second quartile	Dr.ir. M. Huijben

In any device whether this is an electronic transistor, solid-state battery or a gas sensor, several properties of different materials are combined to achieve a desired functionality. The objective of the module Materials Science and Engineering is to get the student acquainted with the relation between basic properties of materials and their functional application. This includes obtaining knowledge of the direct connection between material properties, structure/composition and material synthesis. At the end of the course, the student should be able to describe the functional properties of materials used in a specific device and be able to connect these to basic material properties in relation to the ability to synthesize these materials.
The module consists of a general part in which first the relation between the functional properties of materials and the microstructure is discussed; subsequently the relation between the microstructure and specific synthesis techniques is studied. The second part is an elective part of either a chemistry track course that focuses on the effects of interfaces in materials with emphasis on catalytic reactions, or a physics track course that focuses on charge transport in semiconductor devices.

Advanced Materials

The course Advanced Materials deals with the relationships between material properties and microstructure/composition. The course provides knowledge and insight into the functional properties of various material classes; and it provides understanding of the relations between microstructure and properties of materials. Topics to be discussed are magnetic materials, dielectric and optical materials, mechanical properties, electrical properties, and thermal properties.
The course consists of lectures on the structure and functional properties of several material classes (polymer, ceramic and metal). In the lectures theory as well as practical cases are discussed.

Furthermore, groups of 3 students will study a specific, technologically relevant material system, which will be presented to the other students.

Fundamentals of Solids

This lecture series addresses a number of fundamental topics that are at the basis of modern materials science. Both thermodynamics and kinetic aspects of solids and solids formation are discussed. The fundamentals of thin film growth kinetics, the theory of nucleation and growth, phase diagrams, and the thermodynamics of phase transformations will be treated. Solid state aspects of diffusion of atoms and ions in crystalline materials will also be addressed in detail.

Chemistry and Technology of Materials

The course Chemistry and technology of materials deals with the relation between material synthesis and structure/composition. It will focus on the effect of specific synthesis techniques on the achieved microstructure, which determines the material properties, and therefore, can determines specific functionalities in materials.

The course consists of lectures on the relation between microstructure and applied synthesis techniques (thin film, thick film, bulk) of inorganic materials. Various physical vapour deposition techniques as well as chemical vapour techniques for films will be discussed as well as sol gel and sintering techniques for obtaining bulk materials. The effect of strain in materials, caused by epitaxial growth, will also be studied. Furthermore, groups of 3 students will study a specific, technologically relevant material system, which will be presented to the other students.

Elective

Semiconductor Devices

Microelectronics strongly affects our daily life. The amount of integrated microelectronic circuits (ICs) rises drastically in many applications such as automotive, telecommunication, health care, portable computing and internet (ICT). In addition there is a continuous trend in increasing the complexity of the basic electronics building block, the microchip, realized in advanced CMOS (complementary metal-oxide semiconductor) technology, partly driven by the desire for increasing functionality. The microchip is formed by several key components, basically semiconductor devices. This course describes the physical working of these basic semiconductor devices and translates those to electrical characteristics.

It covers an introduction to the classical electron devices: the pn-junction and the Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). The physical working is illustrated using diagrams of energy, electric field, electrical potential and concentration, and the principal formulae for the simplified devices are treated. After the lectures and tutorials the students should understand the limits of the electrical performance of classical devices and should perform a literature survey on how to tackle these. Finally, they should write a 5-10 pages report about their findings.

Physical Chemistry of Interfaces

Physical Chemistry of Interfaces is a broad introduction in interfacial science, with a special emphasis on catalysis. Interfaces are everywhere in our daily life and interface effects are in many cases crucial (for instance in the functioning of the lungs). Interfaces become increasingly important when we reduce the dimensions. The behaviour of nanoparticles is for instance, mostly determined by their interfaces. We'll explain the relationship between catalysis and nanotechnology in this course.

We'll start the course with an introduction in (chemical) kinetics: the mathematical description of (the speed) of (chemical) reactions. We also explain some chemical reaction mechanisms. Subsequently we study the physical and chemical properties of different interfaces (solid-gas, solid-liquid, gas-liquid), with special attention for topics like the wetting properties of surfaces (contact angle), stability of colloidal systems (like emulsions and foams). This knowledge is then applied on catalytic reactions, where we study adsorption and desorption of reactants and products, catalytic mechanisms, transport of the reactants/products and the identification of the catalytic mechanisms/materials in detail.

MODULE 6B (CHOICE)	Second year	15.0 EC
Systems and Control	Second quartile	Prof.dr.ir. G.J.M. Krijnen

The module focuses on the analysis, modelling, simulation, and control of dynamic systems and consists for AT students of four parts.

Electronics

In the Electronics part amplifiers, diodes and transistors are introduced both from their fundamentals as well as their application in an active electrical network. This requires a revisit of the method to analyse such networks. The application of electrical networks at higher frequencies (above the kHz range) introduces parasitic characteristics of the elements. They can no longer be treated as just a restor or just a capacitor. The knowledge gained has to be applied to build and test transmission electronics that can operate around 100 MHz.

Engineering System Dynamics

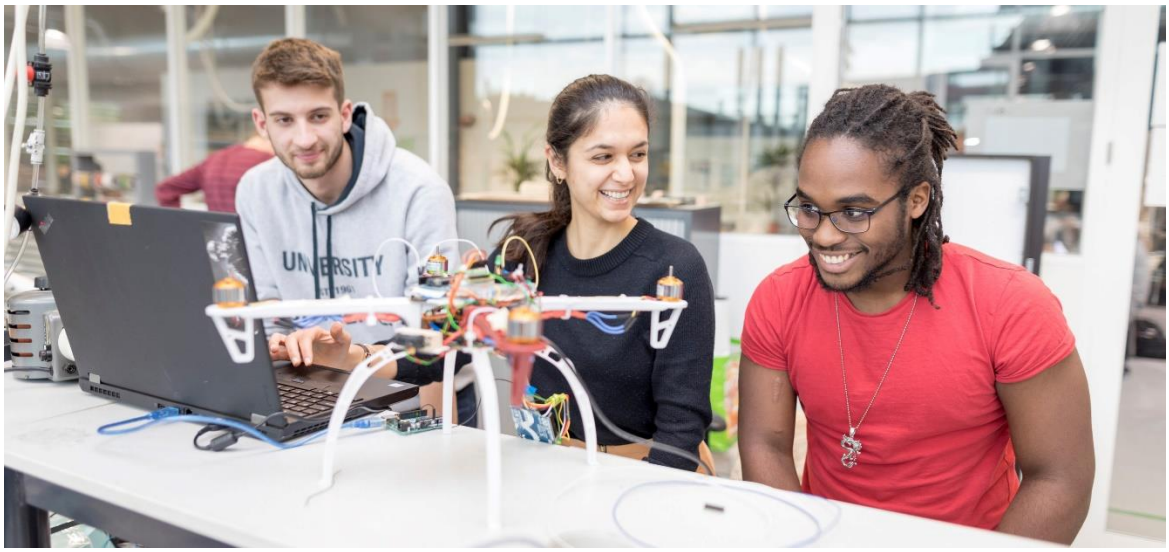
In Engineering System Dynamics the port based modelling and bond graph representation of dynamic systems is introduced to model systems in various physical domains. This approach allows an easy transition of the model to the 20sim simulation package to calculate the response of a system. The knowledge of the behaviour of a system is required to create a successful control strategy of the system.

Control Engineering

In the Control Engineering part various control strategies of systems are treated such as feed-forward, PID controller, lead and lag networks. The essential ingredients for these are the root-locus method, Bode plots and Nyquist diagrams. The performance of successful control strategy is measured from the obtained stability, the response time and the sensitivity for environmental disturbances.

Project

In the project the knowledge of Engineering System Dynamics and Control Engineering has to be applied to design and build a controlled system. Examples of these are a hovercraft and a Segway.



MODULE 6C (CHOICE)	Second year	15.0 EC
Transport Phenomena	Second quartile	Dr.ir. D.W.F. Brilman

For 'Transport Phenomena' as a whole, the course is a first introduction in the field and serves as basis for subsequent courses in the areas of fluid dynamics, transport phenomena, process technology and separation technologies. The course uses a systematic approach to describe quantitatively the transport phenomena occurring the physical and chemical technology and engineering practice.

Fluid Dynamics

In the course 'Fluid Dynamics' is the starting point in these approaches the use of the Laws of Conservations for mass and momentum. These dictate that these quantities can only change, for a given control volume, by means of inflow and outflow or (in case of momentum) by an external force exerted. These 'conservation law'-principles can be applied to macroscopic volumes ("macro balances") but also to infinite small volumes ("micro balances"). This results in the Navier-Stokes equation, which is the fundamental basic differential equation for describing Fluid Dynamics. The latter equation is also at the basis of nearly all fluid dynamic problem descriptions, as encountered in e.g. meteorology, aerodynamics, aeronautics, process technology and bio-rheology. In the course relatively simple, but frequent encountered examples will be discussed, like tube flow and flow past a sphere.

Heat and Mass Transfer

For 'Heat and Mass Transfer' subsequently the different transport mechanisms for heat and mass (molecules) will be introduced and discussed: molecular transport, convective transport and radiation (heat only). For molecular transport (in case of heat and mass this is conduction respectively diffusion) both stationary as well as instationary (transient) transport will be treated, mostly based on analytical solutions (among which the penetration-theory) for Fourier's Law. For convective transport, both forced and free ('natural') convection will be discussed, based on correlations for the transport coefficients. Convective transport will be discussed for flow through tubes and past objects (sphere, plate, cylinder). For laminar flow analytical solutions and approximations will be used (laminar tube flow, boundary layer theory). Tools and methods introduced in the Numerical Methods sections will be applied and used for comparison. For turbulent flow the approach using experiment-based correlations prevails.

