DEPARTMENT OF CHEMICAL ENGINEERING

MODULE DESCRIPTIONS

MSc Chemical Process Engineering

2018-19

Chemical Engineering Module Descriptions 2018-19[1]

Module Registration

Students can view the modules they are registered for on Portico (http://www.ucl.ac.uk/portico) and choose the optional modules they wish to take during their programme.

Full details of all modules offered by the Department can be found in this document. Details on modules offered by other Departments is included where this is available.

When choosing options, please ensure you check for timetable clashes using the Online Timetable (https://timetable.ucl.ac.uk/tt/).

Queries relating to module choices should be directed to the appropriate tutor, Deputy Head (Education) or the Teaching & Learning Team:

- Your Personal Tutor
- Teaching & Learning Administrators – chemeng.teaching.admin@ucl.ac.uk
- Departmental Tutor – Dr Vivek Dua (chemeng.departmental-tutor@ucl.ac.uk)
- MSc Chemical Process Engineering Tutor – Dr Luca Mazzei
- MSc Global Management of Natural Resources Tutor – Prof Alberto Striolo
- Deputy Head (Education) – Prof Eva Sorensen

Safety

Many of the activities in the Department have potential dangers unless sensible precautions are taken at all times. The Department's safety regulations are contained in the departmental booklet "**Arrangements for Safety and Security**" which is available on the Student Intranet as well as in the Programme Handbooks.

UCL has a duty of care to safeguard, so far as is reasonably practicable, the health, safety and welfare of their employees, students and general public who may be affected by its activities. Similarly, students have a duty to take reasonable care to avoid injury to themselves or to others who may be affected by their work activities.

All undergraduate laboratory work must be supervised by an appropriate member of staff - this is part of our duty of care. Similarly, for safety and personal security reasons, unsupervised undergraduates are not allowed inside the Department outside the Department's normal hours of work.

Safety Contact:
Dr Simon Barrass - Departmental Safety Officer

[1] Version 1: 10 September 2018

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MSc Chemical Process Engineering

Advanced Chemical Engineering Route (TMSCENSACE01):

Compulsory modules

- CENG0032 Chemical Process Engineering Research Project (90 credits)
- CENG0025 Process Systems Modelling and Design

Chemical Engineering Optional modules
(Minimum 2 modules from Depth and 2 modules from Breadth)

Depth modules:

- CENG0018 Chemical Reaction Engineering II*
- CENG0019 Transport Phenomena II*
- CENG0020 Advanced Safety and Loss Prevention*
- CENG0023 Advanced Process Engineering
- CENG0024 Fluid Particle Systems
- CENG0027 Molecular Thermodynamics
- CENG0033 Advanced Separation Processes

Breadth modules:

- CENG0026 Energy Systems and Sustainability
- CENG0028 Electrochemical Engineering and Power Sources
- CENG0029 Nature Inspired Chemical Engineering
- CENG0030 Advanced Materials Processes & Nanotechnology

*: if not already taken as part of first degree

Optional modules offered by other departments (max 1 modules)

Department of Biochemical Engineering:

- BENG0090 Advanced Bioreactor Engineering

Department of Civil, Environmental and Geomatic Engineering:

- CEGE0015 Environmental Systems
- CEGE0016 Financial Aspects of Project Engineering and Contracting
- CEGE0022 Water and Wastewater Treatment

School of Management (max 1 module from these):

- MSIN0053 Mastering Entrepreneurship
- MSIN0068 Project Management

Research Route (MSCENSRES01):

Compulsory module

- CENG0032 Chemical Process Engineering Research Project (90 credits)

Chemical Engineering Optional modules

(Minimum 60 credits, maximum 90 credits)

- CENG0010 Separation Processes I*
- CENG0015 Chemical Reaction Engineering*
- CENG0017 Process Dynamics and Control*
- CENG0019 Transport Phenomena II*
- CENG0020 Advanced Safety and Loss Prevention**
- CENG0023 Advanced Process Engineering
- CENG0024 Fluid Particle Systems
- CENG0025 Process Systems Modelling and Design
- CENG0026 Energy Systems and Sustainability
- CENG0027 Molecular Thermodynamics
- CENG0028 Electrochemical Engineering and Power Sources
- CENG0029 Nature Inspired Chemical Engineering
- CENG0030 Advanced Materials Processes & Nanotechnology
- CENG0033 Advanced Separation Processes

Optional modules offered by other departments

(Minimum 0 credits, maximum 15 credits)

Department of Biochemical Engineering:

- BENG0090 Advanced Bioreactor Engineering

Department of Civil, Environmental and Geomatic Engineering:

- CEGE0015 Environmental Systems
- CEGE0016 Financial Aspects of Project Engineering and Contracting
- CEGE0022 Water and Wastewater Treatment

School of Management (max 15 credits from these):

- MSIN0053 Mastering Entrepreneurship
- MSIN0068 Project Management

<u>Design Route</u> (TMSCENSDES01):

Compulsory modules

- CENG0043 Advanced Process Plant Design Project (60 credits)
- CENG0009 Process Heat Transfer
- CENG0010 Separation Processes I
- CENG0015 Chemical Reaction Engineering
- CENG0017 Process Dynamics and Control
- CENG0019 Transport Phenomena II
- CENG0020 Advanced Safety and Loss Prevention
- CENG0052 Advanced Process Design Principles

Optional module

- CENG0023 Advanced Process Engineering
- CENG0024 Fluid Particle Systems
- CENG0026 Energy Systems and Sustainability
- CENG0027 Molecular Thermodynamics
- CENG0028 Electrochemical Engineering and Power Sources
- CENG0029 Nature Inspired Chemical Engineering
- CENG0030 Advanced Materials Processes & Nanotechnology
- CENG0033 Advanced Separation Processes

Module Code:	CENG0009	Module Title:	Process Heat Transfer
Weighting:	15 credits 7.5 ECTS	Pass mark:	40%
Year of Study:	2 (L5)	Level:	L5 - Compulsory

Teaching Staff: **Prof J Tang**

Aims:

- To provide a broad study in the principles of steady and unsteady state heat transfer, heat transfer with phase change and radiation heat transfer.
- To develop skills in the design of practical heat transfer equipment with emphasis on improving efficiencies and the use of renewable energy sources.

Learning Outcomes:

On completion of this module students should:

- be able to understand the physical phenomena present in heat transfer processes;
- be able to calculate or estimate heat transfer coefficients;
- be familiar with the procedures for the design of heat transfer equipment ;
- Understand pressure drop and fouling factors in a heat exchanger;
- Select an appropriate heat exchanger to meet the required heat transfer rate or heat transfer area

Synopsis:

- Key mechanisms of heat transfer: conduction, convection and radiation;
- Fourier's law; Conduction in cylindrical and spherical shells;
- Derivation of heat conduction equations for transient and multidimensional cases;
- Methods for solving 1-D transient heat conduction equation; lumped heat transfer coefficient;
- Forced convection; Natural convection; Correlations for heat transfer coefficient;
- Thermal radiation; Radiation transfer through gases;
- Evaporation and Boiling;
- Condensation; Film condensation;
- Heat exchangers; Condensers and Reboilers; Logarithmic mean temperature difference;
- Direct contact gas-solid exchangers

Textbooks:

Cengel, Y.A., Heat Transfer a Practical Approach, Higher Education, 2006.

Incropera, F.P. and D.P. Dewitt, Principles of Heat and Mass Transfer, Wiley, 2012.

Levenspiel, O., Engineering Flow and Heat Exchange, Springer, 2014.

Contact Time: 40 hours lectures and problem classes

Coursework: 30%

Examination: 70% (3 hour written exam)

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Module Code:	**CENG0010**	**Module Title:**	**Separation Processes I**
Weighting:	15 credits 7.5 ECTS	Pass mark:	40% (L5) 50% (L7)
Year of Study:	2 (L5) 4 (L7U) MSc (L7P)	Level:	L5 - Compulsory L7U – Option L7P – Option

Teaching Staff: **Prof E Sorensen**

Aims:

- To provide an understanding of the principles of fluid separation processes;
- To develop skills in the design of practical fluid separation equipment in the context of sustainability and sustainable development;
- To provide a basic understanding of process simulation

Learning Outcomes: On completion of this module students should:

- be able to understand the mass and heat transfer phenomena involved in fluid processes;
- be familiar with the procedures for the design of fluid separation equipment in the context of sustainability and sustainable development;
- be able to select an appropriate fluid separation process to meet a required separation performance;
- be able to simulate simple steady-state process flowsheets and mass transfer operations

Synopsis: Fundamentals of mass transfer including driving forces, the ideal stage, mass transfer units, stage efficiency; and methods of two-phase contacting for the purpose of mass transfer;
With a focus on distillation, absorption and extraction consider:

- Estimation of thermodynamic properties;
- Design and analysis methodologies;
- Graphical methods for analysis;
- Equipment design including olumn design and column internals;

Fundamentals of process flowsheeting and mass transfer simulation.

Textbooks:
Gorak, A. and E. Sorensen, Distillation: Fundamentals and Principles, Academic Press, 2014.
McCabe, W.L., J.C. Smith and P. Harriott, Unit Operations of Chemical Engineering, McGraw-Hill International Editions, 7th ed., 2005.
Richardson, J.F. and J.H. Harker, Coulson & Richardson's Chemical Engineering, Vol 2, 5th ed., Butterworth Heinemann, 2002.
Seader, J.D., E.J. Henley and D.K. Roper, Separation Process Principles, 3rd ed., John Wiley & Sons, 2013.
Sinnott, R.K., Coulson & Richardson's Chemical Engineering, Vol 6, 4th ed., Butterworth Heinemann, 2005.
Treybal, R.E., Mass-Transfer Operations, 3rd ed., McGraw-Hill International Editions, 1981.

Contact Time: 40 hours lectures and problem classes

Coursework: 30%

Examination: 70% (3 hour written exam)

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Module Code:	**CENG0015**	**Module Title:**	**Chemical Reaction Engineering**
Weighting:	15 credits 7.5 ECTS	**Pass mark:**	50%
Year of Study:	MSc (L7P) MSc Chemical Process Engineering – Design route only	**Level:**	L7 - Compulsory

Teaching Staff: **Dr G Manos**

Aims: To provide a basic understanding of the principles of reactor design and of the reasons underlying the selection of reactor type to meet particular sets of process conditions. Reactor selection and design is presented and discussed accounting for safety and sustainability considerations

Learning Outcomes: On completion the students will be expected:

- to be able to design simple ideal reactors;
- to appreciate technical, economic, safety and sustainability issues that can arise during reactor design;
- to understand the interaction of transport phenomena with reactions in a chemical, biochemical or catalytic reactors.

Synopsis: Introduction: Brief survey of the scope of the subject together with a review of some of its foundations.
Mole Balances: Definition of reaction rate. The general mole balance. The batch, plug flow and continuous stirred reactors. Industrial reactors.
Conversion and Reactor Sizing: Definition of conversion. Design equations for batch and flow systems. Reactors in series. Space velocity and space time.
Rate Laws and Stoichiometry: Concepts of reaction rate, reaction order, elementary reaction and molecularity. Stoichiometric table. Reactions with phase change.
Isothermal Reactor Design: Design structure for isothermal batch, plug flow and continuous stirred reactors. Design of multiple reactor systems. Pressure drop in reactors. Reversible reactions.
Non-isothermal Reactor Design: The energy balance. Algorithms for non-isothermal plug flow and continuous stirred reactor design. Equilibrium conversion. Steady state multiplicity.
Multiple Reactions: Conditions for maximising yield and selectivity in parallel and series reactions.
Biocatalysis: Characteristics of enzyme catalysed reactions. Biocatalyst selection and production. Use of immobilised biocatalysts. Reactor selection and operation.
External Diffusion Effects in Heterogeneous Reactions: Mass transfer fundamentals. Binary diffusion. External resistance to mass transfer.
Diffusion and Reaction in Porous Catalysts: Diffusion and reaction in spherical pellet. Internal effectiveness factor. Falsified kinetics.
Models for Non-ideal Reactors: One-parameter models. Two-parameter models.

Textbooks: Fogler, H.S., Elements of Chemical Reaction Engineering, Pearson, 2013.

Levenspiel, O., Chemical Reaction Engineering, John Wiley & Son, 3rd ed., 1998.

Contact Time: 37 hours

Coursework: 20%

Examination: 80% (3 hour written exam)

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Module Code:	**CENG0017**	**Module Title:**	**Process Dynamics and Control**
Weighting:	15 credits 7.5 ECTS	**Pass mark:**	40% (L6) 50% (L7U – L7P)
Year of Study:	3 (L6) 4 (L7U) MSc (L7P)	**Level**:	L6 - Compulsory L7U – Option L7P - Option

Teaching Staff: **Dr F Galvanin**, Dr V Dua

Aims: The aim of the module is to consider the concepts of process dynamics and control showing why, and how, control ensures safe, smooth and stable operation of process plants, in the context of sustainability and sustainable development.

Learning Outcomes: On completion of this module, students are expected:

- to be aware, and have an appreciation of, the importance of process control in the safe, efficient, economic and sustainable operation of process plants;
- understand system dynamics, be able to predict the response to changes in a dynamic system, and be able to design and determine the characteristics and performance of measurement and control functions;
- to have an understanding of the elements of control loops in regards to feedback and more complex systems, the types of controllers available and the methods of controller tuning;
- to have an understanding of the fundamentals of instrumentation for control purposes.

Synopsis: To consider the concepts of:

- Modelling and analysis of the behaviour and dynamics of typical chemical processes;
- Description and analysis of chemical processes in terms of block diagrams to represent behaviour with associated controlled variables, manipulated variables and disturbances;
- The essential functionality of feedback control loops and the circumstances in which their potential benefits may be realised;
- Control system design and functionality;
- Advanced, complex and plantwide control;
- Instrumentation for control

The Masters level (level 7) version of the module (CENG0017 and CENG0017) has a stronger focus on unseen, and more open ended, problem solving.

Textbooks:

Seborg, D.E., T. F. Edgar, Process Dynamics and Control, Wiley, 2nd Ed, 2004.

Stephanopoulos, G., Chemical Process Control, Prentice Hall, 1984.

Luyben, W. L., Process Modeling, Simulation and Control for Chemical Engineers, 2nd ed., McGraw Hill, 1990.

Ogunnaike, B.A. and W.H. Ray, Process Dynamics, Modeling and Control, Oxford University Press, 1995.

W.Y. Svrcek, D.P. Mahoney and B.R. Young. A Real-time Approach to Process Control, 3rd Ed., Wiley, 2014.

Contact Time: 40 hours lectures & problem classes
6 hours experimentation

Coursework: 20%

Examination: 80% (3 hour written exam)

Updated August 2017

Module Code:	**CENG0018**	**Module Title:**	**Chemical Reaction Engineering II**
Weighting:	15 credits 7.5 ECTS	**Pass mark**:	40% (L6) 50% (L7P)
Year of Study:	3 (L6) 4 (L7U) MSc (L7P)	**Level**:	L6 - Compulsory L7U - Option L7P - Option
Teaching Staff:	**Prof A Gavriilidis**		

Aims: To provide an understanding of advanced reactor design and the principles and phenomena that are present in multiphase and catalytic reactions.

Learning Outcomes: Upon completion of this module student should:

- be able to design advanced chemical reactors
- be able to evaluate the influence of mass transfer and hydrodynamics on reactor performance
- to apply advanced concepts for the design of chemical reactors.
- to combine analytical and computational approaches for reactors design
- to critically evaluate what phenomena and under what circumstances need to be considered as related to the level of accuracy required for a specific design problem
- to gain experience on the operation and data analysis form laboratory chemical reactors

Synopsis:

- Nonisothermal reactor design at steady and unsteady state
- Multiple reactions in PFR/CSTR
- Introduction to heterogeneous catalysis
- Mass transfer and reaction in heterogeneous catalytic reactions
- Design of fixed bed reactors
- Mass transfer and reaction in gas/liquid and gas/liquid/solid reactions
- Design of gas/liquid and las/liquid/solid reactors
- Nonideal reactors and residence time distribution

The Masters level (level 7) version of the module (CENG0018) has a stronger focus on unseen, and more open ended, problem solving.

Textbooks:

Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice-Hall, 5th Ed., 2016.

Levenspiel, O., Chemical Reaction Engineering, John Wiley & Sons, 3rd Ed., 1998.

Froment, G.F., Bischoff, K.B., De Wilde, J., Chemical Reactor Analysis and Design, Wiley International, 3rd Ed., 2011.

Salmi, T.O., Mikkola, J.P., Warna, J.P., Chemical Reaction Engineering and Reactor Technology, CRC Press, 2009.

Contact Time: 40 hours lectures & problem classes
6 hours experimentation

Coursework: 20%

Examination: 80% (3 hour written exam)

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Module Code:	CENG0019	Module Title:	Transport Phenomena II
Weighting:	15 credits 7.5 ECTS	**Pass mark**:	40% (L6) 50% (L7U) 50% (L7P)
Year of Study:	3 (L6) 4 (L7U) MSc (L7P)	**Level**:	L6 - Compulsory L7U - Option L7P - Option
Teaching Staff:	**Dr L Mazzei**		

Aims: To convey advanced concepts and their application to problem solving in the areas of fluid dynamics, transport phenomena (with focus on mass and linear momentum transport), non-Newtonian flow and mass transfer with chemical reaction.

Learning Outcomes: On completion of this module students will be expected to:

- be able to apply the mass and linear momentum balance equations to analyze simple flow problems
- be able to interpret the physical meaning of transport equations and estimate the relative importance of the terms featuring in them
- be able to apply scaling and order-of-magnitude arguments to simplify transport equations before attempting to solve them
- analyze problems involving diffusion of mass, linear momentum and energy
- be able to analyze turbulent flows using simple modelling approaches
- be aware of non-Newtonian fluid behavior and how to model it
- analyze simple problems involving mass transfer with chemical reaction

Synopsis:

- Mass and linear momentum balance equations (Eulerian and Lagrangian forms)
- Stress within a fluid and problem of closure
- Scaling of transport equations and order of magnitude analysis
- Penetration theory (diffusion of mass, linear momentum and energy)
- Boundary layer theory
- Turbulent flow (characteristics of turbulent flows, averaged transport equations, Reynolds stress, problem of closure, mixing length theory, Kolmogorov theory)
- Non-Newtonian fluids (shear thinning, shear thickening, Bingham fluids)
- Mass transfer with chemical reaction (film and penetration theories)

The Masters level (level 7) version of the module (CENG0019 and CENG0019) has a stronger focus on unseen, and more open ended, problem solving.

Textbooks:

Deen, W.M., Introduction to Chemical Engineering Fluid Mechanics, Cambridge University Press, 2016.

Bernard, P.S., Fluid Dynamics, Cambridge University Press, 2015.

Bird, R.B., W.E. Stewart, and E.N. Lightfoot, Transport Phenomena, 2nd ed., Wiley, 2007.

Welty, R., G.L. Rorrer and D.G. Foster, Fundamentals of Momentum, Heat and Mass Transfer, Wiley, 2014.

Contact Time: 40 hours lectures & problem classes

Coursework: 20%

Examination: 80% (3 hour written exam)

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Module Code:	CENG0020	Module Title:	Advanced Safety and Loss Prevention
Weighting:	15 credits 7.5 ECTS	**Pass mark**:	40% (L6) 50% (L7U) 50% (L7P)
Year of Study:	3 (L6) 4 (L7U) MSc (L7P)	**Level**:	L6 - Compulsory L7U - Option L7P - Option
Teaching Staff:	**Prof H Mahgerefteh**		

Aims: To provide students with advanced training in hazard identification, quantification and mitigation as well as risk management.

Learning Outcomes: On completion students should:

- be able to fully appreciate the importance of Safety and Loss Prevention in the process industries;
- be able to identify, quantify and manage hazards in terms of their potential to cause damage to the environment, the work force and the general population outside the perimeter fence;
- be able to apply their knowledge during conceptual design, operation and decommissioning of process plant.

Synopsis: The application of safety as an inherent part of process plant design will be dealt with and procedures for its implementation are discussed. Incidents which have been significant in achieving changes in culture will be highlighted. Formal present-day requirements of engineering for safety, including the methodology for establishing necessary criteria, implementation and monitoring, verification and validation of safety systems, and responsibility for auditing.
Basic procedures for Hazard Identification and Development (HAZID), Hazard and Operability Studies (HAZOP) and Quantitative Risk Assessment (QRA). Safety Studies, Safety Cases and their development, Safety Management Systems and the role of the Health and Safety Executive.
Key consequences arising from gas accumulation and dispersion, explosion, escalation and smoke, area classification and transportation.

The Masters level (level 7) version of the module (CENG0020 and CENG0020) has a stronger focus on unseen, and more open ended, problem solving.

Textbooks: Mannan, S., Lees' Loss Prevention in the Process Industries: Hazard, Identification, Assessment and Control, 4th Ed., Butterworth-Heinemann, 2012.

CCPS Publication, Introduction to Process Safety for Undergraduates and Engineers, Willey, 2016.

Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety Fundamentals with Applications, 3rd Ed., Prentice Hall, 2011.

Contact Time: 40 hours lectures and problem classes

Coursework: 20%

Examination: 80% (3 hour written exam)

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Module Code:	**CENG0023**	**Module Title:**	**Advanced Process Engineering**
Weighting:	15 credits 7.5 ECTS	Pass mark:	50%
Year of Study:	4 (L7U) MSc (L7P)	Level:	L7U - Option L7P - Option
Teaching Staff:	**Prof L G Papageorgiou,** Prof I D L Bogle		

Aims: Advanced use of computers in process design, operation and management. Particular emphasis is placed on Process Synthesis.

Learning Outcomes:

On completion the students will be expected:

- to be aware of the role of optimisation techniques in plant design, operation and management;
- to be aware of numerical techniques for solving continuous and discrete optimisation problems;
- to be able to formulate and solve complex optimisation problems both analytically and using computational tools;
- to be aware of techniques for process synthesis and be familiar with a contemporary tool.

Synopsis:

Approaches to process synthesis and process optimisation.
Linear programming by the simplex and graphical methods.
Introduction non-linear process optimisation, optimality criteria, conditions for an optimum, unconstrained optimisation, constrained optimisation. Application to flowsheet optimisation.
Discrete modelling of process systems. Solution methods for discrete optimisation problems: integer programming, mixed integer linear programming, mixed integer non-linear programming. Process synthesis using implicit enumeration. Algorithmic approaches to synthesis of sustainable systems: heat exchanger networks.
Process synthesis under uncertainty. Flexibility analysis.

Textbooks:

Beigler, L.T., I.E. Grossmann and A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall, 1997.

Edgar, T.F. and D.A. Himmelblau, Optimisation of Chemical Processes, McGraw Hill 1988.

Floudas, C.A., Nonlinear and mixed-integer Optimization, Oxford University Press 1995.

Seider, W.D., J.D Seader, D.R Lewin and S. Widagdo, Product and Process Design Principles: Synthesis, Analysis and Design, 3rd ed., Wiley, 2009.

Williams, H.P., Model Building in Mathematical Programming, Wiley 2013.

Contact Time: 45 hours

Coursework: 50%

Examination: 50% (2 hour written exam)

Updated TBC

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Module Code:	**CENG0024**	**Module Title:**	**Fluid Particle Systems**
Weighting:	15 credits 7.5 ECTS	Pass mark:	50%
Year of Study:	4 (L7U) MSc (L7P)	Level:	L7U - Option L7P - Option
Teaching Staff:	**Dr L Mazzei**, Dr M Materazzi		

Aims: This course is designed to convey the fundamentals of fluidization and crystallization and their applications to industrial scale units and sustainable development.

Learning Outcomes: On completion, students are expected:

- to be able to formulate realistic differential equation descriptions of multiphase systems;
- to have an understanding of the two-phase nature of gas-solid fluidized beds and of how to apply their basic quantitative features to the design of reactors;
- to be able to apply methods to analyse the characteristics and performance of particulate crystal formation systems and to design crystallization equipment.

Synopsis:

Fundamentals of gas-solid and liquid-solid systems. Fluid-particle interaction. Fluid-bed stability theory. Bubble dynamics. Particle mixing and segregation. Heat and mass transfer. Fluidized bed chemical reactors.
Theories of nucleation and crystal growth. Measurement of nucleation and growth kinetics.
Crystallization processes and crystallizers. The population balance equation and crystallizer design.

Textbooks:

Gibilaro, L.G., Fluidization-Dynamics, Butterworth-Heinemann, 2001.

Kunii, D. and O. Levenspiel, Fluidization Engineering, 2nd ed., Butterworth-Heinemann, 1991.

Mullin, J.W., Crystallization, 3rd ed., Crystallization, Butterworth-Heinemann, 1993,

Jones, A.G., Crystallization Process Systems, Oxford: Butterworth-Heinemann, 2002.

Contact Time: 40 hours

Coursework: 20%

Examination: 80% (3 hour written exam)

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Module Code:	CENG0025	Module Title:	Process Systems Modelling and Design
Weighting:	15 credits 7.5 ECTS	**Pass mark:**	50%
Year of Study:	4 (L7U) MSc (L7P)	**Level:**	L7U – Compulsory (MEng) L7P – Option (MSc)
Teaching Staff:	**Dr F Galvanin**, Dr M Stamatakis		
Aims:	The module aims to develop modelling concepts and simulation skills to consider complex process design in the context of safety and sustainable process plant development		
Learning Outcomes:	On completion of this module, the students will be expected to be: • able to develop computational models for complex plant items; • able to use contemporary simulation tools to modelling process behaviour; • able to make informed decisions on process design based on conflicting and missing information in the context of safety and sustainable process plant development		
Synopsis:	The following issues will be considered: process systems engineering, process modelling, process synthesis, process optimisation, dynamic simulation and control system design. Lectures, tutorials and e-learning resources will provide training in the techniques and tools required to carry out design projects applying advanced design concepts and computational tools.		
Textbooks:	Felder, R.M., Elementary Principles of Chemical Processes, Wiley, 2004. McCabe, W.L., J.C. Smith and P. Harriott, Unit Operations of Chemical Engineering, McGraw-Hill International Editions, 7th ed., 2005. Towler, G. and R. Sinnott, Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 2nd rev. ed., Butterworth-Heinemann, 2012.		
Contact Time:	30 hours		
Coursework:	100%		
Examination:	0%		

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Module Code:	CENG0026	Module Title:	Energy Systems and Sustainability
Weighting:	15 credits 7.5 ECTS	Pass mark:	50%
Year of Study:	4 (L7U) MSc (L7P)	Level:	L7U - Option L7P - Option
Teaching Staff:	**Prof D J L Brett**		
Aims:	To provide a broad study of conventional and renewable Energy Systems and an advanced knowledge of selected emerging energy technologies. To develop skills in the design of energy systems with emphasis on sustainability, improving efficiencies and the use of renewable energy sources.		
Learning Outcomes:	On completion, students should: • Have a broad knowledge of the various conventional and renewable energy conversion technologies and enhanced knowledge of selected advanced topics. • Understand the concept of Sustainable Development in Energy and be familiar with issues related to Technology Needs and Barriers, Environmental Impact and Energy Economics.		
Synopsis:	Energy Concepts: efficiency; energy cycles. Energy Resources and Use: Conventional fuels; alternative fuels; demand side issues; changing pattern of energy use; future energy scenarios. Conventional Energy Conversion: heat engines, turbine systems; nuclear fission, heat transfer. Renewable Energy: Hydro, wave, wind, solar thermal, photovoltaics, biofuels, nuclear fusion etc. Advanced Subjects: E.g. Fuel cells; waste to energy; energy system optimization Energy in a Sustainable Future: Concept of sustainability		
Textbooks:	Andrews, J., Jelly, N., Energy Science, Principles, Technologies and Impacts, Oxford University Press, 2007. Breeze, P., Power Generation Technologies, Elsevier, 2005. Boyle, G., Renewable Energy, Power for a Sustainable Future, Oxford University Press, 2004. Boyle, G., Everett, B., Ramage, J., Energy Systems and Sustainability, Power for a Sustainable Future, Oxford University Press, 2003. Franchi, J. R., Energy Technology and Directions for the Future, Elsevier, 2004. Goswami, D. Y, Kreith, F., Energy Conversion, CRC Press, 2008. Jayamaha, L., Energy-Efficient Building Systems, McGraw-Hill, 2006. Gevorkian, P., Sustainable Energy Systems Engineering, McGraw-Hill, 2007. Kreith, F., Kreider, J. F., Principles of Sustainable Energy, CRC Press, 2011. Larminie J.C., Dicks, A, Fuel Cell Systems Explained, John Wiley and Sons Ltd., 2003. O'Hayre, R., Cha, S-W., Colella, W., Prinz, F. B. Fuel Cell Fundamentals, 2009 Ramage, J., Energy, A Guidebook, Oxford University Press, 1997. Sorensen, B., Renewable Energy: Physics, Engineering, Environmental Impacts, Economics & Planning, 4th ed., Elsevier, 2010.		
Contact Time:	24 hours		
Coursework:	40%		
Examination:	60% (2 hour written exam)		

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Module Code	CENG0027	Module Title:	Molecular Thermodynamics
Weighting:	15 credits 7.5 ECTS	**Pass mark:**	50%
Year of Study:	4 (L7U) MSc (L7P)	**Level:**	L7U - Option L7P - Option

Teaching Staff: **Prof A Striolo**, Dr O Yazaydin

Aims:

With the present emphasis on nano and bio technologies, molecular level descriptions and understandings offered by statistical thermodynamics are of increasing interest and importance.

The aim of this module is to describe what statistical thermodynamics is, and to emphasize how chemical engineers can use it to advance practical applications.

One goal is to demonstrate how molecular level approximations are applied to understand the physical world, how macroscopic thermodynamic models engineers use derive from such approximations, and the importance of remembering the approximations assumed while developing the models.

The students will become familiar with molecular-level computer simulations.

Learning Outcomes:

On successfully completing the module, the students will:

- relate concepts taught in classical thermodynamics to intermolecular interactions
- recognize the basics of statistical thermodynamics
- learn the fundamentals of commonly used molecular simulation techniques, such as Monte Carlo and molecular dynamics
- employ molecular simulation techniques to calculate macroscopic properties from intermolecular forces
- relate molecular-level understanding of matter to a number of modern practical applications.

Synopsis:

In this course we will study theories for describing and predicting the phase equilibria of systems of interest to the modern chemical engineer. We will begin by a description of classical thermodynamics concepts, focusing on how such concepts depend on our understanding of intermolecular interactions. Then we will discuss how statistical thermodynamics techniques allow us to predict macroscopic properties from the knowledge of intermolecular interactions and other molecular properties. The statistical mechanics framework will be used to introduce the modern tools of Monte Carlo and molecular dynamics simulations. We will then demonstrate how the results of molecular simulations can be used to enrich the molecular theories of matter. Finally we will discuss how statistical thermodynamic concepts are useful for advancing practical applications.

Examples will include, but will not be limited to, self-assembling structures, materials and processes for separations, and strategies for energy storage.

Textbooks:

Chandler, Introduction to Modern Statistical Mechanics, Oxford University Press, 1987.

Prausnitz, J.M., R.N. Lichtenthaler and E.G. de Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd ed., Prentice Hall, 1998.

Contact Time: 40 hours

Coursework: 60% (CW1 40%, CW2 20%)

Examination: 40%(3 hour written exam, open book)

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Module Code	CENG0028	Module Title:	Electrochemical Engineering and Power Sources
Weighting:	15 credits 7.5 ECTS	**Pass mark:**	50%
Year of Study:	4 (L7U) MSc (L7P)	**Level:**	L7U - Option L7P – Option
Teaching Staff:	**Prof P Shearing**, Dr R Jervis		

Aims:

The module will introduce and develop the fundamental concepts of Electrochemical Engineering and explore their application to real world problems in chemical processing and electrochemical power sources.

The module will provide an opportunity for students to gain theoretical, practical and techno-economic knowledge of electrochemical technology.

Learning Outcomes:

On completion of this course students will be able to:

- Describe a range of electrochemical technologies from theory through to application and compare the benefits of a range of electrochemical technologies
- Apply qualitative analysis techniques to understand electrochemical phenomena, analyse these results and use modeling tools to explain them
- Evaluate electrochemical technologies based on sound technical and techno-economic judgment
- Design and develop experiments to gain practical understanding of elements of electrochemistry and electrochemical engineering
- Identify problems in electrochemical technologies and construct a toolbox of theory and practice to produce solutions
- Understand the ethical and environmental dimensions of problems and issues facing chemical engineers

Synopsis:

- Standard potentials
- The Governing Equations: Faraday Nernst and Butler Volmer
- Chlor Alkali and Electrolysis
- Corrosion
- Pourbaix diagrams
- Batteries: Pb, Ni cad, NIMH and Lithium batteries
- Fuel cells: PEMFC and SOFC
- Fuel cells as electrolysers
- Electro-catalysis
- Capacitors and other power sources
- Modelling electrochemical power sources
- Advanced electrochemical characterization

Textbooks:

Bard, A.J. and L.R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley, 2001.

Huggins, R., Advanced Batteries: Materials Science Aspects, 2008.

Larminie, J. and A. Dicks, Fuel Cell Systems Explained, 2nd ed., 2003.

Newman, J. and K.E. Thomas-Alyea, Electrochemical Systems, 3rd ed., 2004.

Mench, M., Fuel Cell Engines, Wiley, 2008.

Prentice, G.A., Electrochemical Engineering Principles, 1990.

Root, M., The TAB Battery Book: An In-Depth Guide to Construction, Design, and Use, Tab Electronics, 2011.

West, A.C., Electrochemistry and Electrochemical Engineering. An Introduction, 2012.

Contact Time:	40 hours
Coursework:	30% (Coursework 20%, Project 10%)
Examination:	70% (3 hour written exam)

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Module Code	CENG0029	Module Title:	Nature Inspired Chemical Engineering
Weighting:	15 credits 7.5 ECTS	**Pass mark:**	50%
Year of Study:	4 (L7U) MSc (L7P)	**Level:**	L7U - Option L7P - Option
Teaching Staff:	**Prof M-O Coppens**		

Aims:

The module aims to grow an understanding of ways to learn from solutions adopted by nature to solve similar issues in (chemical) engineering problems;

this is done by distilling the fundamental causes behind desirable features in the model natural system, and applying these to the technological system.

The module aims to stimulate creative thought, and to engage students in coming up with innovative solutions by using the chemical engineering "toolbox" with a fresh pair of eyes.

Learning Outcomes:

On successfully completing the module, the students will:

- look at nature, and the balance between nature and technology, in a different way
- learn the fundamentals and opportunities of the nature-inspired chemical engineering (NICE) approach
- apply fundamental principles, borrowed from natural systems to chemical engineering problems
- recognize situations where a NICE approach might bring up a new, more performing solution
- employ the NICE toolbox to solve engineering problems

Synopsis:

Nature-inspired chemical engineering (NICE) is introduced as a powerful approach to guide the design of new processes and materials for applications, ranging from energy and energy efficiency to chemical production and therapeutics.

The module will illustrate and empower the student to apply fundamental chemical engineering principles to achieve higher performance (efficiency, scalability, robustness, etc.) and come up with innovative approaches to solve challenging problems, by taking guidance from natural systems that are ideally structured to achieve this high performance.

Key to the NICE approach is that this is done cognizant of the often-different context of biology and technological applications.

Textbooks:

Bejan, A., Shape and Structure, From Engineering to Nature, Cambridge University Press, 2000.

Mandelbrot, B.B., The Fractal Geometry of Nature, Updated and augmented ed. Freeman, San Francisco, 1983.

Vicsek, T., Fractal Growth Phenomena, World Scientific, 2nd ed., Singapore 1992.

Links from http://cnie.org.uk (Centre for Nature Inspired Engineering)

Contact Time:	40 hours
Coursework:	100% (70% coursework, 30% project)
Examination:	-

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Module Code:	**CENG0030**	**Module Title:**	**Advanced Materials Processes and Nanotechnology**
Weighting:	15 credits 7.5 ECTS	**Pass mark**:	50%
Year of Study:	4 (L7U) MSc (L7P)	**Level**:	L7U - Option L7P - Option

Teaching Staff: **Dr M Stamatakis**, Dr S Guldin

Aims: To give students an understanding of processes involved in the production of novel materials. To provide students with a systematic approach to the selection of material fabrication routes with applications to the biomedical, coating, fine chemical, food, microelectronic and semiconductor industries.

Learning Outcomes: On completion of this course students are expected to:

- be aware of novel materials and recently developed material processes;
- understand essential concepts in materials science at multiple scales, from the molecules to manufacturing;
- be able to apply fundamental chemical engineering principles (such as transport phenomena, chemical kinetics, thermodynamics) in the design and operation of materials processes involving nanofabrication, templating, self-assembly.

Synopsis: To introduce the concepts of:

1. Processes in the electronics industry:
   a. epitaxial & polycrystalline silicon production
   b. silicon doping
   c. microlithography
   d. chemical vapour deposition
   e. physical vapour deposition.

2. Soft matter fundamentals & applications: Lipids, proteins, colloids, polymers, emulsions, self-assembly, thin-film processing, templating

Textbooks: Hench, L.L. and J.K. West, Chemical Processing of Advanced Materials, Wiley, 1992.

Middleman, S., and A K Hochberg, Process Engineering Analysis in Semiconductor Device Fabrication, McGraw-Hill, 1993.

Hirst, L.S., Fundamentals of Soft Matter Science, 1st Ed., CRC press, 2012.

Barnes, G. and I. Gentle, Interfacial Science: An Introduction, 2nd Ed., Oxford University Press, 2011.

Israelachvili, J.N., Intermolecular and Surface Forces, 3rd Ed., Elsevier, 2011.

Jones, R.A.L., Soft Condensed Matter, 1st ed., Oxford University Press, 2002.

Jones, R.A.L., Soft Machines: Nanotechnology and Life, Jones, 1st Ed., Oxford University Press, 2009.

Contact Time: 40 hours

Coursework: 20%

Examination: 80% (3 hour written exam)

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Module Code:	**CENG0032**	**Module Title:**	**Chemical Process Engineering Research Project**
Weighting:	90 credits 45 ECTS	**Pass mark**:	50%
Year of Study:	MSc (L7P)	**Level**:	L7P - Option

Teaching Staff: **Dr Sergey Martynov**, Dr Richard Porter, all teaching staff

Aims: To develop advanced skills in undertaking an individual research project including: critical literature survey, design of experiments, collection of data, analysis and presentation of results, conclusions and recommendations in a clear a concise manner at a level equivalent to published papers.

Learning Outcomes: On completion of this course students are expected to:

- be aware of advanced research methods including if applicable the use of relevant engineering/mathematical software;
- be able to demonstrate independent thought and critical analysis of research results;
- have developed skills for presentation of their results in the research report in a clear and concise manner worthy of publication;
- present the research findings orally at a standard similar to that expected for presentations at national and international conferences.

Synopsis: An individual research project working under the supervision of a member of the academic staff of the department. Topics are usually selected from aspects of a continuing research speciality of the department. Each student normally undertakes a literature survey, experimental work, modelling, discussion and analysis of data followed by conclusions and recommendations for future work presented in the form of a thesis and oral presentation.

Textbooks: As recommended by project supervisor.

A.M. Coghill, and L.R. Garson, ACS Style Guide: Effective Communication of Scientific Information. 3rd Ed.,. Oxford University Press, 2006.

Contact Time: Meeting with supervisor every 2 weeks

Coursework: 75% (Research project report, 18,000 words)

Examination: 25% Oral Examination (**must be passed (at 50%) in order to pass module**)

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Module Code:	**CENG0033**	**Module Title:**	**Advanced Separation Processes**
Weighting:	15 credits 7.5 ECTS	**Pass mark**:	50%
Year of Study:	4 (L7U) MSc (L7P)	**Level**:	L7U - Option L7P - Option

Teaching Staff: **Prof E Sorensen,** Dr M Salvalaglio

Aims: The aim of this module is to extend the students' knowledge of basic fluid separation processes to more complex systems commonly found in the chemical processing industry. Students will develop:

- a thorough understanding of the underlying chemical & physical phenomena of the processes;
- a working knowledge of methods for design and operation of industrial separation units;
- a working knowledge of simulation tools applicable for the analysis and design; skills to propose energy efficient and sustainable design solutions.

Learning Outcomes: On completion of this module students should:

- be able to understand the mass and heat transfer phenomena involved in complex fluid separation processes;
- be familiar with the procedures for the design of complex fluid separation equipment in the context of sustainability and sustainable development;
- be able to select an appropriate fluid separation process to meet a required separation performance;
- be able to apply conceptual design methods for simple and complex distillation columns;
- be able to simulate process flowsheets and mass transfer operations with an appropriate level of detail

Synopsis: To provide an understanding of the principles of complex fluid separation processes, as well as an ability to suggest energy efficient and sustainable design & operation alternatives thereof, such as:

- Extractive, azeotropic and reactive distillation
- Pressure- and temperature-swing absorption (PSA/TSA)
- Multi-component distillation & absorption separations, including column sequencing
- Advanced chromatographic processes (e.g. Simulated Moving Bed)
- Cooling and Evaporative Crystallization

Textbooks: J. D. Seader, E. J. Henley, and D. Roper. Separation process principles: chemical and biochemical operations. Wiley 3rd ed.
P. C. Wankat. Separation process engineering. Prentice Hall 2nd ed.
R. K. Sinnott, J. F. Richardson, J. R. Backhurst, J. H. Harker, and J. M. Coulson. Coulson & Richardson's Chemical Engineering. Vol. 6. Butterworth-Heinemann 3rd ed.
R. Smith. Chemical Process Design and Integration, Wiley.

Contact Time: 40 hours

Coursework: 40%

Examination: 60% (3 hour written exam)

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Module Code:	CENG0043		Module Title:	Advanced Process Plant Design Project
Weighting:	60 credits	30 ECTS	**Pass mark**:	50%
Year of Study:	MSc (L7P)		**Level**:	L7P – Compulsory MSc Chemical Process Engineering, Design route only
Teaching Staff:	**Dr Richard Porter**, Dr Sergey Martynov, Prof H Mahgerefteh			
Aims:	The module aims to further develop and test the students' ability to apply the knowledge gained in earlier modules and to apply this to the design of a chemical processing plant in a sustainable context. