

First year

Year 1 Courses

Faculty of Science and Engineering

Engineering in a Circular Economy

Full course description

This course sets the stage for the pressing need of circular engineers in the modern world that is to face two huge societal challenges: to cope with the scarcity of raw materials and to balance the impact on the environment as wealth continues to increase. In this course, you get an overview of what it entails to become and to be a circular engineer by introducing the concept of circular economy. The circular economy approach addresses material supply challenges by keeping materials in use much longer and by returning materials for new use. The principle is that waste must be minimised and that by the reuse of materials less energy is required to manufacture new products. You are able to explain the concepts of reuse, repair, remanufacture and recycle and their mutual relationship in product design. Furthermore, you can describe state-of-the-art circular design methods that lead to less waste and energy, loss of value and loss of resources and explain issues that rise when implementing such circular economic principles from various perspectives (manufacturer, consumer, government).

Course objectives

At the end of this course, you are able to:

1. Describe and classify various circular economy and design terms, methods, and regulations, such as circularity indicators, value retention strategies, circularity metrics, product life cycle, cradle-to-cradle, circular design, industrial sustainability and ecology, Life Cycle Assessment, energy labels, and carbon footprint.
2. Generate possible circularity improvements in existing product life cycles by studying comparable products that already meet the requirements of circularity.
3. Explain the four steps to perform a Life Cycle Assessment and summarize its value related to sustainability and circular engineering.
4. Explain the impact of existing Life Cycle Assessment reports on a local, national and global scale.
5. Give your own reflection on a circularity

Recommended reading

Mandatory: The following handbooks and resources are used during the course. Only the topics covered during lectures and tutorials need to be studied.

- Reports - published by the Ellen McArthur Foundation:
- - Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition
- - The New Plastics Economy: Rethinking the future of plastics

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- Book - Life Cycle Assessment: Quantitative Approaches for Decisions that Matter (2014), H. Scott Matthews, Chris Hendrickson, Deanna H. Matthews; available at <https://www.lcatextbook.com/>
- Article - Morsetto P. (2020), Targets for a Circular Economy. Resources, Conservation and Recycling, 153, 104553; available at <https://doi.org/10.1016/j.resconrec.2019.104553>
- Selection of literature on circularity and LCA; the sources are defined in the different tasks for this course

Recommended:

The following handbooks and resources are recommended if you are interested in circularity and/or Life Cycle Assessment and desire to have more in-depth information. They are by no means obligatory for the course.

- Handbook on essential concepts of sustainability: Tom Theis and Jonathan Tomkin, Editors, Sustainability: A Comprehensive Foundation. OpenStax CNX. 06.jan.2015 <http://cnx.org/contents/1741effd-9cda-4b2b-a91e-003e6f587263@43.5>. The book can be read online and is downloadable as PDF or EPUB file Article(s)
- Handbook - General guide for Life Cycle Assessment. European Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010. The pdf file is available at: <http://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf>
- Other reports on circularity published by the Ellen McArthur Foundation

CEN1001

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Instruction language:

English

Coordinator:

- [Y. van der Meer](#)

Teaching methods:

Lecture(s), PBL

Assessment methods:

Final paper, Written exam

Faculty of Science and Engineering

Calculus

Full course description

The aim of this course is to enhance the student's mathematical skills in order to become a technically well-educated circular engineer. The student deepens their insight in how calculus tools

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are used in modern society, science and business, while also training their technical problem solving skills.

Course objectives

The course-level objectives (CLOs) are:

- A. I can compute limits, derivatives, and integrals.
- B. I can analyse functions using limits, derivatives, and integrals.
- C. I can recognize appropriate tools of calculus to solve unfamiliar problems.
- D. I can apply the tools of calculus to solve problems.
- E. I can prove basic theorems and properties of calculus.
- F. I can communicate about concepts of calculus.

Recommended reading

The following literature is mandatory:

- Hass, J., Heil, C., Bogacki, P., Weir, M. D., & Thomas, G. B. (2020). University Calculus: Early Transcendentals (Fourth edition in SI units). Pearson Education Limited. (ISBN: 9781292317304.)*
- Lecture slides, see electronic learning platform.

*Numerical solutions to the odd-numbered exercises can be found in the book. In order to obtain worked-out solutions for exercises, the student should attend the (mandatory) tutorials and/or engage on the discussion forum. The coordinating team is not expected to provide any worked-out solutions to the exercises in any other format under any circumstance.

The following literature is recommended:

- Hass, J., Heil, C., Weir, M.D. (2019). Thomas' Calculus: Early Transcendentals (Fourteenth edition in SI units). Pearson Education Limited. (ISBN: 9781292253114.)
- Adams, R.A., Essex, C. (20). Calculus: A Complete Course (Tenth edition). Pearson. (ISBN: 9780135732588.)

CEN1002

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Instruction language:

English

Coordinator:

- [M. Boussé](#)

Teaching methods:

Lecture(s), PBL

Assessment methods:

Assignment, Written exam

Keywords:

Fundamentals of Engineering

Full course description

This course introduces fundamentals of engineering. It provides an overview of various engineering fields with a specific focus on the open-ended and multidisciplinary nature of typical engineering problems and the underlying scientific principles.

The students familiarize with the engineering design cycle, which consists of formulating a problem, setting design requirements, generating several concepts, selecting the optimal solution, realizing it.

The course focusses on underlying scientific principles and laws related to basic engineering fields. Principles and laws in the field of current, force, energy and power that a broad range of engineers need in their basic knowledge portfolio, also including the future circular engineer. Exercises are included in the course to let students apply and calculate on these principles and laws as is expected of engineers.

The course prepares students for later courses in which they continue the development of their circular engineering skills. In this light, students need to perform this with an understanding of the environmental impact, but also the academic environment as well as ethics, safety and sustainability aspects.

Course objectives

At the end of this course, you are able to:

- Understand and explain basic engineering principles more specific:

Laws of Newton, Ohm, mass, momentum, energy and electric charge conservation, Coulomb, Fourier, Hooke, Fick, ideal gas; the principles of Archimedes, Bernoulli

Elementary modelling involving setting of preconditions, identification of most important scientific principle, sources of losses, deviations and errors

- Analyse principles of physics and engineering and perform basic calculations with characteristic examples in each engineering field
- Apply the design engineering cycle to solve a problem
- Reproduce knowledge on the generic engineering design cycle
- Develop teamwork participating as an active member of a team

Recommended reading

Only topics of lectures and tutorials need to be studied.

- Moaveni S. (2020). Engineering Fundamentals: An Introduction to Engineering, SI Edition. Cengage Learning, 6th edition, ISBN 978-0-357-11215-1. (The library has 2 copies in stock that can be consulted in the library only.)

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- Khandani S (2005), Engineering design process.

CEN1003

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Instruction language:

English

Coordinator:

- [G.J. van Rooij](#)

Teaching methods:

Lecture(s), PBL, Working visit(s), Work in subgroups

Assessment methods:

Written exam, Assignment

Keywords:

Engineering Design Cycle; Instrumentation Design, Modelling and Engineering

Faculty of Science and Engineering

Linear Algebra

Full course description

Linear Algebra is one of the basic mathematics courses of the BSc Circular Engineering programme, just as is the case for most engineering and natural sciences programmes across the globe. It mostly builds on high school mathematics. It prepares for more advanced mathematics courses as well as for computational techniques and skills, which feature in applied modelling and engineering courses and in the projects.

This course is structured around three central themes: algebra, geometry, and dynamics.

Algebra - The first theme is concerned with the most frequently occurring mathematical problem in practical applications: How to solve a system of linear equations? For this problem, a complete algebraic solution procedure is developed which provides you with a way to deal with such problems systematically, regardless of the number of equations or the number of unknowns.

Geometry - The second theme addresses linear functions and mappings, which can be studied naturally from a geometric point of view. This involves geometric 'objects' such as points, lines and planes, and geometric 'actions' such as rotation, reflection, projection and translation. One of the main tools of linear algebra is offered by matrices and vectors, for which a basic theory of matrix-vector computation is developed. This allows one to bring these first two themes together in a common framework, in what turns out to be an exceptionally fruitful way. By introducing the notions of vector spaces, inner products and orthogonality, a deeper understanding of the scope of these techniques is developed. This opens up a large array of rather diverse application areas in engineering and the natural sciences.

Dynamics - The third theme surfaces when a dynamic perspective is taken, where the focus is on the effects of iteration, in this case the repeated application of a linear mapping. This gives rise to a

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basic theory of eigenvalues and eigenvectors, which have many applications in various branches of science as will be discussed.

Many examples and exercises are provided to clarify the issues and to develop practical computational skills. They also serve to demonstrate practical applications where the results of this course can be successfully employed.

You will gain insight into algebraic and geometric concepts including vectors, matrices, linear transformations, eigenvalues and eigenvectors, inner products and orthogonality. You will learn to perform basic algorithmic calculations (matrices, equations, etc.) and solve more abstract algebraic problems. You will also gain insights into the applications of linear algebra in several engineering and scientific disciplines.

Course objectives

At the end of this course, you are able to:

- Solve linear systems of equations using various methods such as Gaussian elimination, LU factorization, the least-squares method, QR factorization, (pseudo)-inverse matrix, and Cramer's rule.
- Compute matrix factorizations such as the LU factorization, QR factorization, eigenvalue decomposition, and singular value decomposition.
- Solve and compute various linear algebra problems using Matlab.
- Communicate and reason about linear algebra problems algebraically and geometrically by interleaving various definitions, theorems, and properties about vectors and matrices, linear systems and factorizations, eigenvalues and eigenvectors, singular values and singular vectors, linear transformations, orthogonality, determinants, etc. In particular, you are able to provide (counter)-examples and proofs for your reasoning.
- Understand that many, seemingly disconnected, problems from various disciplines reduce to linear algebra problems, i.e., solving a linear system and/or computing a factorization.
- Perform calculations with complex numbers.

Recommended reading

Mandatory

- Lecture slides
- David C. Lay, Steven R. Lay, and Judi J. McDonald (2021). Linear Algebra and Its Applications (Sixth Edition). ISBN: 978-1-292-35121-6.

CEN1004

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

Circular Engineering

- [M. Boussé](#)

Teaching methods:

Lecture(s), PBL, Work in subgroups, Assignment(s)

Assessment methods:

Written exam, Assignment

Keywords:

Algebra; Geometry; Dynamics

Faculty of Science and Engineering

Chemical Engineering

Full course description

Many daily used products contain materials produced in industrial chemical plants. 'Chemical engineering' studies the development, design, operation and improvement of these chemical plants, the chemical and physical processes and their safety, sustainability and economic feasibility.

This course will introduce students to the challenges of the modern chemical engineer, in which basic chemical and physical concepts, like material and energy balances, process design and typical unit operations, will be combined with discussions on sustainability/circularity and the business consequences.

The example of industrial fertiliser production, one of the most important chemical processes in modern societies, will be used to exercise with these topics complimentary to lectures and tutorials. By continually building on prior knowledge, you learn about designing chemical processes while developing a deeper understanding of chemical engineering fundamentals.

Course objectives

At the end of this course, you will be able to:

- Know basic process variables and apply them to solve practical problems
- Calculate energy (changes) for fluid streams, and physical and chemical processes.
- Determine the yield, conversion and selectivity of chemical reaction
- Describe some typical chemical industrial unit operations and do simple design calculations
- Complete energy and mass balances and make process flowsheets for steady state continuous and batch chemical processes
- Discuss about transition of the chemical industry towards a safe, sustainable, and circular industry

Prerequisites

None

Recommended reading

Mandatory:

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■ Elementary principles of chemical processes 4th edition, R.M. Felder, R.W. Rousseau, L.G. Bullard, 2016

CEN1005

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [G.J. Phillips](#)

Teaching methods:

Lecture(s), PBL

Assessment methods:

Final paper, Written exam

Keywords:

Chemical Reactions; Chemical Process Design; Sustainability

Faculty of Science and Engineering

Biotechnology

Full course description

This course aims at introducing you to the fields of Biology and Biotechnology. Starting from the definition of life, you will understand its basic characteristics, such as metabolism, growth, reproduction, response to stimuli and communication. You will study the cell as the basic unit of life, will learn the major differences between eukaryotes and prokaryotes, and will understand the classification of organisms to appreciate the principles of the diversity of species and evolution. You will become familiar with population dynamics and understand how it is affected by environmental changes. In addition, a basic understanding of how the genetic information of an organism relates to its phenotype will be gained, laying the basis to comprehend the core concept of biotechnology: the technological application of biological systems. You will become familiar with the major fields of biotechnology and will learn how biotechnological applications have already affected our daily lives.

Course objectives

At the end of this course, you are able to:

- Describe the building blocks of life and their structure-function relationship
- Illustrate how life is organized into hierarchical levels
- Explain the basic concepts of growth, development and reproduction and compare these between unicellular and multicellular organisms
- Describe the mechanisms and strategies that plant organism use to communicate with each other and to respond to the environment
- Explain the most important basic concepts in the fields of ecology and evolution
- Give examples of tools and approaches used in biotechnology
- Explain the relationship between genotype, phenotype and environment

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- Provide examples of how biotechnology can contribute to the circular economy
- Present about a scientific topic to an audience of scientific peers.

Recommended reading

Mandatory

Campbell, N. A., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Reece, J. B. (2018). *Biology: A global approach* (11th ed.). Pearson.

Recommended

Recommended literature and other sources would be at the end of each task. Feel free to approach the coordinator to suggest additional books/articles if you are interested in specific topics and/or desire to have more in depth information.

CEN1006

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [C.M. Padilla Díaz](#)

Teaching methods:

Lecture(s), PBL

Assessment methods:

Assignment, Written exam

Keywords:

Ecology; Evolution; Biotechnological Applications

Faculty of Science and Engineering

Thermodynamics and Engineering Physics

Full course description

Understanding thermodynamics is essential for any engineer as it is key to understanding the functioning of a wide range of mechanical and electronic devices, as well as the principles behind chemical reactions. This course requires the knowledge of Calculus and Linear Algebra as it provides the theoretical frameworks required to mathematically describe the basic concepts of many-particle systems in terms of their macroscopic quantities such as temperature, pressure and volume. The aim of this course is to comprehend the fundamentals of temperature and heat, thermal properties of matter, the laws of thermodynamics, entropy, enthalpy and free energy. These concepts are used to describe the properties gasses, liquids and ideal and non-ideal solids in terms of state functions. Lastly, these fundamental concepts are applied to understand the working mechanisms of basic reactor elements used in chemical engineering, including heaters, coolers, pumps and heat engines. Understanding of the abstract nature of these concepts is essential for further courses.

CEN1007

Circular Engineering

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [L.J.B.M. Kollau](#)

Teaching methods:

Lecture(s), PBL, Assignment(s)

Keywords:

Thermodynamic Principles; Circular Chemical Processes

Faculty of Science and Engineering

Multivariable Calculus

Full course description

Multivariable Calculus is an intermediate level mathematics course that builds on the prerequisite courses Calculus and Linear Algebra. It is an essential course within the programme as it allows you to understand fundamental engineering concepts, such as electromagnetism and mass transfer, of which several are discussed in the parallel course Thermodynamics and Engineering Physics. You get familiar with differentiation and integration of functions involving multiple variables. Considerable attention is devoted to vector calculus, differential equations, constrained optimization and numerical approximation techniques. Differentiation and integration of vector fields is primarily focused in 3-dimensional Euclidean space.

CEN1008

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [P. Diomedé](#)

Teaching methods:

Lecture(s), PBL

Keywords:

Integration Techniques; Dynamical Systems; Mathematical Argumentation

Year 1 Skills

Faculty of Science and Engineering

Academic Skills and Project Management

Full course description

This skills course is vital preparation for study on the BSc Circular Engineering Programme. This skills course will provide the basis of important aspects in a student's study skillset. Students will learn effective study techniques based on academic work in this area, they will learn methods for finding and evaluating information sources and develop their knowledge of the concept of uncertainty, probability and bias. Students will learn the importance of academic integrity as applied to university work specifically and academic study and technical work generally. Students will learn skills related to a variety of methods of assessment including the oral presentation of information.

Course objectives

At the end of this course, you are able to:

1. Identify and explain evidence-based study methods and recognise an effective study plan.
2. Describe methods for finding information sources and assess the quality of information obtained from those sources.
3. Understand the reasons for integrity and ethics in academic study and demonstrate the use of techniques such as paraphrasing and reference citation when presenting academic work for assessment.
4. Describe and demonstrate effective methods for presenting data and information orally and in writing.

Recommended reading

EdLab Web resources for study smart.
<https://www.studysmartpbl.com/>

SKI1101

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [G.J. Phillips](#)

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Assessment methods:

Assignment, Presentation

Keywords:

Academic Research and Writing; Project Management

Faculty of Science and Engineering

Basic Programming Skills

Full course description

In this course you will learn how to use the engineering software package MATLAB® environment (Mathworks Inc.) to perform mathematical computations and plot data. In parallel, you will get acquainted with basic programming, creating and running scripts, making m-files, and debugging.

A direct relation is with the course Linear Algebra, as you will perform matrix calculations with MATLAB. By learning to work with MATLAB, you will be able to solve many technical or mathematical problems also in other courses of this programme.

Course objectives

At the end of this course, you will be able to:

- Write scripts/functions with MATLAB syntax/code, using vectors, matrices, various loops, simple calculations, indexing and various preselected built-in MATLAB functions.
- Visualise data with MATLAB syntax/code including titles, axes, legends, line styles based on prescribed 2D drawings and/or equations of one variable with built in MATLAB functions
- Fit basic curves and numerical analysis with built-in MATLAB functions
- Debug and optimize performance of MATLAB code

Recommended reading

Mandatory

- The MATLAB Manual: Pekalska E., Babuska R. (2014-2015), Introduction to Matlab, Delft University of Technology, Delft, The Netherlands.

Recommended

Please find some other website that introduce MATLAB as well. Perhaps the wording is a bit more intuitive for you. Be aware that the MATLAB Manual is leading in terms of assessment material.

- Griffiths D. F., An introduction to MATLAB, University of Dundee, Dundee, Scotland, 2006. (link)
- The Mathworks, Getting started with MATLAB, The MathWorks, Inc. Natick, USA.

Software

MATLAB (Mathworks Inc.)

Internet, e.g. MATLAB Central

SKI1102

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

Circular Engineering

ECTS credits:

2.5

Coordinator:

- [P. Diomedé](#)

Teaching methods:

Training(s), Assignment(s), Skills

Assessment methods:

Assignment, Written exam

Keywords:

Coding; Scripting; Debugging; MATLAB

Faculty of Science and Engineering

Physics and Electronics Laboratory Skills

Full course description

This skills training is strongly related and therefore complementary to the course Fundamentals of Engineering. You perform physical experiments representative for each of the engineering domains that are studied on a theoretical level in the Fundamentals of Engineering course. You gain a deeper understanding of the fundamental physical principles and understanding that laws and mathematical descriptions are models of the real world. Special attention is paid to an appropriate statistical analysis of the scientific results. You train your interpretative skills by comparing your experimental measurements with theoretical calculations using statistical methods, MATLAB and reporting strategy. Furthermore, you learn to highlight sources of error and when to use theory or experiments to solve engineering problems.

SKI1103

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [B.R.N. van Grinsven](#)

Teaching methods:

Training(s), Assignment(s), Skills

Keywords:

Laws of Physics; Experiments; Statistical Analysis; Scientific Reporting

Faculty of Science and Engineering

Chemistry and Biology Laboratory Skills

Full course description

This skills training focuses on translating the basic concepts of chemistry and biology to laboratory work. You learn to work in a safe manner taking into account rules and regulations, with respect for

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yourself, others and the environment such as handling chemicals, safe use of equipment and usage of safety gear. You learn basic skills such as the accurate measurement of volumes, chemical lab techniques, basic spectroscopic analysis, biological sample preparation and analysis. Special attention is paid to a proper statistical analysis. You are provided with two tasks in which you are assessed on your capability to work safely, accurately, log and report your findings.

SKI1104

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [L.J.B.M. Kollau](#)

Teaching methods:

Lecture(s), Work in subgroups, Skills

Keywords:

Laws of Physics; Experiments; Statistical Analysis; Scientific Reporting

Year 1 Projects

Faculty of Science and Engineering

Life Cycle Assessment Project

Full course description

In the projects, typically (inter)personal skills are trained. In this project, teams of students are challenged to analyse the sustainability of products and production processes introduced by staff members from research groups or company representatives.

The LCA theory for this project was provided in course CEN1001, Engineering in a Circular Economy. In order to be able to execute the Life Cycle Assessment (LCA) project, students are introduced in instruction sessions to the project topic and what is expected from the LCA project. Teams of students will perform a (simplified) LCA study and will report their results at the end of the project.

The completion and success depend on working, thinking, acting, and learning as a team and sharing tasks and responsibilities with peers. The results are orally presented, documented in a report; individual and peer reflections are given on (inter)personal skills development.

Course objectives

At the end of this course, you are able to:

1. Demonstrate understanding of the environmental implications of the project topic and feasible engineering solutions by searching and studying additional literature;
2. Describe the four stages of life cycle assessment (LCA) and explain the important aspects in

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performing an LCA in each stage;

3. Apply the knowledge of the four stages of LCA on a circular engineering topic by performing a basic or partial LCA study and explaining the meaning of the results obtained from the LCA study performed;

4. Communicate on the project process and results by written text, illustrations, and oral presentation;

5. Reflect on your share and that of peers in team performance, your personal development including leadership, and the results of the project.

Prerequisites

None

Recommended reading

Mandatory

- Handbook on Environmental Assessment of Products, by Kirsten Pommer and Pernille Bech (Danish Technological Institute), Henrik Wenzel and Nina Caspersen and Stig Irving Olsen (Technical Knowledge Center of Denmark), 2000, Danish Environmental Protection Agency
- Book: Life Cycle Assessment: Quantitative Approaches for Decisions that Matter (2014), H. Scott Matthews, Chris Hendrickson, Deanna H. Matthews; available at <https://www.lcatextbook.com/>
- As part of the project, students will get information on the project topic. Students are expected to search for additional information. All information sources that are used (literature, books, patents, interviews) should be properly referred by a bibliography (see Library of Maastricht University for help and guidelines to cite).

Recommended

The following handbooks and resources are recommended if you are interested in Life Cycle Assessment and desire to have more in-depth information. They are by no means obligatory for the course.

- Handbook - General guide for Life Cycle Assessment. European Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010. The pdf file is available at: <http://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf>
- Information available at the website of the European platform on Life Cycle Assessment : http://eplca.jrc.ec.europa.eu/?page_id=86
- Book - Jolliet, O., Saade-Sbeih, M., Shaked, S., Jolliet, A., Crettaz, P. (2016). Environmental Life Cycle Assessment. Boca Raton: CRC Press, <https://doi.org/10.1201/b19138>

Software

- MS Word
- MS Excel

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- MS PowerPoint
- LCA calculation tools (internet & MS Excel)

PRO1110

Period 3

8 Jan 2024

2 Feb 2024

[Print course description](#)

ECTS credits:

5.0

Coordinators:

- [Y. van der Meer](#)
- [A. Ghannadzadeh](#)

Teaching methods:

Research, Working visit(s), Work in subgroups, Project-Centered Learning

Assessment methods:

Final paper, Presentation

Keywords:

Life Cycle Assessment; Environmental Impact; Research Project; Project Management

Faculty of Science and Engineering

Design Project

Full course description

You choose one of three projects that each cover one of three concentrations: Circular Chemical Engineering, Sustainable Biotechnology and Engineering Physics for Sustainable Manufacturing. After the end of the second year, you have performed one project related to each of the three concentrations, in your own preferred sequence. The aim of these three projects is to facilitate the integration of acquired knowledge and skills by addressing real-life circular engineering problems in collaboration with one of the Brightlands Campuses. By working in a team to execute the project, you also train your (inter)personal skills. You are introduced to a real-life case and provided with relevant background information in instructional sessions. The case consists of an existing product or process control system that needs to be modified to meet requirements of sustainability and circularity. The teams follow the engineering design cycle to solve the case at a conceptual level using basic calculations, scientific information and a solid line of reasoning. Considering the scope of the assignment, the completion and success depend on working, thinking, acting and learning as a team, sharing tasks and responsibilities among peers. This way of organising projects means that you not only execute the project, but also own and design it. The results are orally presented, documented in a report and individual reflections are written on (inter)personal skills development.

Course objectives

At the end of this course, you are able to: - Apply the design engineering cycle, circular economy concepts and design aspects (such as scarcity of materials, reuse, repair, remanufacturing and recycle, reduction of waste, water and energy consumption, life-cycle assessment), and emerging

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technologies to solve a simple problem in the circular engineering domain - Demonstrate understanding of societal and environmental implications of the project topic and feasible engineering solutions by searching and studying additional literature - Adapt to the professional, cultural and societal merits of the working environment of the representatives that offer the real-life design projects - Communicate on the project process and results by written text, illustrations and oral presentation - Reflect on your share and that of peers in team performance, your personal development including leadership, and the results of the project

Prerequisites

None

PRO2110

Period 6

10 Jun 2024

5 Jul 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [P.P.M. Aarts](#)

Teaching methods:

Research, Working visit(s), Work in subgroups, Project-Centered Learning

Keywords:

Research Project; Project Management; Circular Chemical Engineering; Sustainable Biotechnology; Engineering Physics for Sustainable Manufacturing

Second year

Year 2 Courses

Organic Chemistry

Full course description

This course focuses on the basis of organic chemistry. In the first part of the course, important fundamental topics, such as atomic theory, bonding theory, hybridization, molecular orbital theory and resonance will be discussed. A special topic will be stereochemistry, which is an essential topic in organic chemistry and the life sciences, since stereochemistry often determines the activity of biological compounds or medicines.

Subsequently, the course continues with an introduction into reactivity of organic molecules. Focus will be on a selection of fundamental organic reactions, which form the basis for a wide array of other organic reactions. To this end, a logical review will be provided of the reactivity of the most important functional groups, as applied in organic synthesis.

Course objectives

- To give the ability to recognize and name common organic compounds;
- To know the basic physical and chemical properties of common organic compounds;
- To understand stereochemistry and its impact on the properties and applications of organic molecules;
- To enable you to understand the most important organic reactions and be able to apply these reactions to obtain well defined organic compounds.

Prerequisites

- None

Co-requisites

- PRA2002 Chemical Synthesis

Corequisites

- [Chemical Synthesis](#)

Recommended reading

Klein; "Organic Chemistry"; 2th edition or 3rd edition; Wiley (ISBN: 9781118452288/978-1119110477).

CHE2001

Period 1

4 Sep 2023

27 Oct 2023

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Instruction language:

English

Coordinators:

- [H. Diliën](#)
- [M.B. Baker](#)

Teaching methods:

Lecture(s), PBL, Assignment(s)

Assessment methods:

Written exam, Attendance, Participation

Quantum Theory

Full course description

When looking at the world at very small scales, classical physics (classical mechanics, electromagnetism, thermodynamics) is no longer sufficient to explain our observations. In order to describe the phenomena at these scales, we need Quantum Mechanics and its wave functions, probabilities of reality and Schrödinger's equation.

This course forms an introduction into Quantum Mechanics, aimed at interested physics or chemistry students. Prior knowledge of classical physics, linear algebra and calculus will help with the mathematical part of this course.

In the course, we start from the failings of classical physics, we will see the necessity of describing the world in a different way, and try to make sense of it in terms of classical variables like position and momentum. We will calculate the quantized energy states of various analytically solvable systems like the square well potential and the harmonic oscillator, before turning to the proper linear-algebraic description of quantum mechanics. We will discuss commutation relations of operators, Heisenberg's uncertainty principle, Pauli's exclusion principle and spin. In the final week, we will analyze the hydrogen atom and its orbitals in 3 dimensions.

Course objectives

At the end of the course, students will be able to:

- Understand the foundations underlying Quantum Mechanics;
- Solve Schrödinger's wave equation for analytically solvable potentials;
- Calculate QM expectation values of physical observables and their time evolution;
- Use the operator and vector space notation in calculations;
- Calculate the non-classical behavior resulting from the postulates of QM;
- Describe the modern orbital atomic model of Hydrogen and analyze the corresponding wave functions.

Prerequisites

- MAT2004 Linear Algebra

Co-requisites

- None

Recommended

- MAT2006 Calculus
- PHY2001 Classical Mechanics

Note: Following Linear Algebra simultaneously to PHY2005 allows for a waiver.

- [Linear Algebra](#)

Recommended reading

- "Introduction to Quantum Mechanics", David J Griffiths

PHY2005

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

5.0

Instruction language:

English

Teaching methods:

Lecture(s), PBL

Assessment methods:

Assignment, Written exam, Attendance

Biochemistry

Full course description

Biochemistry is defined as 'the study of the molecules of living things'. However, knowledge about structures and properties of these intrinsically inanimate molecules only provides a static picture of living cells. It does not answer the most important question: How do these molecules confer the remarkable combination of characteristics we call life? That is, how can a living organism be more than the sum of its lifeless parts? Therefore, a more appropriate definition of Biochemistry is that it describes, in molecular terms, the structures, mechanisms and chemical processes shared by all organisms, and provides organizing principles that underlie life: the molecular logic of life. These principles can be summarized as:

- All living organisms build macromolecules from the same kind of rather simple small molecules (monomeric subunits)
- The structure of a macromolecule determines its specific biological function
- Each genus and species is defined by its distinctive set of macromolecules

Aim and approach:

As an introduction to various basic concepts in biochemistry and molecular biology, this course aims to communicate fundamental principles governing structure, function and interactions of biological molecules to students encountering biochemistry for the first time. The course is meant to lead to an increased appreciation of the science of biochemistry and will prepare students to enter more detailed courses on biochemistry and molecular biology to finally allow entrance to various Master programmes in the life sciences. The major objectives are:

- To communicate fundamental principles governing structure, function and interactions of biological molecules to students encountering biochemistry for the first time.
- To increase appreciation of the science of biochemistry.
- To study the synthesis and degradation of large biomacromolecules like proteins, lipids,

Circular Engineering

polysaccharides and nucleotides.

- To create deeper understanding of the basic principles of enzyme catalysis and inhibition.
- To prepare students to enter advanced courses that require more detailed biochemistry knowledge and to allow entrance to various Master programmes in the life sciences.

Course objectives

At the end of the course, you will be able to:

- Communicate on fundamental principles governing structure, function, and interactions of biological molecules;
- Appreciate the science of biochemistry and its relevance to Health and Disease;
- Understand the roles of macromolecules such as proteins, lipids, polysaccharides, and DNA in living cells and relate to diseases such as hyperventilation, thrombosis and scurvy;
- Identify, explain, and discuss the basic principles of enzyme catalysis and inhibition;
- Enter advanced courses that require more detailed biochemistry knowledge and enroll to various Master programs in life sciences.

Prerequisites

- None

Co-requisites

- None

Recommended reading

- Biochemistry (9th ed). ; Berg, J.M., Tymoczko, J.L., Gatto G.J., Stryer, L. ; W.H. Freeman and company. ISBN-10: 1-319-11465-2; ISBN-13: 978-1-319-11465-7;
- Biochemistry (6th ed.); Garrett R.H. and Grisham C.M. ; Cengage Learning. Student ed. ISBN: 978-1-305-57720-6; Loose-leaf ed. ISBN: 978-1-305-88604-9.

CHE2006

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Instruction language:

English

Coordinators:

- [N.M. Deckers](#)
- [L.J. Schurgers](#)
- [A. Jaminon](#)
- [S. Agten](#)
- [S.M. Agten](#)
- [A.M.G. Jaminon](#)

Teaching methods:

Circular Engineering

Lecture(s), PBL, Work in subgroups

Assessment methods:

Attendance, Written exam

Differential Equations

Full course description

This is a course about the art of using differential equations to model different phenomena in Physics, Chemistry and Biology. A differential equation is a mathematical equation for an unknown function of one or several variables that relates the values of the function itself and its derivatives of various orders. Differential equations can be broadly classified as linear and nonlinear, and ordinary and partial. This course is limited to linear and nonlinear ordinary differential equations. We will focus on understanding whether these differential equations have a solution, and if so, what properties this solution has. We will see how to solve first order and higher order differential equations including linear differential equations, second order differential equations with constant coefficients, using undetermined coefficients and variation of parameters. Since nonlinear differential equations are the main tool in the Natural Sciences and the differential equations occurring in real applications almost never can be solved analytically, we will see different numerical methodologies for solving differential equations.

Course objectives

This course is intended to introduce Science students in the essential mathematics to describe continuous systems with multiple variables, especially to analyse continuous time-varying systems as they occur in Electromagnetism, Hydrodynamics, and Quantum Mechanics.

Prerequisites

- MAT2006 Calculus

Co-requisites

- None

Recommended

- MAT1002 or MAT2004 Linear Algebra (highly recommended)
- [Calculus](#)

Recommended reading

We will use (note that you use the right edition!!!): “Calculus, A Complete Course” by A. Adams and C. Essex, (7 or 8) th Edition - Pearson 2014

MAT2008

Period 4

5 Feb 2024

Circular Engineering

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinators:

- [M.A. Hofstee](#)
- [C.E. Blackman](#)

Teaching methods:

Lecture(s), PBL, Skills

Assessment methods:

Written exam, Attendance, Assessment, Computertest

Faculty of Science and Engineering

Imaging Engineering

Full course description

A picture is worth a thousand words, but there are things the human eye cannot detect. Using singlelens microscopes of his own design and make, Dutch scientist Antoni van Leeuwenhoek (1632 - 1723) was the first to discover observe micro-organisms in water and can now be considered the Father of Microbiology. Since then, many more imaging technologies have been developed that allowed for numerous discoveries and these technologies are now commonly used in science, medicine, and industry. Imaging can be (and is) used to answer important questions: Is a paint coating applied homogeneously? Are impurities causing a semiconductor to fail? How and where does a pharmaceutical compound interact with a cell? Where are tumours located within the human body? The possibilities are endless and future Circular Engineers would therefore do well to understand imaging science and technology.

CEN2005

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [S.P.M. van Nuffel](#)

Faculty of Science and Engineering

Remake, Reuse, Repair, Recycle

Full course description

One of the great challenges of our time is to transition away from a linear to a circular economy for both biological (“renewable”) and technical (“finite”) materials. The current make-use-dispose needs to be replaced by circular loops that keep these resources in the system as long as possible. To this end, loops of circular economy have been proposed for both systems.

Circular Engineering

In essence, once a product (composed of materials) is in the market, creating circularity is achieved by first extending as much as possible the effective use of the product (Share, out of scope for this course) or the product lifetime (Maintain/Prolong and Refurbish/Remanufacture). When this has reached its maximum capacity, only then should we allow the product to go to end-of-life, at which point we keep the materials in the system via Recycle. These loops correspond to 3 of the “Rs” which are the topics of this course, namely Reuse, Repair and Recycle respectively. The fourth R is found at start-of-life, before the product is even made and is Remake (sometimes called Redesign), which considers how to make new products more suitable for the Circular Economy. In this course, we will explore the meaning and implications of these four Rs and apply them via several industrial case studies.

Course objectives

At the end of this course, we expect you to be able to:

- Understand and explain to others the basics of the circular economy for technical materials
- Analyze a product’s current fit to the circular economy and select one of the 4 R pathways to improve this, taking most recent developments into account.
- Justify your choice with up-to-date technical and scientific arguments.
- Connect non-engineering aspects (such as economic/ environmental cost, societal impacts) to an engineering challenge and as such grasp the extent

Recommended reading

For context, it is recommended to explore the Ellen MacArthur Foundation Learning Hub (<https://archive.ellenmacarthurfoundation.org/explore>). Topics of particular interest include:

- o What is the Circular Economy
- o The Circular Economy in detail
- o Fashion and the Circular Economy
- o Plastics and the Circular Economy
- o Circular Design
- o Systems and the Circular Economy

Literature related to the lectures and industrial cases will be distributed during the relevant sessions.

CEN2006

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [K.J.P. Ragaert](#)

Teaching methods:

Lecture(s), PBL

Assessment methods:

Fluid Mechanics

Full course description

In this course, you are introduced to the study of fluids in rest and motion, which is essential to many scientific and industrial applications. From nanoscopic DNA manipulation, to the design of microscopic chemical reactors, to macroscopic recycling of plastics by extrusion, these are all engineering examples at different length scales that depend on understanding fluid mechanics.

This course focuses on answering these key questions mainly at a macroscopic scale: what is a fluid? And what properties distinguish its mechanical behavior? Answering these questions will help establish the relationship between fluids and flows, which is significant for designing chemical and material processes and their related equipment. More specifically, understanding fluid flow is central to improving the sustainable processing of materials.

Fluid mechanics is the first building block of transport phenomena (along with mass and energy transport). Transport phenomena are indispensable to circular engineering since they correlate material properties and processing conditions with each other so that one can control the final properties/performance during production. This role is emphasized in this course, particularly in designing sustainable processes.

The course starts with an introduction to fluid properties and their effect on fluid flow and different types of flow, followed by fundamental principles of transport phenomena. Throughout the course, you learn how to apply these principles to solve practical engineering problems. Furthermore, complex fluids such as polymers and molten plastics will be addressed, which is highly relevant for designing the circular processing of plastics. At the end of the course, you are able to apply your acquired knowledge in process designs and optimization.

Course objectives

At the end of this course, we expect students to be able to:

- Understand fluid properties and behavior
- Analyze processes that involve fluid flow
- Improve fluid transport efficiency
- Implement Fluid Mechanics principles in Circular Engineering

Recommended reading

Transport Phenomena, 2nd Edition; R. B. Bird, W. E. Stewart, E. N. Lightfoot; Wiley 2002.

CEN2007

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

- [A. Gooneie](#)

Teaching methods:

PBL, Lecture(s)

Assessment methods:

Assignment, Written exam

Faculty of Science and Engineering

Energy Systems

Full course description

All products and processes consume or produce energy and use the existing energy infrastructure. Engineers often assume that this energy system exists without any limitations when developing or improving products and processes. We are becoming increasingly aware that there are limitations to the current energy system. We also know that the transition towards more sustainable energy requires major changes to the energy system, leading to new challenges to assure a stable and reliable energy supply. These challenges and discussions are not only influenced by technical abilities, but also by economics, markets, policies and regulations.

Energy is an integral part of many courses with the BSc Circular Engineering, because it plays a key role in the making of products and operation of processes. In some of the courses, e.g. Engineering in a Circular Economy and Chemical Engineering, alternative sustainable energy options have been discussed, but none of the courses have yet dealt with the complex energy system itself and how it can be transformed from a fossil-based system towards a sustainable and circular system. This course focusses on the energy system itself. It introduces you to the importance of energy for society while focusing on the urgency of the transition towards renewable energy and the related challenges to obtain a stable and reliable energy system. This makes the course useful for students aiming at any of the concentrations.

Course objectives

At the end of this course, we expect you to be able to:

- Describe and discuss the production, storage and use of energy in the contemporary global economy
- Quantitatively compare energy sources and appraise their utility and impacts within the energy system and on the surroundings/environment
- Assess the appropriateness of integrated energy sources and produce evidenced proposals for energy systems using current academic insights to solve energy circularity challenges

Recommended reading

- T. Bradford (2019), The Energy System; Technology, Economics, Markets, and Policy, The MIT Press (hardcopy available with tutor and library)
- D. Mc Kay (2008), Sustainable Energy- without the hot air, www.withouthotair.com

Circular Engineering

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [C. Koopman](#)

Teaching methods:

PBL, Lecture(s)

Assessment methods:

Assignment, Final paper, Written exam

Faculty of Science and Engineering

Sustainable Food Production

Full course description

One of the most important challenges of our time is to ensure a sustainable future. It is no coincidence that the United Nations (UN) has designated sustainability as a global challenge. We are in need of sustainable solutions for complex, regional and global issues that affect our health and the food system. These issues include - among others - climate change, soil degradation, loss of biodiversity and water shortages. Sustainable food production and consumption requires achieving a new balance between planetary boundaries and agricultural practices without negatively affecting the survivability of the industry.

This course introduces you to food systems in relation to their environmental and economic impact. Increasing or ensuring the availability of safe and healthy food is a complex undertaking, with many challenges related to production, processing, transport, and consumption of food. Circular engineers can play an important role in making production systems more efficient and sustainable. However, as the various components of modern food production systems are inextricably linked, it is difficult to accurately assess the ecological and economic footprint of these systems. This course is centered on global, regional and local case studies involving food production challenges. You will learn how tools and methods of sustainability assessment are applied in the industry (some of which you came across in the first year of the programme).

To bring about changes towards more sustainable food production, it is also necessary to know the different stakeholders involved and to evaluate different possible scenarios. Special attention is paid to the role of consumer acceptance of biotechnological innovations, as this could limit the adoption of more sustainable practices in food production.

CEN2009

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

Polymeric Materials

Full course description

A little more than a century ago, around 1910, a revolution in the field of materials started with the commercialization of synthetic polymers. A new era began – the so-called age of plastics. At that time, plastics were acclaimed seen as extraordinary materials, due to their remarkable properties such as durability, lightweight, and easy processability. Due to these characteristics, coupled with their competitive fabrication costs, polymers gradually substituted conventional materials, such as metals, ceramics, natural fibers, and wood. The application of polymeric materials showed exponential growth starting in the 1940s. Polymeric materials are currently used in countless applications and they are fundamentally important for the well-being of humanity, and they have been used in both ordinary and high-end products, from packaging to the aerospace industry.

The molecular structure of polymers is intimately related to their physicochemical (macroscopic) properties. Controlling the molecular structure – defined during the polymer's synthesis – allows the settings of the polymer properties and broadens their applications. Therefore, understanding their synthesis, flow-ability, thermos-physical characteristics, and structure-properties relationship help in the appropriate selection of polymeric materials according to the application`s requisites.

Furthermore, many processing and recycling techniques may be used to transform polymers. These techniques depend on the design, quality, and demand of the parts, as well as the polymer`s nature, among others, and affects the sustainability aspects of polymeric materials. This course will cover all the topics presented above and is an introduction to the fascinating field of polymeric materials.

Course objectives

At the end of this course, we expect you to be able to:

- Identify the main characteristics of polymers.
- Explain how polymers are synthesized and differentiate their molecular structures.
- Recognize the main physical properties of polymers
- Describe the viscoelastic phenomenon and the flow behaviour of polymers.
- Correlate polymer structures with their properties and applications.
- Distinguish the main processing and recycling methodologies.

Recommended reading

Mandatory

- Rudin, Alfred. Elements of Polymer Science & Engineering: An Introductory Text and Reference for Engineers and Chemists. Elsevier, 1999.
- Nicholson, John W. The Chemistry of Polymers. Royal Society of Chemistry, 2006.
- Davis, Fred J., ed. Polymer chemistry: a practical approach. Oxford University Press on Demand 2004.
- Subramanian, Muralisrinivasan. Basics of polymers: fabrication and processing

Circular Engineering

technology. Momentum Press, 2015.

- Van Krevelen, Dirk Willem, and Klaas Te Nijenhuis. Properties of polymers: their correlation with chemical structure; their numerical estimation and prediction from additive group contributions. Elsevier, 2009.

Recommended:

- Han, Chang Dae. Rheology and processing of polymeric materials: Volume 1: Polymer Rheology. Oxford University Press on Demand, 2007.
- Schramm, Gebhard. A practical approach to rheology and rheometry. Karlsruhe: Haake, 1994.
- Odian, George. Principles of polymerization. John Wiley & Sons, 2004.
- Hiemenz, Paul C., and Timothy P. Lodge. Polymer chemistry. CRC press, 2007.

CEN2013

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [R. Fiorio](#)

Teaching methods:

PBL, Lecture(s)

Assessment methods:

Assessment

Faculty of Science and Engineering

Sustainable Agronomy

Full course description

The course teaches you how various biotechnological concepts can help to reduce the pressure of agriculture on natural resources and the environment. This course is specifically interesting for students preparing for the Sustainable Biotechnology concentration in year 3. This course explores concepts of sustainability in the context of agriculture and horticulture production systems: how can we meet the ever-increasing need of society for food, feed, textiles and biobased materials despite the challenges posed by global climate change and urbanization, and while reducing the pressure on natural resources and the environment? You learn what the main factors are affecting agronomy sustainability in general. In particular, the course focusses on those aspects that can be influenced or addressed using biotechnology. By building on the knowledge acquired in previous courses, you reflect on how biotechnology can aid in reducing the pressure of agriculture on natural resources and the environment. You deepen your understanding of plant-microbe interactions and how these can be exploited and promoted for sustainable agriculture. You learn the importance of biodiversity, its conservation and the utilization of wild gene pools. You understand how classical and new breeding technologies can be applied to e.g. increase the yield per hectare to reduce the use of land; make plants resistant to pathogens or produce bio-pesticides to reduce environmental pollution and increase food quality; develop drought-tolerant crops to reduce the use of water.

CEN2015

Circular Engineering

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [C.M. Padilla Díaz](#)

Faculty of Science and Engineering

Data Science and Analysis

Full course description

The course builds on the knowledge obtained during the course Basic Programming Skills and is valuable to students choosing any of the three concentrations in year 3. Within the modern world and in science, abundant streams of data are generated. This course focuses on methods to pre-process, analyse and interpret relevant information. Items that are introduced are datamining, pre-processing, databases, explore data, datatypes, labelling, machine learning and data visualizations. You apply these techniques in computer assignments that are completed in appropriate software environment. Furthermore, data management is an essential aspect to conduct responsible research. You learn to understand the general rules of appropriate data management and define roles and responsibilities regarding data management. You study scientific literature on this topic with a focus on an engineering and natural sciences point of view. Subsequently, you are required to develop and implement a communication plan dealing with data management issues.

CEN2016

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [M.C. Popa](#)

Faculty of Science and Engineering

Circular Business Development

Full course description

This course builds upon the course Engineering in a Circular Economy and Life Cycle Assessment Project. You are encouraged to apply the concepts of the circular economy to solve cases being representative of linear-to-circular challenges. You approach each case by searching and studying relevant background information and example solutions applied in similar products. You are guided to relevant databases, books and journal papers. To solve the cases, you select and apply one of the circular economy business models which should encompass all economic aspects such as resources,

Circular Engineering

logistics, savings on energy and waste streams, financing and product pricing. Where possible the full footprint is worked out. You should support your solution by a solid line of reasoning, basic calculations, experimental or computational evidence.

CEN2018

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

5.0

Coordinators:

- [N.M.P. Bocken](#)
- [C.D.J.D.A. Bluntz](#)

Faculty of Science and Engineering

Heat and Mass Transfer

Full course description

Heat and mass transfer occur if systems are out of equilibrium. For example, a temperature difference will transfer energy in the form of heat from one system to the other. Thermodynamics deals with the amount of heat that will equilibrate the systems. The science of heat and mass transfer concerns the rate or time scales of transfer. It enables one to design household appliances such as air-conditioners and fridges, car engines, computer chips coolers, home insulation, etc. – as to keep or limit temperature differences to a desired range. Similarly, in chemical reactor engineering, heat differences are required to initiate or stop chemical reactions, as well is mass transfer to exchange products and reactants.

Prerequisites

PREREQUISITE for the Concentration Circular Chemical Engineering in Year 3.

CEN2019

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [G.J. van Rooij](#)

Faculty of Science and Engineering

Genetics and Cell Biology

Full course description

Cells are the building blocks of life on earth, and all organisms consist of at least one cell. In fact, most organisms on our planet (i.e. bacteria) only consist of a single cell. Other organisms such as plants and animals consist of a wide variety of cells, with complex inner workings depending on their location within the organism. The human body, for instance, consists of trillions of cells and hundreds of different types of cells. These cells perform all the functions of the body and thus form the basis of life. In this course, the most important cell biological and cell physiological principles will be discussed.

In each living cell, a network of more than a thousand different chemical reactions is responsible for generating energy and putting together the building blocks for a new cell. When we think of these cells as little factories, the DNA in the cell forms the blueprint of how the factory should be designed and run. These instructions embedded in the genetic code set in motion a complex machinery of countless proteins that function as cogwheels in this “gigantic” machine, which we call the cell. This genetic code not only instructs the cell what to do, but when considered from a broader perspective, also passes on hereditary traits when new cells are formed.

Genetics is the biological science that studies heredity, and its insights – combined with in depth knowledge of cell biology – are very valuable to circular engineers. Currently, different production processes in modern (circular) industries make use of organisms and their specific properties. Bioreactors in chemical processes, for instance, allow microorganisms – mostly bacteria, yeasts or fungi – to thrive and produce useful substances. The production of sufficient, safe and healthy plant foods increasingly relies on high-tech crop breeding methods, such as genetically modifying the traits of seeds. This course is a prerequisite for studying the Circular Engineering concentration Sustainable Biotechnology.

Prerequisites

PREREQUISITE for the Concentration Sustainable Biotechnology in Year 3

CEN2020

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [K.J.P. Verhees](#)

Faculty of Science and Engineering

Electronics Engineering

Full course description

Nearly everything we use in this day and age relies on electronics, from your smartphone to your favourite mode of transportation, without us consciously realizing, electronics are driving the world around us. In this course, you will learn that the user-friendly devices we all know are driven by a complex interplay of electronic components that operate on fundamental electronic principles. The goal of this course is to introduce you into the world of electronic engineering. Students will get acquainted with the most fundamental electrical theories and will learn about the functioning of specific components and how they form the basis of more complex electrical circuits. We hope that throughout this course you learn to appreciate how the technology around you functions and we hope to pull apart some electronic devices to explore their inner workings.

Prerequisites

PREREQUISITE for the Concentration Engineering Physics in Year 3.

CEN2021

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [B.R.N. van Grinsven](#)

Faculty of Science and Engineering

Biobased Materials

Full course description

Concerns about climate change and the secure supply of industrial feedstock sources have accelerated the interest in and the development of biobased materials. However, scientists, companies, and policymakers face technological, environmental, and societal challenges to develop the materials of the future that fulfill the required functions in society and are also more sustainable.

This course aims to create a critical as well as a creative and inventive circular attitude towards biobased materials. Students will be introduced to the field of Biobased Materials in a multidisciplinary approach in which biology, chemistry, engineering, and sustainability studies are integrated to study and design the materials of the future. At the end of the course, students will present a scientific case study and provide and defend their views on the challenges and opportunities of biobased materials.

CEN2022

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

- [Y. van der Meer](#)

Year 2 Skills

Chemical Synthesis

Full course description

This skills focuses on the development of a clear understanding of the synthesis of organic chemical compounds. It is important for the students to learn how to convert their theoretical knowledge on chemical reactivity to actual design and execution of synthetic chemical reactions. Typical topics, which will be covered in this skills training are:

- Safe handling of organic reagents and safe execution of organic experiments.
- Commonly used organic synthetic laboratory techniques.
- Synthetic chemistry of various organic reaction types (e.g. nucleophilic substitutions and eliminations, electrophilic reactions and radical chemistry).
- Stereochemistry in organic synthesis.
- Purifications and separations in chemistry.
- Spectroscopy and characterization of organic compounds.

Course objectives

- To be able to perform organic synthetic experiments in a structured and safe manner;
- To understand specific separation and purification techniques commonly used in organic chemistry;
- To gain a practical understanding of the impact of the choice of reagents, solvents and conditions on the outcome of an organic reaction;
- To gain further skills in scientific research reporting.

Prerequisites

- PRA1101 Introduction to Scientific Research I
- PRA1102 Introduction to Scientific Research II

Co-requisites

- CHE2001 Organic Chemistry

Corequisites

- [Organic Chemistry](#)

Recommended reading

- Practical laboratory instructions;
- For students intending on continuing and specializing in organic chemistry, a practical book, such as “Multiscale Operational Organic Chemistry” by John W. Lehman (Pearson, 2nd edition, 2009) may be interesting

PRA2002

Period 1

4 Sep 2023

27 Oct 2023

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

2.5

Instruction language:

English

Coordinators:

- [H. Diliën](#)
- [M.B. Baker](#)

Teaching methods:

Paper(s), Skills

Assessment methods:

Attendance, Assessment

Faculty of Science and Engineering

Statistics Skills

Full course description

Statistics is the science and technique of processing, interpreting and presenting data. Descriptive statistics helps visualize data and allows data to be presented in a meaningful and understandable way. This allows for a simplified interpretation or summary of the data set in question, for example by describing the relationship between two variables. Going beyond describing data, statistical inference tests specific hypotheses with respect to the data. As these statistical methods are used to convert large amounts of data into useful information, they are a valuable instrument in the toolbox of the circular engineer.

Marketing communication in circular economy is full of statistical claims, and it is well-known that statistical tools are not always used correctly. In fact, greenwashing and various kinds of biases and undisclosed assumptions have caused a lot of damage for the reputation of certain companies and individual workers. Understanding of the statistical claims of competitors, partners, and stakeholders, and the ability produce statistically plausible evidence on the impact and benefits of your own work are vital for high quality of work in circular engineering.

SKI2101

Period 2

30 Oct 2023

Circular Engineering

22 Dec 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [A.S. Härmä](#)

Faculty of Science and Engineering

Bioinformatics Skills

Full course description

Bioinformatics uses computational approaches to manage, analyze and visualize biological data. Especially in the biotechnology field but also in chemical engineering, bioinformatics has a major contribution when considering the advances in e.g. data management, sequencing data analysis, or drug design. In recent years, the complexity of biological systems has gained attention. An entirely new field emerged, Systems Biology, that now drives the development of computational approaches to model and simulate biological systems on different scales.

In this course, you can apply your programming skills from the basic programming course in the first year, and study complex real-world biological systems using different computational techniques. Many of the methodologies are already used in biotechnology when modeling metabolism for increasing microbial potential, modeling plant segregation using Mendel's law, or simulating population growth. We selected five relevant and commonly used approaches for this skills course. You will realize how versatile and widely applicable many of the methods are so you can apply them in a completely different (even non-biological) setting.

Experts in the particular approaches from the Maastricht Centre for Systems Biology (MaCSBio) and related departments will teach the different sessions.

SKI2102

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [M. Summer - Kutmon](#)

Faculty of Science and Engineering

Genetics Skills

Full course description

Genetics is the study of how genes bring about characteristics (or traits) in living organisms and how those characteristics are inherited, and its insights - combined with in depth knowledge of cell

Circular Engineering

biology - are very valuable to circular engineers. Currently, different production processes in modern (circular) industries make use of (micro)organisms and their specific properties. Bioreactors in chemical processes, for instance, allow microorganisms - mostly bacteria, yeasts or fungi - to thrive and produce useful substances/compounds. Furthermore, the production of sufficient, safe and healthy plant foods increasingly relies on high-tech crop breeding methods (e.g. genetically modifying seeds). At the heart of these technological developments lies genetic engineering, which comprises a host of laboratory-based technologies to alter the DNA makeup of an organism.

This skills course is aimed at obtaining a basic introduction to techniques and methods currently used in modern molecular biology, thus providing the student with technical, hands-on experience in the field of genetics/molecular biology. This laboratory course is strongly related to the course *CEN2020 Genetics & Cell Biology*. This training is a particular useful preparation for the *Sustainable Biotechnology* concentration in year 3 and consists primarily of "wet lab" sessions, in combination with self-study (protocols, questionnaires, data analysis) and *in silico* analysis.

At the end of this course, we expect you to be able to:

- Purify genomic DNA from eukaryotic cells (buccal cells);
- Perform quantitative analyses on nucleic acids (DNA quantification using spectrophotometry);
- Analyse DNA products using agarose gel electrophoresis;
- Comprehend and perform classical polymerase chain reaction (PCR) analysis;
- Perform DNA restriction analysis using restriction enzymes (RE);
- Comprehend analysis of polymorphisms using Restriction Fragment Length Polymorphism (RFLP), including *in silico* analysis;
- To isolate RNA from eukaryotic cells (buccal cells);
- Synthesize complementary DNA (cDNA) by reverse transcription;
- Comprehend and perform real-time quantitative reverse transcription PCR (qRT-PCR or qPCR);
- Perform computational gene expression analysis upon qRT-PCR (qPCR data analysis).

SKI2105

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [K.J.P. Verhees](#)

Faculty of Science and Engineering

Advanced Programming Skills

Full course description

With the modernization and automation trends across all fields and professions, programming and coding skills become imperative for engineers. With more open-source programming languages and hardware becoming available, the step towards custom build set-ups and instrumentation is becoming ever smaller and more accessible.

Circular Engineering

This course is designed as a follow up course to Basic Programming Skills in year 1, where MATLAB is introduced. In this course, you learn how to use the open source programming and scripting language Python. By having to transfer your existing knowledge of MATLAB to Python, you deepen your understanding of both languages and it will lower the barrier to learning more programming languages in the future.

While developing skills in Python, you have to apply this knowledge by using common data analysis techniques, like visualization, smoothing, and fitting to generic and specific functions. In addition to data treatment, you learn how to use Python to program a Raspberry Pi in teams. The addition of data acquisition to your skillset enables you to tackle nearly all practical challenges engineering has to offer. The use of Raspberry Pi's has increased enormously due to the potential it has to build custom set-ups. This can range from controlling sensors to measure e.g. temperature and/or pressures at given intervals or to program a control unit to automate entire experiments. This will especially be useful for circular engineers as the data they need to propose more sustainable processes is often not readily available or can be expensive to obtain with commercial devices.

Students who have completed this skills course will be confident to build a custom set-up for any purpose in their studies and beyond that during their career. You will be challenged to come up with creative solutions to problems by identifying what is the core of the problem and tackling exactly these.

Course objectives

At the end of this course, we expect you to be able to:

- Write scripts/functions with Python syntax/code, using targeted at data processing and visualization.
- Fit advanced curves, numerical and statistical analysis with Python.
- Write a simple program to run on the Raspberry Pi.
- Use the Raspberry Pi to control a given sensor.

Recommended reading

- Python Data Science Handbook: Essential Tools for Working with Data (2016), Jake VanderPlas, O'Reilly Media, USA.

SKI2106

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [L.J.B.M. Kollau](#)

Teaching methods:

PBL, Skills

Assessment methods:

Portfolio, Presentation, Take home exam

Faculty of Science and Engineering

Plant Biology Skills

Full course description

Nowadays our society demands novel, sustainable and nutritious food sources to feed the increasing human population. A potential solution can be found by plant cell cultures due to their possibilities as sources of food, proteins, energy and fiber. Plant cell tissue culture is considered as a key factor in the 'second green agricultural revolution' due to the fact that crop yield and quality are modulated by biotechnological approaches. Plant cell tissue culture combine the biotechnological possibilities of creating new varieties by gene editing in a shorter period of time than traditional breeding techniques in order to solve problems of crop improvement such as disease resistances. Therefore, considering a closed-loop system perspective of recycling plant materials, a sustainable plant biotechnology approach can be found. With the techniques learned in this skill course, you will be able to acquire fundamentals of plant functioning to be applied in a biotechnology and sustainable context.

Course objectives

At the end of this course, we expect you to be able to:

- Identify plant organs and tissues and understand their structure-function relationship
- Manipulate and isolate protoplasts from different plant tissues for different purposes while following complex laboratory protocols
- Understand how small plants (plantlets) can grow under different medium requirements from different types of protoplasts by using diverse laboratory protocols
- Explain the agronomic purpose of propagating and genetically manipulating plants by to a scientific audience
- Provide examples of how plant cell cultures can contribute to the circular economy and agriculture

Recommended reading

Mandatory:

The following concepts from the Biotechnology course (CEN1006) have to be checked in order to fully comprehend new concepts introduced in this course. Therefore, please read again the listed chapters from the following book:

Campbell, N. A., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Reece, J. B. (2018). *Biology: A global approach* (11th ed.). Pearson.

Concept 19.1: DNA sequencing and DNA cloning are valuable tools for genetic engineering and biological inquiry

Concept 19.3: Cloned organisms and stem cells are useful for basic research and other applications

Concept 19.4: The practical applications of DNA-based biotechnology affect our lives in many ways

During the course, please read from Campbell et al. (2018) the following chapters: See the manual.

Recommended:

- Wang, K., & Zhang, F. (2022). *Protoplast Technology* (1st ed.). Humana New York.

Circular Engineering

<https://doi.org/10.1007/978-1-0716-2164-6>

- □ Neumann, K.-H., Kumar, A., & Imani, J. (2020). Plant Cell and Tissue Culture – A Tool in Biotechnology. In Plant Cell and Tissue Culture – A Tool in Biotechnology (2nd ed). Springer Nature. <https://doi.org/10.1007/978-3-030-49098-0>
- □ Collin H.A. & Edwards, G.S. (1998). Plant Cell Culture. Springer

SKI2108

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [C.M. Padilla Díaz](#)

Teaching methods:

PBL, Skills

Assessment methods:

Portfolio, Presentation, Written exam

Faculty of Science and Engineering

Polymer Processing Skills

Full course description

Polymers are deeply rooted in our society as a primary class of materials due to their flexibility to be converted into valuable products through various processing techniques. Today, polymeric materials are used in nearly all areas of our daily life, from medicine and food to transportation, energy, and beyond. Therefore, their production has created major worldwide industries. In recent years, the sustainability of polymers has raised many concerns, and hence, enabling their recycling within circular industrial setups is crucial. This course introduces the students to this topic and addresses its scientific and technological challenges with a focus on thermoplastic polymers.

Polymer processing generally involves transforming polymeric materials from raw and/or recycled resources into the final products. It is a fundamental part of the polymer science and engineering field and is essential to various parts of an intricate industrial complex. Understanding some of the features of polymer processing can be an asset in dealing with production problems encountered not only in the polymer and plastics industry but in the broader scope of manufacturing.

Thermoplastic polymers are often processed in the molten state, where the melt flow in the equipment is at the heart of production. For this reason, polymer processing is intertwined with fluid mechanics and rheology. In this course, students will gain hands-on practice in the processing of thermoplastics in close relation to their rheological and mechanical properties. Furthermore, they will learn the effects of mechanical recycling on the final properties.

SKI2110

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

Circular Engineering

ECTS credits:

2.5

Coordinator:

- [A. Gooneie](#)

Faculty of Science and Engineering

Signal Processing and Control Skills

Full course description

This course builds upon several first year courses such as Calculus, Linear Algebra, Physics and Electronics Laboratory Skills and Basic Programming Skills. In the first year courses, the focus was on data acquisition and introduction of software and basic mathematical tools. In this course, you are introduced to signal processing and control theory such as the relation between continuous and discrete signals, theory of Nyquist, elementary filter techniques, noise, moving average, low and high band pass, Fourier and Laplace transformation, open vs closed control systems and Bode diagrams of 1st and 2nd order systems. Each theoretical aspect is supported by a computer assignment to be performed with appropriate software, where datasets of actual measurements need to be processed and visualised.

SKI2112

Period 5

8 Apr 2024

7 Jun 2024

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [I.G.M. Anthony](#)

Year 2 Projects

Faculty of Science and Engineering

Design Project 2

Full course description

You choose one of three projects that each cover one of three concentrations: Circular Chemical Engineering, Sustainable Biotechnology and Engineering Physics for Sustainable Manufacturing. After the end of the second year, you have performed one project related to each of the three concentrations, in your own preferred sequence. The aim of these three projects is to facilitate the integration of acquired knowledge and skills by addressing real-life circular engineering problems in collaboration with one of the Brightlands Campuses. By working in a team to execute the project, you also train your (inter)personal skills. You are introduced to a real-life case and provided with relevant background information in instructional sessions. The case consists of an existing product

Circular Engineering

or process control system that needs to be modified to meet requirements of sustainability and circularity. The teams follow the engineering design cycle to solve the case at a conceptual level using basic calculations, scientific information and a solid line of reasoning. Considering the scope of the assignment, the completion and success depend on working, thinking, acting and learning as a team, sharing tasks and responsibilities among peers. This way of organising projects means that you not only execute the project, but also own and design it. The results are orally presented, documented in a report and individual reflections are written on (inter)personal skills development.

PRO2111

Period 3

8 Jan 2024

2 Feb 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [P.P.M. Aarts](#)

Teaching methods:

Research, Working visit(s), Work in subgroups, Project-Centered Learning

Faculty of Science and Engineering

Design Project 3

Full course description

You choose one of three projects that each cover one of three concentrations: Circular Chemical Engineering, Sustainable Biotechnology and Engineering Physics for Sustainable Manufacturing. After the end of the second year, you have performed one project related to each of the three concentrations, in your own preferred sequence. The aim of these three projects is to facilitate the integration of acquired knowledge and skills by addressing real-life circular engineering problems in collaboration with one of the Brightlands Campuses. By working in a team to execute the project, you also train your (inter)personal skills. You are introduced to a real-life case and provided with relevant background information in instructional sessions. The case consists of an existing product or process control system that needs to be modified to meet requirements of sustainability and circularity. The teams follow the engineering design cycle to solve the case at a conceptual level using basic calculations, scientific information and a solid line of reasoning. Considering the scope of the assignment, the completion and success depend on working, thinking, acting and learning as a team, sharing tasks and responsibilities among peers. This way of organising projects means that you not only execute the project, but also own and design it. The results are orally presented, documented in a report and individual reflections are written on (inter)personal skills development.

PRO2112

Period 6

10 Jun 2024

5 Jul 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

Circular Engineering

- [P.P.M. Aarts](#)

Teaching methods:

Research, Working visit(s), Work in subgroups, Project-Centered Learning

Third year

Concentration Circular Chemical Engineering

Faculty of Science and Engineering

Chemical Eng. Thermodynamics & Kinetics

Full course description

This course builds upon the first-year course Thermodynamics and Engineering Physics and uses the knowledge of the mathematical courses. In circular and sustainable process engineering, the word symbiosis encompasses the output of one process being the input of another process that traditionally are non-related. Traditionally, chemists and chemical engineers work with pure or refined resources, but inclusion of the circular concepts and symbioses impact process design. In this course, you link concepts in process design, including (i) flow sheet design and topology (using ASPEN software), and (ii) economic and environmental simulation and optimization of reactor, separation and energy conversion unit sequences following extended hierarchical Douglas methodologies to fundamentals of thermodynamics and kinetics. Gibbs free energy and chemical potential are introduced in the context of phase equilibrium, chemical reaction equilibria and rates in ideal and heterogeneous systems. Additionally, concepts in power generation and refrigeration cycles are introduced and analysed.

CEN3001

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [L.J.B.M. Kollau](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Reactor Engineering

Full course description

This course builds on the first-year courses Chemical Engineering, Basic Programming Skills and the mathematical courses. You are introduced in the creation and analysis of mole balances for the three elementary reactor models being the perfectly-mixed Batch reactor, the Continuous Stirred Tank Reactor (CSTR) and Plug-Flow Reactor (PFR). Besides a profound understanding of rate laws,

Circular Engineering

stoichiometry, reaction rates and order, conversion and selectivity and function of temperature and pressure are pivotal. Numerical analysis to the design and performance of the reactors and their comparison is adopted for simple and more complex reaction chemistries such as gas reactions, recycle reactors, serial CSTR and autocatalytic reactions.

CEN3002

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [T.D. Butterworth](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Industrial Process Design Skills

Full course description

In this skills course, teams of students operate at the pilot plants of the Brightlands Chemelot Campus and use knowledge from courses such as Chemical Engineering, Engineering in a Circular Economy, Thermodynamics and Engineering Physics, Basic Programming Skills as well as the second-year elective courses. You no longer merely optimise these plants from an economic perspective, but also consider environmental and social criteria for optimization. You propose a strategy for developing a pilot process for the fabrication of biofuel from algae, which must result in technologically viable solutions and also demands the combination of process analysis and simulations, mole and energy balances and product life cycle analysis.

SKI3101

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [C. Koopman](#)

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Faculty of Science and Engineering

Separations Processes

Full course description

The course integrates insights from with the mathematical courses, Chemical Engineering, Basic Programming Skills and Heat and Mass Transfer and introduces you to various separation techniques used in the field of chemical engineering. You learn when and how to use these techniques by studying key concepts and by performing design calculations. One example is the evaporative separation in distillation towers. These towers are designed to separate liquid mixtures based on a difference of volatility and with the McCabe-Thiele method you can calculate the size of the column to separate the liquids. Similar approaches studied are absorption techniques, liquid-liquid extractions, crystallization or precipitation and filtration. Lastly, you are required to analyse strengths and weaknesses of the separation techniques and convert this knowledge to criteria such as economics, feasibility, product stability, reliability and sustainability and circularity and use these for the selection of separation methods in sustainable chemical processes.

CEN3003

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [C. Koopman](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Chemical Plant Design

Full course description

This course builds on the previous courses of the Circular Chemical Engineering concentration as you learn how to integrate aspects of energy efficiency, sustainability and circularity in designing a process and plant design of the future. The course provides an overview of project steps required to obtain a chemical plant design and is structured accordingly. First, you learn how to translate a process objective to a process flowsheet including the selection, specification and chemical engineering design of equipment. From various design options, you then select an optimal process design by considering investment and operating costs, safety, environment, energy efficiency, flexibility, circularity etc. Lastly, you learn how to translate the chosen process design into a plant design, in which aspects of sustainability and circularity should also be taken into account.

CEN3004

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

Circular Engineering

- [C. Koopman](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Unit Operations Skills

Full course description

In this skills course, you are introduced to the various unit operations used in the field of chemical engineering. Through examples from textbooks and the infrastructure existing on the Brightlands Chemelot Campus, you evaluate the four basic unit operations including fluid mechanics, heat and mass transfer, equilibrium stages and operations involving particulate solids. Starting from process flow diagrams in combination with visits of real life production plants, you discuss various components including cooling towers, refrigerators/heat pumps, distillation towers (boiling/condensation), mixing and emulsification processes and their typical equipment design and operation.

SKI3102

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [C. Koopman](#)

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Faculty of Science and Engineering

Circular Process Design and Control

Full course description

This course follows up on the core course in Chemical Engineering as well as the previous concentration courses in Reactor Engineering, Chemical Separations and Unit Operation Skills. Combining all knowledge, insights and experiences, you are required to address sustainability issues of existing reactor design and the accompanying industrial challenges in upgrading/updating existing production plants. To this end, you are provided with relevant background information on state-of-the-art reactor design and process intensification technology, based upon which you could select an approach for your assignment. Subsequently, teams of students perform a technical and economic evaluation for a real-life application, such as the production of biofuel from algae on the Brightlands Chemelot Campus and blend in sustainability and/or circularity requirements. You set up design criteria, use ASPEN software for the calculation of the relevant separation techniques and the corresponding energy and mass balances and diverge to find optimal settings of the process by calculating different scenarios. You evaluate your work and discuss weaknesses and strengths of

Circular Engineering

your approach.

CEN3005

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [G.J. van Rooij](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Ethical and Philosophical Reflections

Full course description

In preparation of the bachelor thesis and your future studies or career, this course provides you with the main theoretical approaches within ethics, philosophy of science, as well as the relevant rules and regulations in the field of circular engineering. You develop the skills required to apply and reflect on these topics. Typical questions that are addressed are: what is the role of observation in science? What is a scientific explanation? What roles do theories and experiments play in science? Are there boundaries to genetic modifications? How can we approach multinationals that break environmental laws? What would you do if you would find out that your company is performing illegal dumping of waste or provides misleading information of the circularity or footprint of their products? You study typical ethical dilemmas, search representative examples that are related to the posed questions and discuss your findings with your peers.

CEN3006

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [P.P.M. Aarts](#)

Teaching methods:

Lecture(s), PBL

Concentration Sustainable Biotechnology

Faculty of Science and Engineering

Separations Processes

Full course description

The course integrates insights from with the mathematical courses, Chemical Engineering, Basic Programming Skills and Heat and Mass Transfer and introduces you to various separation techniques used in the field of chemical engineering. You learn when and how to use these techniques by studying key concepts and by performing design calculations. One example is the evaporative separation in distillation towers. These towers are designed to separate liquid mixtures based on a difference of volatility and with the McCabe-Thiele method you can calculate the size of the column to separate the liquids. Similar approaches studied are absorption techniques, liquid-liquid extractions, crystallization or precipitation and filtration. Lastly, you are required to analyse strengths and weaknesses of the separation techniques and convert this knowledge to criteria such as economics, feasibility, product stability, reliability and sustainability and circularity and use these for the selection of separation methods in sustainable chemical processes.

CEN3003

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [C. Koopman](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Ethical and Philosophical Reflections

Full course description

In preparation of the bachelor thesis and your future studies or career, this course provides you with the main theoretical approaches within ethics, philosophy of science, as well as the relevant rules and regulations in the field of circular engineering. You develop the skills required to apply and reflect on these topics. Typical questions that are addressed are: what is the role of observation in science? What is a scientific explanation? What roles do theories and experiments play in science? Are there boundaries to genetic modifications? How can we approach multinationals that break environmental laws? What would you do if you would find out that your company is performing illegal dumping of waste or provides misleading information of the circularity or footprint of their products? You study typical ethical dilemmas, search representative examples that are related to the posed questions and discuss your findings with your peers.

CEN3006

Period 4

5 Feb 2024

5 Apr 2024

Circular Engineering

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [P.P.M. Aarts](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Gene Technology

Full course description

In this course, you integrate the knowledge acquired in the courses Biotechnology, Genetics Skills and Genetics and Cell Biology, and learn how genetic modification of living organisms can be achieved in practice. This course introduces you to the most advanced approaches to alter the genetic makeup of an organism, including gene insertion, activation, repression and modification. You learn the principles of modern recombinant DNA technologies to generate expression vectors and the most efficient techniques to transform plants and microbes. You are able to illustrate the two main cellular DNA repair pathways - homologous recombination and non-homologous end joining - which form the basis for understanding the application and potential of genome editing technologies such as the CRISPR/Cas 9 system. You are also able to define genetically modified organisms. You apply your knowledge to a case for which you need to review existing gene technologies and select the one most suited for the case. This has to be argued based on a solid line of reasoning using the set criteria.

CEN3010

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [L. Bortesi](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Biological Separations

Full course description

This course builds on knowledge introduced in the course Plants and Microbes, further explored in Plant Biology Skills, and aims at giving an overview of the different techniques available for the separation, recovery and purification of specific biosynthetic products from natural or recombinant sources, such as plant biomass or microbial cultures. The typical five stages in downstream

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processing are studied: 1. Solid- liquid separation (flotation, flocculation, filtration, centrifugation, distillation); 2. Release of intracellular products (cell disruption by physical, chemical, enzymatic methods or combinations thereof); 3. Concentration (dialysis, evaporation, liquid-liquid extraction, filtration, precipitation, adsorption); 4. Purification (chromatography), and; 5. Formulation (crystallization, drying, use of stabilising agents and additives, sterilization). In addition, the principles of biomass upgrading and biorefinery technologies are also studied. Particular attention is given to the concepts of recovery, recycling and upgrading of waste materials, in which new trends as well as commercially viable examples are discussed.

CEN3011

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Biotechnology Skills

Full course description

In this skills course, you deepen and apply the theoretical knowledge learned in the previous years and in the Gene Technology and Biological Separations courses by performing a set of interconnected experiments involving different techniques. Experiments include: cloning of an insert into an expression plasmid, bacterial transformation, selection of positive clones by check PCR and restriction digestion of the plasmid; extraction and isolation of a recombinant protein from a bacterial culture using affinity chromatography, SDS-PAGE and Western blot analysis of the purified protein; Design of guide RNA for CRISPR/Cas9-mediated genome editing and detection of indels using different techniques such as T7E1 assay and RFLP. Furthermore, you are introduced to the concepts of Standard Operating Procedure (SOP) and Good Laboratory Practice (GLP), and their importance in ensuring the quality and reproducibility of the results both in academic and industrial settings.

SKI3103

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [L. Bortesi](#)

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Faculty of Science and Engineering

Plant Biotechnology

Full course description

The course builds on the biotechnological knowledge obtained in year 1, some principles introduced in elective courses such as Plants and Microbes and Genetics and Cell Biology and the technological background acquired in Gene Technology. This course starts with a thorough introduction into plant disease resistance. You learn to understand the difference between pre-formed disease resistance and pathogen-induced responses; you are able to describe the difference between diseases resistance, tolerance and susceptibility and their genetic basis (R genes and R proteins); you learn what type of defence-activating compounds are produced by the plant. You are introduced to plant biotechnology on genetically-modified organisms (GMO). In this way, you get familiar with trans-gensis approaches such as the expression of genes from microbes to induce plant resistance to insects or the expression of resistance genes from other plant species to obtain microbial resistance in the host plant. In addition, other techniques such as cis-gensis (expression of genes of the same species modify endogenous processes) and targeted mutagenesis are introduced.

CEN3012

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [L. Bortesi](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Bioreactors

Full course description

This course links to various concepts introduced in the course Plants and Microbes and provides you with a general understanding of the use of bioreactors within the field of biotechnology. You acquire a deep knowledge of cell culture growth parameters and kinetics and gain an overview of the available technologies for their cultivation. You learn the principles of fermentation, the influence of nutrient availability, temperature, pH and O₂ concentration on cell growth and how an equal distribution of these can be achieved within a bioreactor. You learn the principles of the three operation modes of bioreactors, and understand the differences in design and function between the most widely used bioreactor types for submerged fermentation. Distinctions between bioreactors for microbial vs. plant cell cultures are highlighted and photobioreactors used to culture algae are also described. The difference between bioreactors to produce metabolites, chemicals, proteins or biomass on the one hand and bioreactors that are designed to remove pollutants (e.g. denitrification) is also discussed. You are requested to study two methods commonly used to increase cell biomass inside a reactor and compare them based upon a number of set criteria: the use of membranes and the immobilization of cells. The approach of integrating different

Circular Engineering

microorganisms in a single process configuration and considerations on the properties of the microorganisms required to implement this in a bioreactor is covered. Scaling up aspects from a shake flask to a bench-top to a large-scale fermenters is be studied. Finally, the use of disposable bioreactors and the socio- economic importance of bioreactors in our rapidly developing economy is discussed.

CEN3013

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [J.D. Jansing](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Microbiology and Fermentations Skills

Full course description

In this skills course, you expand and apply the theoretical knowledge on the growth of microbes and cell cultures obtained in the previous years and in the Bioreactors course. You are introduced to the 12 principles of green chemistry and experiment with fermentation as an ideal technique to perform environmentally sustainable chemistry. In order to do so, you learn how to identify, characterise and maintain a microbial culture for fermentation purposes; you gain practice with media preparation, differential staining and microscopy. You perform serial dilutions and learn how to calculate the colony forming units/ml of samples from the plate counts. You apply the Monod equation to calculate the maximum growth rate for a specific microorganism and the minimum amount of substrate needed to achieve it. You also practice extraction of natural products from the bacterial culture, and the purification and characterization of metabolites. As a separate topic, you also experiment how bacteria produce biofilms and how different surfaces can influence biofilm formation.

SKI3104

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [J.D. Jansing](#)

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Faculty of Science and Engineering

Biotechnology for Sustainable Processes

Full course description

This course aims at completing and integrating the insights acquired during the programme and especially of the previous courses in the concentration Sustainable Biotechnology. In this course, you analyse known industrial examples of sustainable manufacturing practices as case studies. For example, you identify the potential impact of protein or metabolic engineering on the overall improvement of a production process, you understand the importance of using dedicated software for flow sheeting and process simulation to solve mass and energy balances of bioprocesses, and you see how waste and bleed streams can be effectively recycled. As a major part of this course, you have to propose a biotechnology-based approach to increase the sustainability of a process of your choice.

CEN3014

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [A. Ghannadzadeh](#)

Teaching methods:

Lecture(s), PBL

Concentration Engineering Physics for Sustainable Manufacturing

Faculty of Science and Engineering

Ethical and Philosophical Reflections

Full course description

In preparation of the bachelor thesis and your future studies or career, this course provides you with the main theoretical approaches within ethics, philosophy of science, as well as the relevant rules and regulations in the field of circular engineering. You develop the skills required to apply and reflect on these topics. Typical questions that are addressed are: what is the role of observation in science? What is a scientific explanation? What roles do theories and experiments play in science? Are there boundaries to genetic modifications? How can we approach multinationals that break environmental laws? What would you do if you would find out that your company is performing illegal dumping of waste or provides misleading information of the circularity or footprint of their products? You study typical ethical dilemmas, search representative examples that are related to the posed questions and discuss your findings with your peers.

CEN3006

Period 4

Circular Engineering

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [P.P.M. Aarts](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Mechanical Physics

Full course description

This course elaborates on statics and strength of materials as introduced in the course Fundamentals of Engineering. Statics is the analysis of physical loads that are exerted on a product, system or component when these systems are in equilibrium. With this precondition, Newton's law to calculate (unknown) reaction forces can be applied and you learn to perform such calculations on 2-dimensional engineering problems. Once all loads on a system are known, analysis of the stresses or deformations of the system can be performed, needed in order to assess weak points that could lead to material failure. You learn how such an analysis helps in the dimensioning and selection of materials when designing new systems. Overall, you learn to calculate stress distribution, maximum stress and its location, as well as deformation and point of failure of elementary components. In addition to loads, other physical phenomena such as temperature, corrosion, time (aging) can influence the stresses and deformations in materials are studied as well.

CEN3020

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [F. Fontenele Araujo Junior](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Sensors, Instrumentation and Measurement

Full course description

Sensors systems are part of many aspects in daily life. They are present in almost every home, office or industrial plant and play an essential role in optimizing and automizing industrial processes to increase efficiency, decrease pollution and create a more sustainable and circular economy. In this

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course, the elements of measurement systems are further explored: transducers, amplifiers, filters and analog-to-digital converters. The different sources of error (noise, interference, offset, non-linearity, aliasing) that limit the performance of such systems are discussed. Methods of analytically determining the corresponding detection limits are presented, and in particular how errors can be referred to the input of a system and represented by equivalent voltage/current sources. Several techniques for mitigating measurement errors are studied in detail, such as the use of feedback, filtering, synchronous modulation, chopping, auto-zeroing, dynamic element matching etc. In order to fully exploit an instrument's potential, you need to be aware of its limitations, correctly interpret the measurement results and be able to arrive at well-balanced decisions relating to the purchasing, repairing, expansion or replacement of electronic equipment. You learn how to identify the correct instrumentation to address specific circularity and sustainability issues in problem-based learning sessions, analysing for example, how waste-stream monitoring and feedback loops can reduce the waste production in an industrial process line.

CEN3021

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [S. Hild](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Mechanical Design Skills

Full course description

This course provides you with basic skills to perform computer aided design (CAD). You use theoretical knowledge introduced in Mechanical Physics to complete 3D designs in CAD. First, you are familiarized with the 3D CAD software package. You follow a computer tutorial with exercises to build 3D designs of simple products, assign dimensions, tolerances and materials. Subsequently, your skills are deepened by preparing for and making a design with 3D-printing and by performing a structural and thermal analysis of a component using the theoretic knowledge of the course Mechanical Physics.

SKI3105

Period 1

4 Sep 2023

27 Oct 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

- [F. Fontenele Araujo Junior](#)

Circular Engineering

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Faculty of Science and Engineering

Materials and Production Engineering

Full course description

In this course, materials science and production engineering are introduced by exploring how the the microstructure of a material relates to its physical properties, which in turn allows you to explore its production and manufacturing possibilities. You first learn to understand the atomic structure and interatomic bonding in materials and to understand phase diagrams. Subsequently, the material classes (metals, ceramics, polymers, composites) are introduced. You learn to analyse characteristic material properties which are primary relevant to production (density, elasticity, strength, toughness, durability, melting point, specific heat, thermal expansion and reflectance/absorbance). Finally, you are introduced to conventional and some advanced manufacturing techniques. As an integral part of this course, there is a visit to the machine workshop of Maastricht University. In addition to an exam, you execute a group assignment related to the process of turning bulk materials into value-added products and accompanying footprint, you perform a material selection and generate a fabrication plan at conceptual level for a basic product and discuss circularity aspects.

CEN3022

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [K.J.P. Ragaert](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Advanced Electronics and Sensor Technolo

Full course description

This course builds on the knowledge obtained in the concentration course Sensors, Instrumentation and Measurements and provides a deeper understanding of advanced electronics and sensor technology by focusing on three major topics in (bio)medical sensors. First, you are acquainted with applications using surfaces as carrier to generate a sensing principle. Aspects such as the physical and biochemical properties of surfaces and their relation to chemical or biologic activity are discussed, as well as physical and chemical principles that underlay these interactions and methods to study them (e.g. optics, thermodynamics and chemical bond formation). In addition, you acquire an overview of the state-of-the-art technologies which are involved in the detection of biomolecules, metabolites, and organic/inorganic contaminants. You are able to describe the different technical

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layouts and physical working principles of different types of bio(mimetic) sensors, focusing mainly on electrochemical, optical and physical readout techniques to identify individual molecules.

CEN3023

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [B.R.N. van Grinsven](#)

Teaching methods:

Lecture(s), PBL

Faculty of Science and Engineering

Advanced Electronics Skills

Full course description

In this skills training, you learn how to bring the theoretical knowledge from the course Advanced Electronics and Sensor Technology into practice. The course is split into three, two-week long advanced-level projects covering the following topic areas: digital electronics for computing which covers the basics of binary number systems, Boolean algebra, and logic devices. You build a digital clock to provide an appreciation of how digital devices can perform different functions. A similar device will be built using the Arduino microcontroller to better understand how an integrated microcontroller can achieve the same functions of many discrete logic components and understand how microcontrollers can contribute to optimize the efficiency of industrial processes and thereby contribute to their sustainability. Analogue electronics with bioengineering applications in which you build an ECG generator and measurement unit using analogue components with the aim of better understanding analogue electronics and their potential applications in biomedical engineering. You gain a more detailed insight into the charging and discharging characteristics of biological and technological capacitors as well as understanding the function of amplifiers, filters and counters. Finally, you acquire hands-on experience with electrochemical impedance measurements and learn how this technology can be used for biosensor technology that can be used to monitor industrial processes and make them more sustainable by e.g. decreasing their impact on the environment by reducing waste production. You also learn how advanced electronics and sensors can be used to analyse re-used materials and screen them for defects. You work in small teams on a different project every two weeks.

SKI3106

Period 2

30 Oct 2023

22 Dec 2023

[Print course description](#)

ECTS credits:

2.5

Coordinator:

Circular Engineering

- [B.R.N. van Grinsven](#)

Teaching methods:

Lecture(s), Training(s), Work in subgroups, Skills

Faculty of Science and Engineering

Product and Process Design for Sustainable

Full course description

In this course, you integrate the insights you have obtained during the first semester of the final year to solve two circular engineering case studies. Teams of students apply their knowledge and skills of circular engineering to develop an actual solution for one of two themes: a) Redesign of a consumer product to fulfil the requirements of repair and reassemble at component level, or; b) Optimization of the process control of an existing processing plant for energy and water use efficiency. You follow the engineering design cycle from analysis of the existing systems, defining circular engineering requirements, diverging to generate several conceptual solutions, selecting the most promising and developing that into a working functional solution. Finally, you evaluate the performance of the solution quantitatively and discuss the results.

CEN3024

Period 4

5 Feb 2024

5 Apr 2024

[Print course description](#)

ECTS credits:

5.0

Coordinator:

- [M.C.P. van Eijk](#)

Teaching methods:

Lecture(s), PBL

Bachelor's Thesis

Faculty of Science and Engineering

Bachelor Thesis

Full course description

All students write a proposal in period 3, before they start their thesis. As part of drafting the proposal, all students are further introduced into scientific methodology of translating research questions in hypothesis. Detailed attention is paid to correct formulation. In addition, if applicable to the research topic, sample size calculation and the meaning of significance levels and statistical power are addressed for the most common statistical models (t-test, ANOVA, Mann-Whitney U, Kruskal Wallis, Pearson correlation, ICC and Kappa). The thesis coordinator approves the topic and location of the thesis and safeguards overall quality. Bachelor Thesis Research and Design: The bachelor thesis project is the final proof-of-capability for BSc Circular Engineering students. The

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individual project enables you to realise your academic profile through an integrated piece of research or research-based design. The size of the thesis allows you to contribute to the circular engineering discipline by a) either conducting an entire scientific cycle which consists of an analysis of lacking knowledge, formulating a hypothesis, formulating a research plan, executing experiments and reporting, or b) conducting a research-based engineering design cycle which consists of formulating a problem, setting of design requirements based on scientific evidence, generating several concepts and performing an evidence-based selection of the most optimal solution and reporting. Bachelor Thesis and Thesis Defence: You summarise and present the results in your bachelor thesis. As a form of public defence, you give an oral public presentation on your thesis work, in which you motivate your research plan in light of identified problem statements and research questions to be addressed. You carefully disclaim the approaches you took, the methods used for the data collection and processing and the results you obtained. You critically analyse your work in a discussion section and conclude the thesis within a final chapter that also contains a reflection of your work and the value of your work for society.

BTH3010

Period 3

8 Jan 2024

2 Feb 2024

Semester 2

5 Feb 2024

5 Jul 2024

Period 5

8 Apr 2024

7 Jun 2024

Period 6

10 Jun 2024

5 Jul 2024

[Print course description](#)

ECTS credits:

25.0

Coordinator:

- [K. Saralidze](#)

Faculty of Science and Engineering

Bachelor Thesis Info Course

BTH3012

Period 3

8 Jan 2024

2 Feb 2024

Semester 2

5 Feb 2024

5 Jul 2024

Period 5

8 Apr 2024

7 Jun 2024

Period 6

10 Jun 2024

5 Jul 2024

Circular Engineering

[Print course description](#)

ECTS credits:

0.0

Coordinator:

- [K. Saralidze](#)