Heat transfer by radiation is confined to (chemical) engineering applications. Mass transfer from one phase to another will be introduced as analogy to heat transport. Hereby the film model will be introduced. Attention will be given to the specific differences between heat and mass transfer, like a difference in solubility (distribution coefficient) and a possible effect of drift flux. Additionally, the phenomenon of coupled heat and mass transport will be discussed.
Finally, conceptual descriptions for concurrent and counter current apparatuses for heat and mass transfer will be discussed.

Numerical Methods

Transport phenomena are ubiquitous in science and technology, with a wide range of applications in different fields. Transport processes are usually described by a set of mathematical (differential) equations, which often cannot be solved analytically. Consequently, a numerical approach is valuable and needed to understand the transport problems. This course will introduce the fundamentals of numerical computation, programming and solving of (differential) equations. A powerful software package, Matlab, will be used. The examples, problems and assignments used in this course will be closely related to the Transport Phenomena discussed elsewhere in the module.

MODULE 6D (CHOICE)	Second year	15.0 EC
Software Systems & Introduction to Mathematical Analysis	Second quartile	dr. L. Ferreira Pires

In this module the students are introduced to the design, implementation and testing of software systems, and to performing a project independently.

Design theory and project

For the design of software systems, they learn to use Software Engineering models, particularly the UML diagrams (class diagrams, activity diagrams and statecharts), and they get acquainted with the waterfall software development processes.

Programming theory and project

For the programming of software systems, they learn the core concepts of program structuring, object-orientation and multi-threading with the help of the Java programming language, with attention to correctness by means of (informal) preconditions and postconditions. In addition, the module addresses security engineering aspects in the context of Java. For testing software systems, the students learn to distinguish among the different levels at which testing can be performed (specially unit testing and system testing), the principles underlying a test plan and a couple of relatively simple testing techniques.

Skills

For academic and project skills, attention is given to project management, planning, time- and self-management, and reflection on one's own behavior with respect to planning.

Introduction to Mathematical Analysis

The course aims at providing a further step to real mathematical thinking. You will develop an arsenal of techniques to help you unlock the meaning of definitions, theorems and proofs, solve problems, and write mathematics effectively. All the major methods of proof - direct method, cases, induction, contradiction and contrapositive - are featured. Concrete examples are taken from the field of real analysis: concepts like completeness, limit, continuity, differentiability, integrability and (uniform) convergence of series and functions are treated. The objective is that you'll be able to catch the motivation behind the mathematics and be able to construct your own valid proofs.

MODULE 7	Second year	15.0 EC
Fields & Waves	Third quartile	Dr.ir. M.P. de Jong

Complex engineering problems – like describing a wing's airflow profile, or an electrical spool's magnetic field – require a mathematical description that employs vectors, a quantity that has both a magnitude and a direction in 3 dimensional space. In this module you will apply vector mathematics in the field of electromagnetism. The behaviour of electric and magnetic fields and their interaction is given by the so-called Maxwell equations. Just four differential equations that describe a wealth of phenomena ranging from big magnets used for medical imaging to the behaviour of light (which is an electromagnetic phenomena) to the interaction between electrons and protons. In a Problem Based Learning style you will solve and discuss successive problems with a small group of students to get insight first in electrostatics, followed by magnetostatics. With magnetostatics you are already able to understand the design of electromagnets, magnetic fields created by a constant current. Electrostatics and magnetostatics are combined in the field of electrodynamics, the mutual interaction of electric and magnetic fields. This forms the basis to understand optical effects and wireless communication. This knowledge will have to be used in the project team for the design and realization of an antenna that works as well as possible within the 100 MHz range. To support the antenna design process the Finite Element Method is introduced. The Finite Element method is used in many engineering areas to evaluate a system described by (partial) differential equations such as fluid motion, thermal behaviour, mechanical stress and bending as well as electromagnetic phenomena. In many engineering problems

it is actually a combination of these effects that play a role, for example the cooling of a mechanical structure to prevent thermal expansion with the flow of a cooling fluid. Working with a Finite Element method is not just ask the computer for an answer, as an answer it will give. Therefore this technique can only be used with a proper set-up of the problem and the validation of the results.
In the last few years one week of this module was spent on an excursion to CERN to see large magnets of various designs at work. During this visit several problems associated with particle beam dynamics and magnet design and realization are made. Above all this trip provides insight in this international renown institute.

Explanation of the design of one of the elements for bending the particles in the LHC at CERN.

Group picture of second year AT students on the CERN trip.

MODULE 8	Second year	15.0 EC
Business & Society	Fourth quartile	Dr. M.R. Stienstra

The development and commercialization of a complex technological system is the central theme of this module for Advanced Technology. Students will obtain hands-on project experience in the entire innovation process from working on an initial technological idea to delivering a commercially viable system. For this purpose students will learn key theories, tools and methods from the fields of Systems Engineering, Entrepreneurship and Innovation Management, and Knowledge Production in Innovation. Thus, students will not only be able to understand complex system design, but also commercial, organizational and societal aspects that are at least as important for success as the technology itself. Since group work is an important part of the module, effective collaboration, reflection and presentation skills will also receive substantial attention.

3.5 The third year

The flexible third year of the Bachelor's in Advanced Technology provides a solid preparation for a wide range of Master's programmes. You can take your Master's at the University of Twente, another university in the Netherlands or, like an increasing number of our students, you can opt for a Master's abroad.

During your third year, you will choose three modules (modules 9, 10 and 11) in line with your ambitions and interests. Educational units can also be taken at other universities, inside or outside the Netherlands. The University of Twente is part of the Erasmus exchange programme for exchange of students within Europe, but also several programmes for studying outside Europe are available. Like with the educational units within the University of Twente this all depends on your personal choice. The only requirement is that the educational units should comply with the programme learning outcomes for a third-year student.
The third year concludes with the Bachelor's assignment, in which you will prove that you have what it takes to continue your studies at Master's level. The assignment involves working independently on a research project within one of our research groups, often under the guidance of a PhD student.

MODULE 9	Third year	15.0 EC
Free choice – master preparation	First quartile	

The content depends on the admission requirements of the master's programme of your choice.

MODULE 10	Third year	15.0 EC
Free choice – master preparation	Second quartile	

The content depends on the admission requirements of the master's programme of your choice.

MODULE 11	Third year	15.0 EC
Free choice – master preparation	Third quartile	

The content depends on the admission requirements of the master's programme of your choice.

MODULE 12	Third year	15.0 EC
Bachelor assignment	Fourth quartile	Dr. H.K. Hemmes

The individual Bachelor's assignment completes the Bachelor's programme. The main objective of the BSc-assignment is to learn how to apply a suitable research methodology under supervision on a complex problem.
The assignment is performed under supervision of a Bachelor's Assignment Committee (BAC). The assignment can be done in one of the research chairs of the UT. Under certain conditions, the assignment can be done (partially) at an external organization.

The main goal is to learn how to execute a research assignment starting from a problem description, translating that in research question applying a suitable research methodology and communicating on the results. All under supervision. It is the first time that the individual student is confronted with a substantial research problem where the results have to be written down in a report and presented to an audience. Apart from the scientific aspects the student should also develop a time-effective and critical attitude towards planning and execution of the assignment. The final grade is therefore determined by scientific skills and academic skills (like communication, cooperation, work-attitude, etc.) The subject of the bachelor's assignment and the composition of the committee has to be approved by the board of examiners.

The research performed by the student is done under daily supervision of a member of the scientific staff. During the first weeks of the assignment, the student has to define a research plan in accordance

with the daily supervisor and the BAC. The assignment is completed with a written report (the BSc-thesis) and a public oral presentation.

Students receiving their diploma during the bachelor's graduation ceremony.

3.6 Additional programme challenges

Next to the bachelor's programme, there is the possibility to do something extra during your studies, such as the honours programmes or participation in one of the dream teams.

Honours Programmes

Are you talented and do you have an entrepreneurial mindset? Do you like to think out of the box? Do you push the boundaries of disciplines and do you look for ways to make sure your ideas have an influence on society? If that's you, then the University of Twente has a challenging programme for you: the honours programme. The University of Twente offers an intensive and interesting programme that challenges ambitious students to perform their best. Our programmes are high tech, human touch: it combines technology and social sciences. The honours programme in the bachelor's programmes is mostly broadening.

The programme starts in February each year and is only open to the top five percent students of each programme that the University of Twente offers. In about one and a half year you will follow a programme of 30 ECTS. As the programme is open to all sorts of bachelor's students, you will work with an interdisciplinary group with excellent and motivated students. During the programme, you will be intensively guided and lectures will be given by a select group of scientists with different backgrounds and from different research areas. You will learn about scientific breakthroughs and revolutionary designs, and you will learn to ask questions about everyday technology. You will also learn how to write a research proposal and you will work with a team on a final assignment.

Dream teams

At Advanced Technology we encourage students to do something extra next to their bachelor's programme. A lot of AT students decide to join one of the so-called dream teams: multidisciplinary teams in which students from different educational programmes join forces.
Below you can read some experiences from AT students that are active or have been active in one of the dream teams.

Annefleur Uitzetter - Green Team Twente

Hi, my name is Annefleur Uitzetter and I am currently a third year student in Advanced Technology. During my studies, it came to my attention that the University of Twente offers plenty of activities to meet new people and grow your skills. As I wanted to boost my practical skills as well as my soft skills, I decided to become a part-time member of student team Green Team Twente during my second year.
Green Team Twente is a student team that is pioneering sustainable mobility, as the team designs, builds and races one of the world's most fuel-efficient hydrogen cars. It is an international multidisciplinary team that consisted in my year of 23 students who all believed in hydrogen as the perfect alternative for fossil fuels. Every year Green Team Twente participates in the Shell Eco Marathon, where it competes with student teams from all around Europe for the title of Most efficient hydrogen car.

In my year, we build a brand new hydrogen car from scratch. Thereby, it came to my attention how important it is to see the interrelation between different disciplines. I realized that my study Advanced Technology allowed me to do so, as we had already experienced many different settings in which we had to solve problems. By combining my diverse knowledge, I was able to examine problems from different perspectives.
Of course it was not only sunshine and rainbows. We had months which were filled with setbacks, hard work and not much sleep. Although, this does not sound as a great experience at all, it certainly was. While being part of Green Team Twente, I learnt how to turn an idea from paper to reality, overcome obstacles and most importantly, we had a great time with each other. The common goal encouraged us to get the best out of one another. We complemented each other well and I learnt a lot from each and every one. So if you ever have the opportunity to become part of a student team, I can only recommend it!

Jeroen Minnema – Solar Team Twente

Imagine driving a hyper efficient racing machine which you built, together with fellow students, through 3000km of Australian outback, solely powered by solar energy. A car with an air friction coefficient similar to the mirror of a Ford Transit and which requires less electrical power than a hair dryer to cruise at 90km/h. That's what you will do when you join Solar Team Twente, one of the student teams at the UT. We compete in the biannual World Solar Challenge in Australia and last September, we became European champions for the second time in a row. After finishing my bachelor Advanced Technology I joined the solarteam as an aerodynamics engineer and later on, after the production started, I started working on the race strategy. Joining a student team is one of the amazing opportunities available to you when studying in Twente.

Already right from the start of the project I experienced the added value of my AT background. A solar car contains elements from many different engineering disciplines including but not limited to aerodynamics, composites, mechanics and electronics. It became very clear to me that one does not design the best solar car by merely optimizing all individual aspects of a solar car: aerodynamics but that one continuously has to make tradeoffs between all disciplines and precisely that is where AT students are at their very best. A good example off this is the interface between the solar array and the aerodynamically shaped wing profile of the car. In order to maximize incoming solar radiation an electrical engineer would prefer a perfectly flat upper area of the car. However, the aerodynamic engineers would prefer a heavily double curved shape with very low air resistance. The question that arises then is: what is the optimal shape which maximizes the solar income and minimizes friction. That's one of the many multi-disciplinary problems which I had to tackle during my time at the team. I really found that my broad engineering background helped me a lot to solve problems like this, the project really allowed me to apply the knowledge and skills I obtained during my studies in practical engineering problems.

In addition, it was very interesting to go through the entire cycle of product development: from the concept phase at our office in Enschede, to the production of our car at several aerospace companies in the Netherlands all the way to testing the car in a wind tunnel and at a race track and finally of course the race in Australia. Besides all these awesome moments and all engineering experience I obtained during the project, I also learned a lot on a personal level. This includes but is definitely not limited to: working very intensively in a team, collaborating with (sometimes very slow) companies, dealing with media, I even saw my own face appearing on the Dutch television... All in all, participating in Solar Team Twente was by far the most amazing experience I have had so far in Enschede and AT taught me several essential skills which helped me a lot during the project.

Photos by: Jerome Wassenaar

Patrick Bos – Electric Superbike Twente

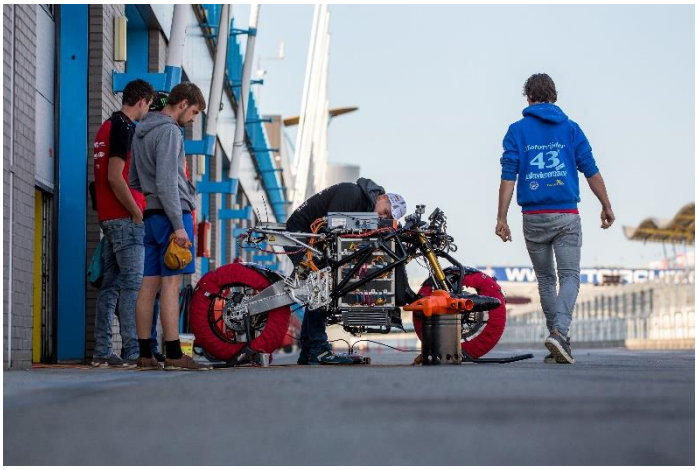
Electric superbike Twente is one of the student teams of the University of Twente. Similar to the Solar team or the Green team, the Electric Superbike team designs and builds an electric vehicle to compete in the European or worldwide championship. In our case, this electric vehicle is an electric superbike that is capable of going 250 km/h and from 0-100 km/h in around 3 seconds. A specially designed electromotor capable of producing 100 kilowatts of power, and a battery pack consisting of 1440 li-ion cells is what makes all of this possible. Every year around 15 students either part or full time, take on this challenge, these students are chosen from different disciplines to be part of the team to help to try to build the fastest electric superbike of the world.

In the season 2017-2018 the Electric superbike team set as goal to compete in the MotoE championship, which was won that season, making the first generation of the Electric Superbike team European champions. But in order to be able to achieve such a goal, the team builds a new motorcycle every year to make sure there is significant improvement. Some components will be bought like wheels, suspensions and brakes, however most components will be designed, build, and tested by the team itself. And every year the new team can learn from the experience of the previous teams and their design choices.

As someone who studied Advanced Technology for two years before joining the team I can say that a student team such as the Electric Superbike team fits very well to Advanced Technology. Many parts of the bike require knowledge of not only electrical or mechanical systems but a combination of both, let alone other disciplines. Next to that it is really nice to be able to actually apply the knowledge you have gathered during your study on a real life application instead of just exercises or experiments.

As someone who likes to work with his hands I sometimes missed the practical work during my study, together with my enthusiasm for motorcycles the Electric Superbike team was perfect for me. To be able to put together a design with a team and then see it drive at the end of the year is astonishing.
During the year you will also come in contact with a lot of different companies, for me this was very insightful. Companies are also happy to see students work on these kind of projects.
Next to working hard, it is also a lot of fun, and you can learn a lot from others and their experiences. The race weekends themselves might be the best part of the year for me. A race weekend consists of quite a lot of travelling, sleeping in the pitbox, keeping the bike working, watching races, analyzing data, meeting new people and fun evenings. And at the end of the whole road, hopefully winning the competition.

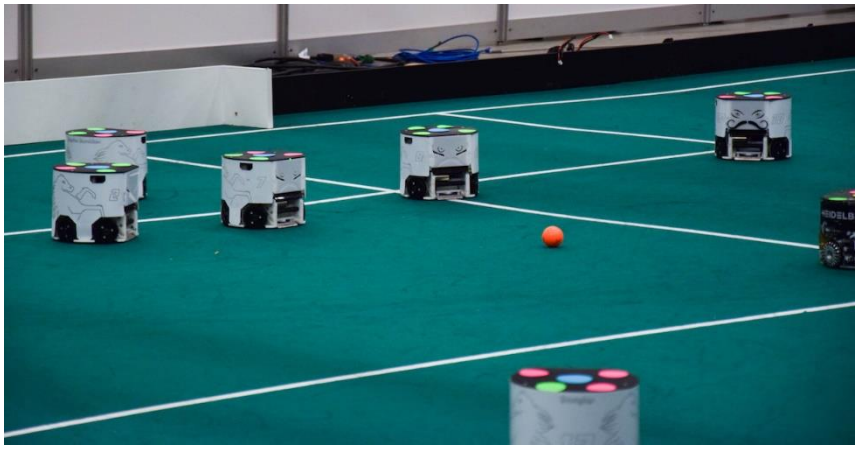
If you are interested you can find more information on www.electricsuperbiketwente.nl or follow us on Facebook, Instagram or Twitter.



Freek Nijweide – RoboTeam Twente

My name is Freek Nijweide, and I am a member of the RoboTeam Twente this year. I will be doing this part-time, as I am a third year student of the Advanced Technology doing minor courses in computer science. I have always loved computers and robots, and that is why I chose to join this team.

RoboTeam Twente makes small robots that can autonomously play football, as a team. Each year, we send our team to the RoboCup, the biggest international robotics competition in the world. No human control is allowed during these matches, so the robots must play on their own, which is quite a challenge for the tams. Small mistakes can lead to the entire system freezing up, which is why there is no room for error. All components of the robot must be functioning correctly and interact with the other components: the mechanical parts, electronics, control software for the motors, and the AI-based tactics. I will mainly be working on the software, but my AT background helps a lot in understanding problems in other disciplines as well, which is great for such a multidisciplinary project!



3.7 Studying Abroad

The University of Twente offers several opportunities for adding an international dimension to your curriculum. In this way, a student can determine if "going abroad" suits and wants it to play a role in a future career. At the University of Twente, we believe a stay abroad is a valuable component of the study; therefore stimulating measures like the Twente Mobility Fund (TMF-fund) and the Erasmus-scholarship are available.
When you have decided to go abroad, the next step is to decide what you prefer to do abroad. Keep in mind that it takes 6 to 12 months to make all the necessary arrangements to study in a foreign country; so planning must start as soon as possible.

Possibilities adding an international component to your curriculum by studying abroad:

- exchange in the context of the Erasmus programme
- minor
- bachelor assignment
- international study tour

Global E3 consortium

Advanced Technology students can also apply for an exchange semester/year through the Global E3 consortium. GE3 is a consortium of universities that includes US institutions. Since a limited number of places is available (2 per year) a selection takes place based on grades and motivation. Please note that in order to take part in an exchange you usually have to provide proof of English proficiency (IELTS, TOEFL, Cambridge).

Partnership University Carlos III of Madrid to connect to Biomedical Engineering

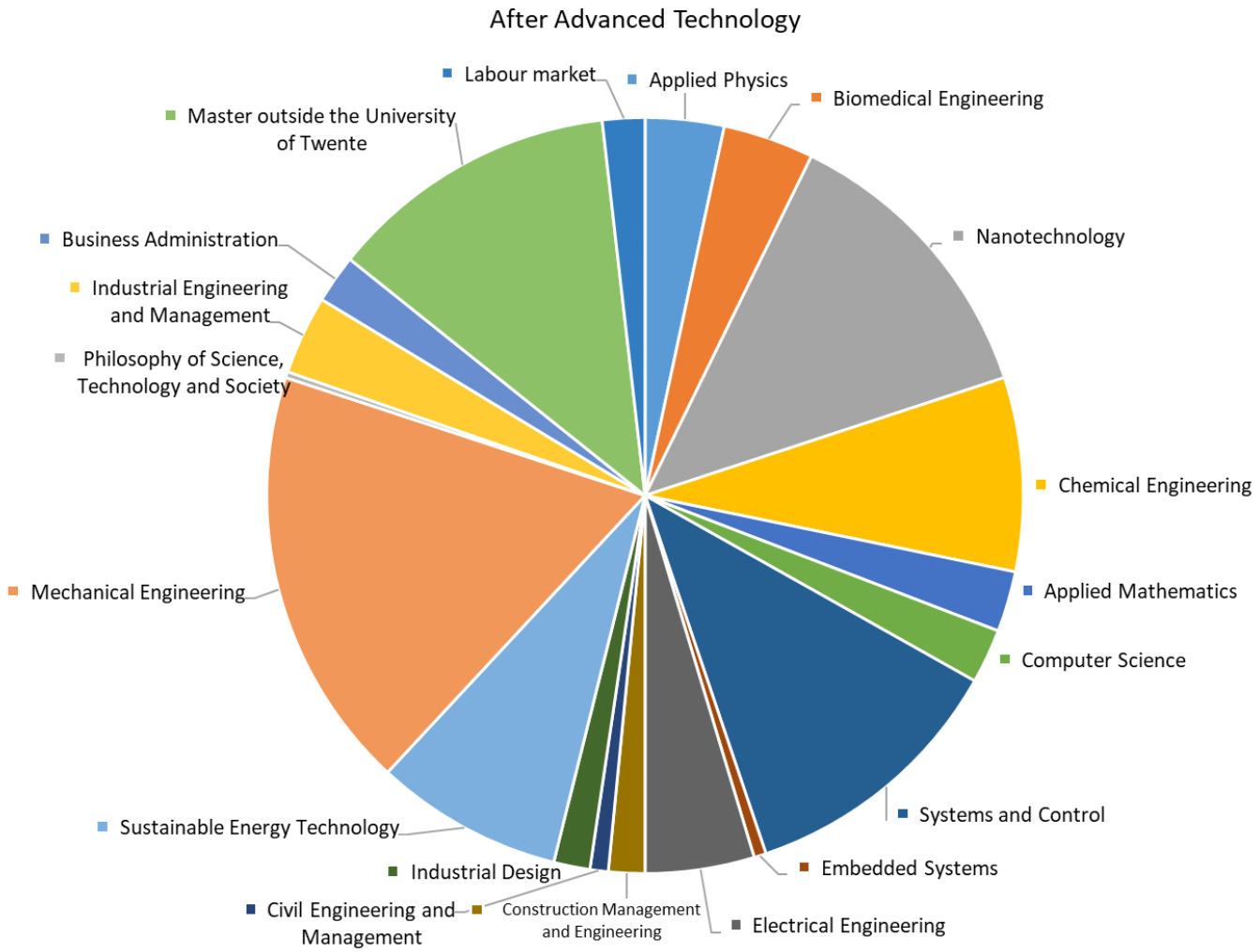
The Advanced Technology programme offers you the opportunity to study abroad. The courses taken have to comply with the AT programme. With the University Carlos III of Madrid we agreed upon a specific programme, with a set of courses which allows you to start with the Bionanotechnology track of the Biomedical Engineering programme. This exchange programme is especially of interest for international students that want to go in a Biomedical Engineering direction, since the University of Twente itself only offers a Dutch Biomedical Engineering bachelor's programme. However, the University's master's programme is in English and the agreement with University Carlos III makes a transition to a Biomedical Engineering master's programme possible.
Many other exchange programmes are possible and are based on a student's initiative which assures that the programme is aligned with his/her interests.

4 AFTER GRADUATION

4.1 Master's programmes

After graduation, Advanced Technology students choose from a wide range of master's programmes. As the third year of the Advanced Technology programme is very flexible, it allows students to prepare for master's outside the University of Twente. The AT programme has good connections with Universities located outside the Netherlands. Therefore, it is also possible to continue with your master's programme abroad.

If students continue their master's at the University of Twente, they can choose from a range of more than 16 different Master's programmes. These include engineering programmes such as Applied Physics, Mechanical Engineering, Nanotechnology, Sustainable Energy Technology and Systems & Control (Robotics & Mechatronics), but also Master's programmes in areas such as Business Administration and Philosophy. Information about all master's programmes offered at the University of Twente can be found here: https://www.utwente.nl/en/education/master/



Overview of where students continue after they finish the AT programme.

4.2 Experiences Alumni

At the Advanced Technology programme, we find it very important to keep contact with our former students, our alumni. The opinions of our alumni are important for improving our programme and to make sure that the qualifications of our future graduates fit the requirements of the market.
Below you can read some experiences from our AT alumni.

RUUD MEULENBROEK

Graduated from AT in September 2010 and is currently Process Engineer at BTG-BTL: Biomass-to-liquid.

After finishing his Bachelor's programme in Advanced Technology, Ruud Meulenbroek opted for a Master's programme in Mechanical Engineering at the University Twente. Since 2012 he has been working at BTG BioLiquids in Enschede.

ADVANCED TECHNOLOGY AND MY MASTER'S DEGREE

I have always had a broad interest in science and technology. I was drawn to the idea behind the Bachelor's programme in Advanced Technology: that most innovations emerge in areas where traditional disciplines like physics and chemistry overlap. I liked the notion that we should start taking a multidisciplinary approach to training our scientists and engineers, and supply them with a healthy dose of entrepreneurial spirit as part of the bargain.

During my Bachelor's programme, I discovered an interest in mechanical engineering, fluid flow and modelling. This led me to take a minor in Aeronautical Engineering and pre-Master's courses for the Thermal Engineering specialization in the Master's programme in Mechanical Engineering at the University of Twente. This Master's programme has allowed me to dig deeper into these subjects and has introduced me to the world of numerical modelling, which enables engineers and scientists to solve highly complex problems.

MY DAILY ACTIVITIES

BTG BioLiquids wants to contribute to a cleaner energy supply by substituting fossil fuels with fuels from renewable sources. The pyrolysis technology we provide efficiently converts most types of non-food biomass into second-generation biofuel within seconds. This technology was originally conceived at the University of Twente and was further developed by BTG, the University of Twente's first spin-off company. As a process engineer I am involved in designing and commissioning these pyrolysis plants, the first of which is currently under construction in the Dutch town of Hengelo.

I graduated while working at a global oil and gas company but I decided to change tack and apply to the small sustainable start-up company where I currently work. The set-up here means that there is less time to specialize in a particular subject and you have to be a jack-of-all-trades. I can be working on PR, sales, engineering and project development all in the course of a single working day!

HOW ARE YOU USING WHAT YOU LEARNED DURING YOUR STUDIES?

The thorough grounding in mathematical engineering I received at Twente really pays off when it comes to getting to the heart of an engineering problem quickly and effectively, especially when there is heat and mass transfer involved. I have even had the opportunity to put the business courses from Advanced Technology to good use. In my first year at BTG, I was asked to write the business plan for our company!

Advanced Technology really challenges you to perform at your best. It also enables you to discover which area of science and engineering you feel most passionately about so that you can start to specialize. For me it was an excellent stepping stone to a great job.

MY ADVICE TO PROSPECTIVE STUDENTS

Follow your own interests when it comes to deciding which courses to take. Go ahead and join a study or sports association. Becoming a good engineer also means that you need to develop your organizational and leadership skills.

JOEL VAN TIEM

Graduated from AT in January 2013 and is currently Business Market Analyst at Liander.

Open days. Being a “student for a day”. Lots of pens with university logos. In my final year of high school I was very busy trying to decide what to study afterward. It wasn’t until after I’d had the opportunity to join a first-year student of Advanced Technology for a day that I thought: ‘This is what I can picture myself studying next year.’ Which is exactly what happened.

To me the programme’s main feature was the analytical and multidisciplinary approach. You learn to really analyze and comprehend complex problems. In my second year a fellow student and I built a radio transmitter in ten weeks’ time. While at the start of the quarter we hardly knew what an antenna was, we concluded the project hearing our music on our neighbours’ FM radio. It’s really awesome to be able to use what you’ve learned in such a direct way.

After my studies I got a job at Liander, a company that manages the electricity and natural gas grids in most of The Netherlands. My team, Market & Business Intelligence, charts future developments in the energy industry and their impact on the networks. It’s hardly a radio station, but it’s a complex problem nonetheless. I’m grateful for Advanced Technology to have taught me how to deal with this type of problems.

MARTIJN BAKKER

Graduated from AT in July 2015 and is currently Software Engineer at Citadel Securities in London.

'London is the place to be!' That is certainly the case where Martijn Bakker, Advanced Technology alumnus, is concerned. His studies at the University of Twente enabled him to get a job as Software Engineer at Citadel Securities in London. His secret: work hard, graduate with distinction, have fun with your fellow students, attend lectures offered by the study association and have a drink during Friday get-togethers.

29 May, Bank holiday! We are here to interview Martijn, Software Engineer at Citadel Securities in London. He has long working hours – often getting on his bike at 7 in the morning to ride to work and returning home at 10 in the evening – but his work is interesting: he builds systems that are used for option trading worldwide (financial contracts where the buyer has the option of buying the product concerned on a fixed date at a fixed price). Martijn says: "I work for Citadel Securities, a subsidiary of the Citadel hedge fund. Contrary to the hedge fund, we do not have external investors and trade using only the owner's capital, meaning there are less restrictions regarding allowed trade strategies. At the Securities department, we deal with the purchase and sale of stocks, COB bonds, currencies, bitcoins and options, which I am involved with. Everything runs fully automatic and is based on mathematical models that decide in nanoseconds whether we should buy or sell something. Human activity is, however, still needed and we can intervene when the system does not work as required. I am a member of a small team of about ten people, many of whom studied at the University of Cambridge or the University of Oxford. We are a tight group."

How did you end up studying Advanced Technology?

Martijn: "Even before I went to university, I already had a broad interest in everything to do with engineering and technology. That is why I opted for Advanced Technology. A broad technical study with a direct link to society. During my first year, I basically attended lectures from 9 to 5, followed by a test at the end. That suited me just fine. During the second year, there were more activities in group context. Me and three other AT students formed a study group to do our assignments. It was very nice to interact with the same people all the time: you know each other, you know where you stand with each other and can learn from each other's expertise. Because even though you are only in your second year, there are topics you are more interested in and better at. We complemented each other. Great times! During the third year, you choose the subjects you want to pursue. I opted for Computer Science subjects. I have been interested in IT since I was a boy. That is why I did a Bachelor's thesis at the interface of IT and Advanced Technology. I developed hardware for solving differential equations. I wanted to develop hardcore technology that did not exist yet. My tutor, Ruud van Damme, encouraged me to not just do the assignment but to take that extra step. It was really inspiring: trying to do just a bit more than you think you are capable of. I really like that!"

Have you kept in touch with the members of your work group?

"I am still in regular contact with two of the three students I did assignments with during my second year. We all graduated with distinction and then set off into the wide world. After obtaining a Bachelor's degree in Advanced Technology and a Master's degree in Nanotechnology at the University of Twente, Yorick went to Standford University in America. After that he went to Saudi Arabia for three months as

a visiting student researcher in the Functional Nanomaterials and Devices group at the King Abdullah University of Science and Technology. Later he returned to the University of Twente to finish a PhD in Applied Physics. Another member of the work group, Kevin, obtained two Master's degrees at the University of Twente after his Bachelor's in Advanced Technology, one in Applied Physics and one in Nanotechnology. He then started a PhD at the ETH Zürich/Paul Scherrer Institut in Switzerland. Quite an international little group of scientists. After having obtained my Master's degree in Computer Science at the University of Cambridge, I ended up in London where I feel completely at home. I do, however, intent to return to obtain a PhD. My PhD research will deal with the development of a new way of designing computer processors. With the current processor generations, the greater portion of the chip is not used for doing calculations but for storing data. We will design them differently, using thousands of small, independent processors in order to achieve more with less energy", Martijn explains.

Tell me, what was life like at the University of Twente, besides education?
"Like many students I was a member of a study association. You not only get discount on textbooks, but they also organize fun activities at a scientific and social level. I did not organize activities, but was often present when others did. Lectures were always interesting and enabled you to learn about what was yet to come, get-togethers were good for your social life and then there was the trip to the UK, and particularly Cambridge, which I remember clearly. That visit inspired me to pursue the Master's degree in Computer Science at the University of Cambridge. I was also a member of the board of Musica Silvestra Orchestra for a year, the student orchestra of the University of Twente. I was responsible for finding new musical compositions, ensuring there were sufficient musicians, distributing new sheet music to the members and finding locations where we could organize concerts or practice weekends. A nice side job for a bassoon player", Martijn says smiling.

What are your plans for the future?
Martijn: "I was always certain what my future would be like. Apparently you sometimes know early on. So after my pre-university education (VWO) I went to the University of Twente. I then left for Cambridge where I obtained my Master's degree in Computer Science with distinction, after which I started looking for a job to gain experience. I really like working for Citadel Securities. But blood is still thicker than water. So I decided to start my PhD research at the University of Cambridge in October. And following my PhD defence, I intent to start my own company in developing technology in the area of the theory and implementation of general intelligence theory, which is one of the applications of the processors I will be working on during my PhD research. So: lots to do and lots to learn."

5 BACHELOR ASSIGNMENTS

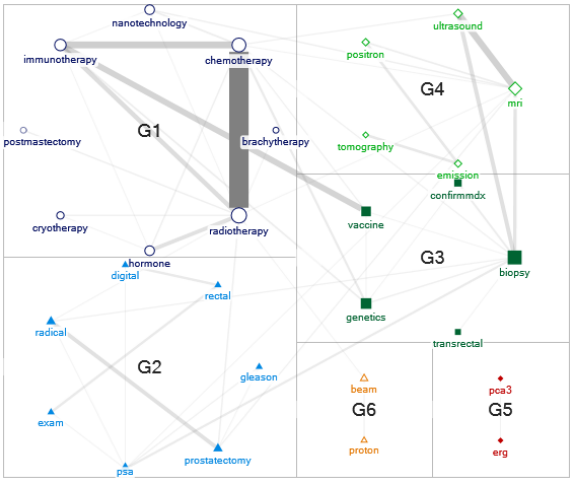
The last step for students to be able to finish their AT programme is the bachelor assignment. Some examples of previous bachelor assignments are described below.

BALSAM AWLAD WADAIR

Nederlands Instituut voor Kennisintensief Ondernemerschap (NIKOS)
After AT: Business Administration

Who tweets about health technology? An exploratory study on the relation between societal identies of twitter users and knowledge of prostate and testicular cancer treatments.

Cancer awareness campaigns like Movember have a great potential of effectively educating people about cancer and ways of its early detection. In the past few years, the Movember campaign relied on social media platforms such as Twitter to reach its objective of raising awareness about men's health, in particular Prostate and Testicular cancers early detection and treatments. However, little is known on whether such online campaigns promote people's knowledge and awareness about technologies and treatments for cancer. This article presents an analysis of the United Kingdom (UK) 2014 Movember campaign on Twitter and investigates 1) whether Twitter users are tweeting about technologies used for the detection and treatments of Prostate and Testicular cancers; 2) and how these users frame such discourse online. Furthermore, social identity theory is used to identify the profiles of those tweeting about technologies and treatments. The following study provides three main contributions to existing literature. First, the findings suggest that only 0:5% of the tweets from the UK 2014 Movember campaign are related to Prostate and Testicular cancers technologies and treatments. Second, results obtained from sentiment and semantic analysis show that Twitter users adopt mostly negative tone in their tweets and they frame their discourse around two main thematic clusters: generic treatments (such as Radiotherapy, Chemotherapy, Immunotherapy) and specific diagnostic techniques (such as Transrectal Ultrasound and Proton Beam Therapy). Third, people tweeting about technologies and treatments were predominantly classified into the 'Occupation' social identity category. These findings offer basis for further research on the topic and provide practical implications for campaign organizations.



ALEXANDER DIJKSHOORN

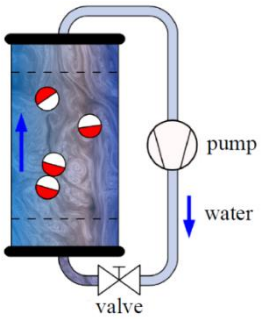
Nature Inspired Fabrication and Transduction (NIFTy)
After AT: Electrical Engineering, Robotics and Mechatronics (UT)

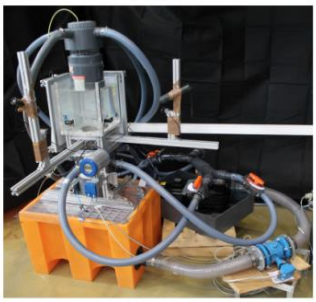
Design, Fabrication and Testing of 3D-Printed Spheres for Macro Self-Assembly Experiments

Manufacturing techniques for complex products improved by copying from nature, using self-assembly. Self-Assembly is a process were building blocks assemble in the desired system while external energy is applied. Important examples in nature are DNA replication and crystal formation. In the NIFTy group it is researched by use of macro scale experiments with 3D printed spheres containing magnets. The spheres are placed inside a tube in a turbulent water flow to form chains and rings of spheres; which is filmed with video cameras. However when more spheres are used spheres start to block the camera view and another measurement system is needed.

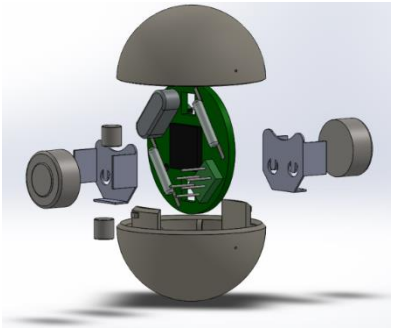
Within my assignment I designed, fabricated and tested spheres with sensors and data storage inside to solve the problems with video measurements. For designing the spheres systems engineering was used. By looking at the needed functionality I split the spheres into several needed components: magnets, sensors, data storage, electronics, a shell and a battery. For these parts options were considered and scenarios with suited options were made. The best scenario was picked and could be used. For a final design different calculations and tests had to be done. A magnet lay-out was chosen and numerical calculations and experiments showed that it works. A sensing mechanism with reed switches (magnetic switches) was designed and tested. Everything was integrated on a printed circuit board with a micro-controller and flash memory to measure connections via the reed switches and save data on the flash memory. Experiments were done to test the full system. Tests with rolling spheres without water showed everything works.

For the final testing I had to go to Germany were the total set-up is located (at the Korean Institute for Science and Technology in Saarbrucken). A lot of work was done in Germany and the spheres worked in the reactor; however data could not be retrieved due to problems with the water tightness. During my research within NIFTy, I have learned a lot about doing research. It was an inspiring working environment and I really felt involved in the group.





Schematic set-up (top) and experimental set-up (bottom) of the self-assembly reactor.



Final sphere design with electronics, magnets, sensors and batteries

ERIK LANDMAN

Robotics and Mechatronics

After AT: Design Engineering, Mechatronics (KTH Stockholm)

Designing a test rig for the Robird

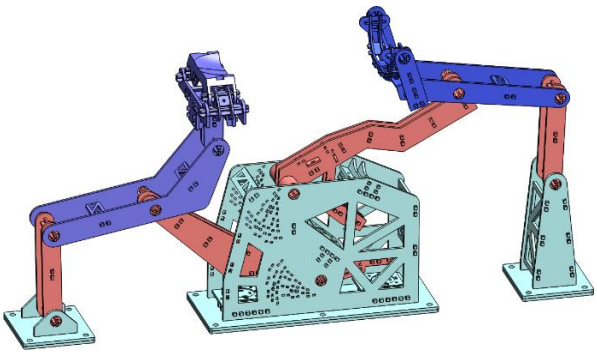
The Robird is a robotic bird designed by Clear Flight Solutions, that flies by flapping its wings. The Robird mimicks the flight characteristics and looks of a peregrine falcon. Because of this the Robird can be used for effective pest bird control, since it works on the natural instinct of the pest birds to flee from predators.

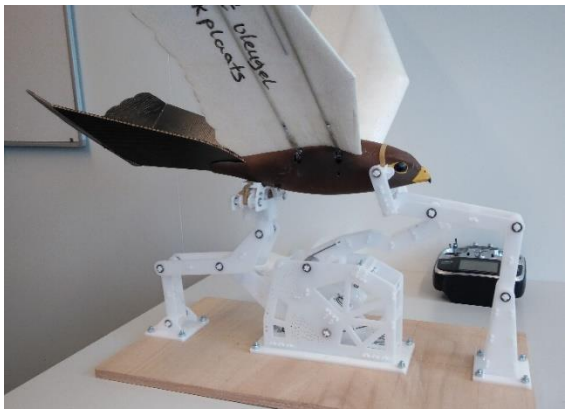
The Robird was developed by trial-and-error from a hobby prototype. Because of this there is still a lot unknown about the dynamics of the Robird and various aspects of the Robird can still be improved. In order to do this, reliable and accurate measurements must be able to be performed on the Robird in which real flight dynamics are simulated.

First the requirements for the test rig were made. It should at least be able to move vertically and to pitch. Forward motion can be simulated in a wind tunnel, so does not need to be in the test rig.

Implementing other degrees of freedom is optional. The test rig should be table top and must not add more than 400g to the Robird. Additionally the test rig should not introduce resonance.

The vertical motions of the Robird were modeled taking into account the friction forces on the wings and the change in center of mass due to the motions of the wings. Based on this model a design was made using two Evans straight-line mechanisms. One allows the front of the Robird to move vertically, while the other allows the back-side of the Robird to move vertically. If they move in opposite directions pitching is also allowed. Weak torsion springs with a combined spring constant of 16Nmm/° and a large pre-load of 130° were used to counteract gravity and conical springs with a maximum force of 70N were used to stop excessively large motions. Test were performed on the test rig to verify that it was working properly. It was found that oscillations became too large at 40% throttle. Recommendations were made to solve this limitation without major changes to the test rig.





RONA YURISMONO
STP research group and CSTM research group
After AT: Project Management

Case Study on Conversion of Bio-Ethanol Process Liquid Waste Using Cassava Feedstock in Indonesia: Waste to Energy Process

The case study has been evaluated using operational data from Bio-ethanol plant in Lampung, Indonesia. The plant produces bio ethanol, as the replacement of fossil fuel, as well as high amount of liquid waste with extremely very high COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) contents. This liquid waste mostly consists of thin slops which cover around 60% of the total waste. To reduce the high COD and BOD concentration in thin slops, Waste Water Treatment Plant (WWTP) has to be implemented to convert thin slops into harmless liquid waste with COD and BOD level of less than 300 ppm that comply with the regulation in discharging into the environment.

In order to determine the efficiency of the WWTP used in this case study (Continuous Stirred Tank Reactor called CSTR), a comparative analysis is conducted with two other reactors technology which are Up-flow Anaerobic Sludge Blanket (UASB) and Covered In-ground Anaerobic Reactor (CIGAR). This study showed that CSTR is the most efficient reactor with higher loading rate and reduction rate (90% COD reduction). The CSTR produces higher amount of methane gas of about 20,475 Nm3/day but it is costly on its investment and electricity consumption. While CIGAR occupies the second position in its effectiveness (85% COD reduction) and offers low investment cost as well as power usage. However CIGAR has a critical problem when applied to the waste with high loading rate, this is mainly because of the poor natural mixing that lead to a creation of dead zone which reduces the reactor's effective volume. Consequently, UASB turns out to be the least efficient reactor (80% COD reduction) with its low loading rate. On the other hand, it does not require large area and has lower chance to develop dead zone due to its effective mixing unlike CIGAR.

According to this study, it seems likely that UASB turns out to be suitable for smaller company with lower loading rate, and CSTR is the most appropriate reactor for higher loading rate and efficient COD reduction, while companies with larger area might be compatible with CIGAR. This study is important as it helps companies in choosing the right method of waste water treatment that correspond to the characteristics of the liquid waste produced and the area owns by the company as well as the amount of funds that the company have for WWTP investment cost.

Besides that, the reactors have its own advantages and drawbacks hence, each reactor is useful for different conditions as long as it is responsible in reducing COD level under the required regulation level. The regulation which concerns the environmental safety for Indonesia is Environmental Impact Analysis Study (AMDAL). Based on the survey, it is effective in acquiring permits from the Bio-ethanol companies in Indonesia as six out of eight companies provides permits and waste analysis as stated in AMDAL

Future researchers should carry on further evaluation on the method to increase the COD reduction percentage in UASB and CIGAR so that the next companies will include WWTP to the system as UASB and CIGAR require lower investment cost. regulation. However, its monitoring and control are less efficient since only three companies possess the appropriate WWTP. Therefore, suggestion is made to propose a new WWTP that is suitable for each company.

NATHNAEL SHENKUTE

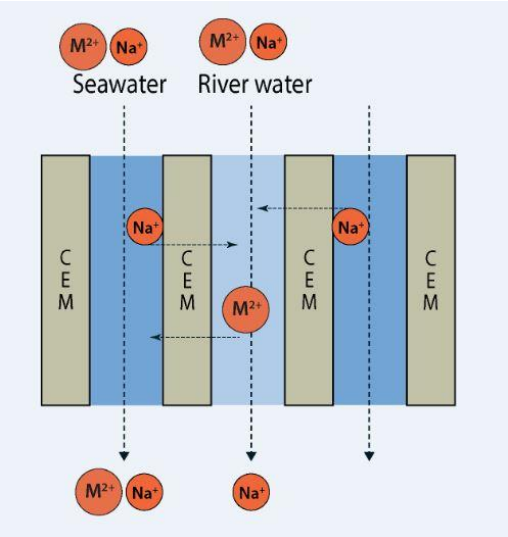
Membrane science and technology (MST)
After AT: Chemical Engineering (UT)

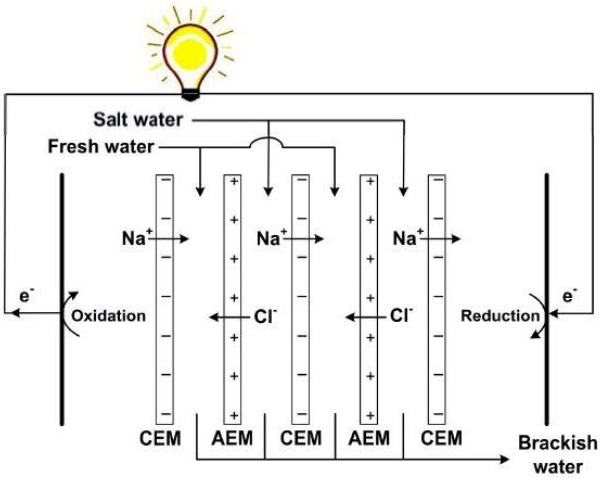
Donnan Dialysis as a Pretreatment for RED

During my time at the membrane science and technology research group (MST) at the UT, I had the opportunity to contribute towards research in a renewable energy source. This source is called reverse electrodialysis, or in its more catchy acronym RED. The RED project was a relatively new method of harvesting energy from the natural environment in a sustainable way. The principle is straightforward, it utilizes ion exchange membranes to capture the Gibbs free energy of mixing between a dilute electrolyte solution and a concentrated electrolyte solution; simply speaking it takes advantage of the spontaneous ionic movement during the mixing of highly saline sea water with fresh river water.

Currently laboratory experiments result in high efficiencies (as high as 95% \cite) for RED cells with solutions that contain only monovalent ions such as Na+ and Cl-. However, real sea and river waters contain ions which are non-monovalent such as Mg2+ and SO42-. This irregularity of ionic distribution reduces efficiency in a RED cell because it causes a higher stack resistance and loss in stack voltage, this is especially relevant when the non-monovalent ions are present in the dilute solution (i.e. fresh water).

The research goal regarding these RED cells was to improve their efficiency. Donnan dialysis was used to pretreat a dilute electrolyte solution (fresh water) in order to remove multivalent ions and exchange them for monovalent ions. Several solutions were prepared, ranging from simple ones that contain only Na+ , Mg2+ , and Cl- ions to a more complex, and hence natural like, solutions that contain Na+ , Mg2+, Ca2+, and Cl- ions. The treatment was done in a two compartment diffusion cell and commercially available cation exchange membranes. Furthermore, ion chromatography was used as an analysis tool in order to quantify the amount of ions present before and after pretreatment. The results showed the removal of multivalent ions to negligible amounts and increase of Na+ ions towards optimum values that result in a higher efficiency.





MATTHIAS VERMEER

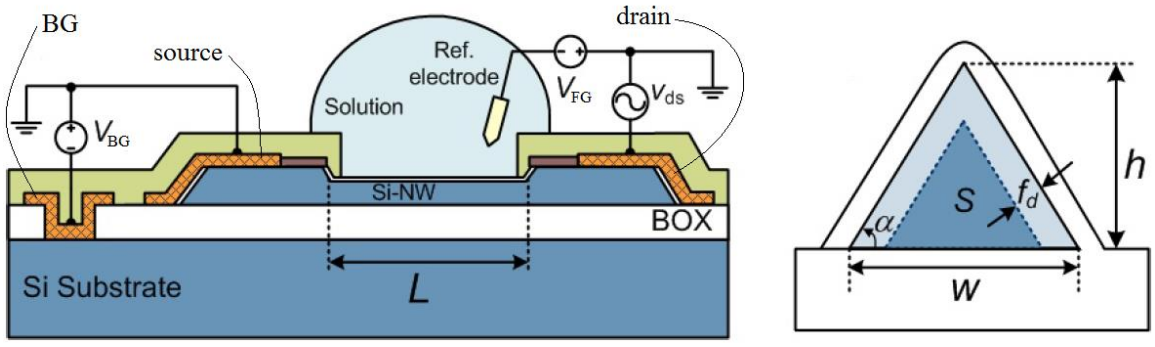
BIOS Lab-on-a-Chip

After AT: Electrical Engineering, Semiconductor Components (UT)

Analysis of Silicon Nanowires Ion Sensitive Field-Effect Transistor for DNA Detection

I analysed a certain kind of transistor for my bachelor assignment, in order to find out if the device is suitable for DNA detection for early bladder cancer screening. A sensor needed for DNA detection consists of a sensor surface to which receptor molecules are bound. These receptor molecules can only bind to cancerous DNA and a change in sensor signal due to this binding can thus be related to the concentration of cancerous DNA in the sample solution. My work for this detection principle was mainly on characterization of a certain type of sensor and on the ability of this sensor to detect different DNA concentrations. The sensor I used for this is called Silicon Nanowires Ion Sensitive Field-Effect Transistor (Si-NWs ISFET). The sensor is based on the MOSFET (Metal Oxide Semiconductor Field-Effect Transistor) working principle, and is shown in the accompanying figures.

A current can flow from drain to source (or vice versa), through the Si-NWs, for an applied potential at the drain. This current changes due to an applied potential at front-gate or back-gate. If the receptor molecules able to bind to cancerous DNA are now attached at the Si-NWs surfaces, the binding of receptors and DNA molecules will have the same effect as changing the front-gate and will thus induce a change in output current. The device could therefore, theoretically, be used as DNA sensor. In order to test this theory, I tested the device for changing drain-source currents, front-gate voltages and back-gate voltages in order to fully understand how the basic device behaves and I tested the device for different pH solutions. Also, I tested the influence of temperature on device performance and I experimented with depositing gold and silicon-dioxide nanoparticles on top of the Si-NWs. Finally, I tested the dependence of the device on different DNA concentrations when using the proper receptor molecules. Device performance was found to be very unstable and the devices could not detect DNA properly. The results show that there were no reliable measurements, such a shame…



FRANCK DE VRIES
Robotics and Mechatronics (RaM)
After AT: Systems and Control (UT)

Design of a robot for in-pipe inspection using omnidirectional wheels

This bachelor assignment consisted of the design and realization of a system for moving in small diameter pipes. For this the assignment continues on the omniwheel prototype of the PIRATE project, which uses a propulsion mechanism using omnidirectional wheels, which allows direct control of the orientation of the robot in the pipe.

The PIRATE project aims at designing in-pipe inspection robots capable of autonomous inspection of the low-pressure gas distribution network. The robots should eventually be able to inspect the quality of the gas distribution pipes and locate weaknesses which could lead to leaks or even gas explosions. By locating these weaknesses it is possible to determine which pipelines have to be replaced in order to prevent such accidents from happening.

For the design of this assignment, first the design of the omniwheels of the robot was done, for which a custom 3D print design was made which allows a motor to partially fit inside the wheel, making the design more compact. A joint mechanism was designed to make sure that the orientation of the omniwheels inside the pipe stays correct in order for the propulsion mechanism of the robot to work. Also an active clamping mechanism has been implemented, which allows the robot to actively clamp inside pipes, such that the wheels have enough friction to operate, and to adapt to diameter changes. Finally a skeleton has been designed such that all of the made designs fit together and after that the designed robot was realized using 3D printing.

After the design had been realized, control had to be implemented in order for the robot to be able to drive through the pipes. For this control boards were implemented in the design and software had to be adapted for this specific design. When this was done, tests were conducted inside pipes of different diameters, which showed that the robot is able to drive through the pipes, can change its orientation by rotating inside the pipes and can actively clamp and unclamp, making it possible to adapt to diameter changes.

ARIE DEDDING

Mechanical Automation – Automation & Control
After AT: Mechanical Engineering, Precision and Microsystems Engineering (TU Delft)

Helicopter Drone Positioning and Control

My Bachelor Thesis involved the work on the positioning and control of a helicopter drone. For the positioning a close look was taken at different methods to track the position of a drone. These different methods involved GPS, ultrasonic sensors and optical flow sensors. From this comparison it was concluded that the optical flow sensor provided great opportunity for the tracking of a drone position due to its light weight and good accuracy. The optical flow sensor involves a camera and a small computer unit to measure the movement between different frames the camera records. From this the position change can be found. This method is closely based on how a lot of insects track their position. Some problems still encountered in the use of these optical flow sensors was discussed including their solutions. Furthermore, from different experiments conducted on these sensors found in literature the accuracy of the optical flow sensor was discussed as well as possible use cases of these sensors.

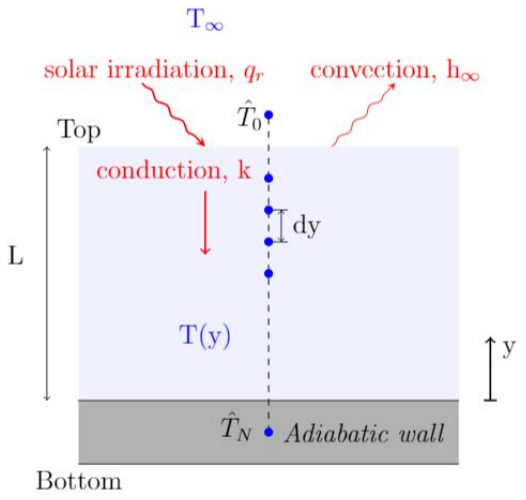
Besides the positioning of a drone, also the behavior of a helicopter drone when a pendulum is attached underneath it was researched. First the forces on the helicopter caused by a pendulum were investigated both when the pendulum is free to move and when a moment was applied to it, mimicking a robot arm. A controller was designed to counteract these forces caused on the helicopter and to make it hover stable in the air. This controller involved a feedforward controller, which uses the knowledge of the forces on the helicopter when a certain moment is applied from the model and uses this to counteract these same forces.

EVA VAN BEURDEN

Thermal and Fluid Engineering

After AT: Mechanical Engineering (UT)

Solar energy has been used since the ancient Grecian times and nowadays it is sought for optimisation of the existing technologies. In the field of solar collectors, which convert solar irradiation into thermal energy, two main developments occurred. First of all, the amount of conversion steps is reduced by directly absorbing the solar irradiation by the heat transfer fluid (HTF). Secondly, the thermal properties of the HTF are enhanced by means of adding nanoparticles to the fluid and in this way creating a so-called 'nanofluid'. A research group at the UT wanted to combine these two solutions and take it even one step further. They proposed to add phase change material (PCM) to the fluid. This PCM can absorb large amounts of heat, while maintaining the same temperature. This reduces the amount of heat lost to the environment, but maintains the amount of energy stored in the system and thus increases the efficiency of the solar collector. The proposed configuration of PCM encapsulated by nanoparticles inside a direct absorption solar collector (DASC) is investigated both experimentally and numerically. This bachelor assignment focused on the 1-dimensional numerical analysis of the DASC, where the temperature profile within the collector was of interest. In order to find this profile, the energy equation for a system with solar irradiation and the appropriate boundary conditions were set up. Then, the domain was discretized and the energy equation was transformed into a finite difference equation in order to be able to solve the problem numerically with Matlab. The problem was split up in different cases where at first only the temperature profile of water was solved for, then the nanoparticles and lastly the PCM was added to the fluid. The addition of particles to the fluid was realised by finding new expressions for the fluid properties, such as the thermal conductivity and the extinction coefficient. When solving for the temperature profile, the energy stored as well as the energy lost to the environment could be calculated and with those values the final efficiency of the DASC could be evaluated. It was found that adding PCM encapsulated by nanoparticles indeed increases the efficiency of a DASC.



Schematic of the DASC in 1D.

ERWIN LUESINK
Applied Analysis (AA)
After AT: Applied Mathematics (UT)

Bursts of brain activity

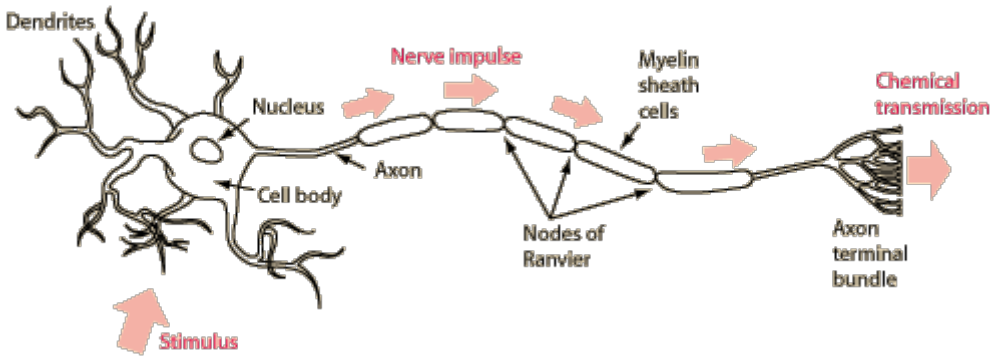
The most important element in my bachelor assignment was the modelling of a neuronal population. The brain is an extremely complex dynamical system. This means that the processes that happen inside the brain are very difficult to accurately describe. For a single brain cell, called a 'neuron', there exist a number of mathematical models that describes the behavior very accurately. However, often these models are, due to the complexity of the brain, made with equations that are very hard to solve, even with the computer. So we are happy if the model is less accurate, but computationally a lot simpler, since that allows us to set up a model of a neuronal population and do computations with this model within reasonable time. This motivates the decision for the Izhikevich model which is depicted below. This model consists of two ordinary differential equations (ODE) and a reset and is such a single neuron model. The next step is to build a neuronal population by connecting neurons to each other in a proper way and include other important effects. After that had been done, I built a computer model in order to be able to actually do simulations.

In Advanced Technology we learn how to deal with these type of equations (ODEs) and why they can be used to model dynamical systems. We are also taught how to implement mathematical models into the computer. So Advanced Technology gave me a number of tools to properly analyze these equations and use them to construct a population model that works for hundreds of thousands of neurons.

$$\frac{dv}{dt} = 0.04v^2 + 5v + 140 - u + I$$

$$\frac{du}{dt} = a(bv - u)$$

$$v \geq 30mV, \begin{cases} v \leftarrow c \\ u \leftarrow u + d \end{cases}$$



KEVIN HOFHUIS

Physics of Interfaces and Nanomaterials (PIN)
After AT: Applied Physics and Nanotechnology (UT)

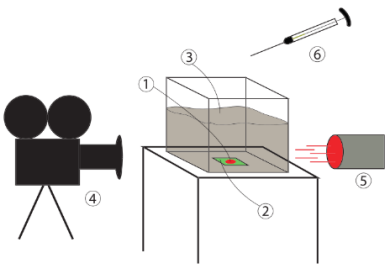
Dissolution kinetics of submerged surface droplets

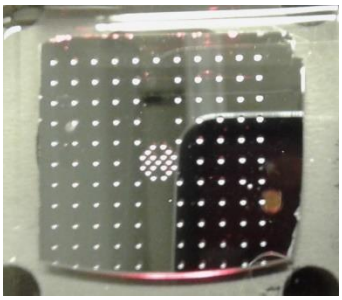
The evaporation of liquids in air is of key importance for inkjet printing, surface coating, cleaning, and the deposition of small particles. A great deal of research has been done on this system, but the completely analogous system of liquid in another liquid remains underdeveloped. In my thesis at the Physics of Interfaces and Nanomaterials group (PIN) I worked on the dissolution kinetics of submerged surface droplets. This simple system of liquid-liquid interfaces occurs in every household. However, dissolving droplets show a great deal of physics when studied closely. The research conducted is considered empirical; hence it had plenty of hands on experimental work that could be done.

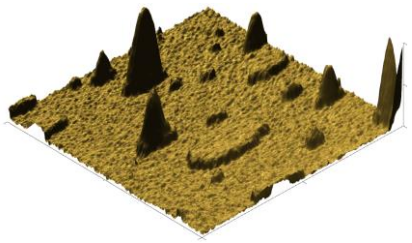
Conventional wisdom says oil does not dissolve in water. However, long-chain alcohols are slightly soluble in water. Hence it is the perfect system to disentangle diffusive and convective contributions to the dissolution process. The experimental data obtained could be further processed using non-dimensional numbers such as Sherwood, Rayleigh, Reynolds and the Schmidt to map out the diffusive and convective regime. This was done successfully and resulted in the writings of an article about the role convection has in the dissolution process. This goes to show that your thesis work does not have to end after the final presentation.

Working at the PIN has been a pleasant experience; the people are friendly and open for a joke. Bringing cake when it's your birthday helps to open up conversations. Furthermore, I learned that your daily supervisor, and all those involved in your project and in the group are all willing to discuss your research and I urge to do so in any group one might end up.

Next to the research conducted for your thesis, there is always spare room for Friday afternoon experiments such as the included photograph, showing a nicely symmetric pattern of droplets. These measurement results turned out to coincide with theoretical models that are developed in Oxford. Further we could do Atomic Force Microscopy (AFM) measurements of the surface that I prepared, just because of curiosity and that should be at the root of your thesis, curiosity.







MAAIKE RUMP
Physics of Interfaces and Nanomaterials (PIN)
After AT: Nanotechnology (UT)

Dissolution dynamics of binary sessile alcohol droplets

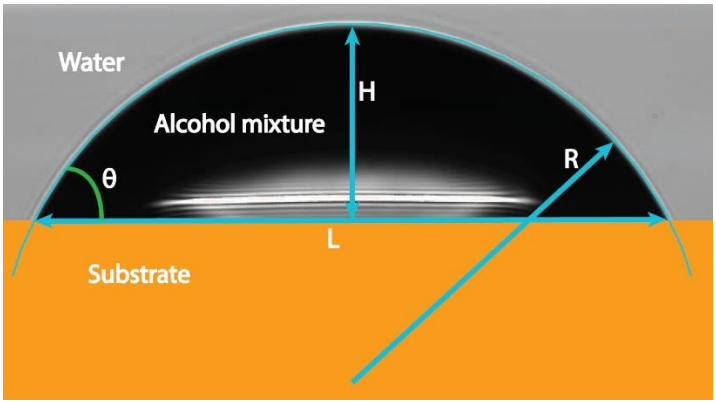
In a lot of daily situations (even without realising) do we encounter droplets, like windows covered with raindrops or tables with coffee stains. In processes like liquid-liquid extraction or mixing procedures, also droplets play a role. Knowing what happens at the droplets interface and in the bulk can improve these systems by improving the models describing them.

During my bachelor assignment at the Physics of Interfaces and Nanomaterials group, I have been studying submerged droplets containing two components to understand what happens at the interface of the droplet with the water (see figure). The two components are alcohols that are only limited soluble in water, hence forming a droplet on the substrate. The substrate is a piece of silicon wafer which we coated in order to obtain hydrophobic properties.

The content of my work was focussed on doing experiments and afterwards analysing the data, which sounds easier than it is. The experiment of course has to be of good quality, meaning not only the droplet has to be in focus but you also have to be able to zoom in enough as the droplets were around 20 nL in volume. This volume is determined afterwards when the images of the experiment have been processed by a Matlab code able to work with sub-pixel accuracy.

To find what actually happens at the interface, experiments are compared and different phenomena can be observed by studying certain parameters of the droplet in combination with its known properties and theoretical models.

Doing my thesis at PIN taught me many new aspects of research which were really enjoyable. Especially the realisation of results from analysis giving you so much more insight in what is actually happening. Also the opportunities for discussing my work with not only the supervisor but also the others in the lab, even though they work on different subjects, was very inspiring and made working within an accepting group even more appreciative.



A 20 nL alcohol droplet on a coated silicon substrate in a tank with water, with L the base diameter, R the radius of curvature, H for the height, and ϑ as the contact angle with the substrate.

YORICK BIRKHOLZER

Inorganic Materials Science (IMS)
After AT: Nanotechnology (UT)

Nanomechanical sensing of hypermethylated DNA for the detection of bladder cancer

Bladder cancer is the fifth most common type of cancer in the western world. The earlier the disease is detected, the more effective the treatment can be. Cancer screening and early detection have saved thousands of lives. That is why, for decades, extensive research on biosensors has been performed.

Scientists are developing tests that identify differences in the DNA of cancer cells and normal cells in order to diagnose cancer. Currently much research is conducted on the detection of bladder cancer in urine. It has been shown that DNA methylation contributes to the development of various cancers including bladder cancer.

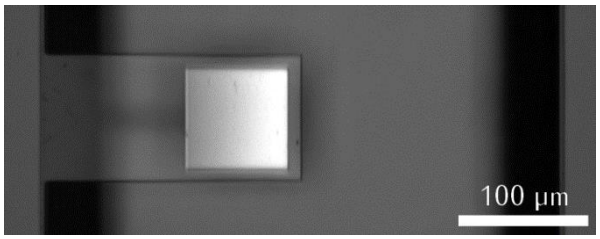
With my background in Advanced Technology, I looked for a broad and challenging, multidisciplinary thesis assignment. The Nanopil 2.0 project is an excellent example where nanotechnology, materials science, physics, biomedicine, chemistry, and mechanics come together. Within the IMS group, researchers develop a biosensor based on cantilevers which translate the recognition of biomolecules into nanomechanical motion.

The basic principle of the biosensor in this project is the measurement of the resonance frequency shift, e.g. caused by the added mass of target molecules bound to the cantilever surface. However, also the surface stress and the stiff- ness of the cantilevers are influenced by added molecules and these interactions oppose the resonance frequency shift.

A range of effects are expected to play a role, such as humidity of the environment, concentration of the analyte, sensor geometry, functionalization geometry, and non-specific interactions in the control step.

It was my task to carry out a set of experiments that shed more light on the involved interactions influencing the sensing process. Therefore, I investigated different chemical functionalization sequences of the nanomechanical cantilever biosensor.

During my Bachelor assignment, I've been in the MESA+ Nanolab cleanroom multiple times and spend many hours in various labs using a lot of high tech equipment. I enjoyed working in the IMS group and discovered my passion for research.



Released silicon nitride cantilever with gold patch at the tip.

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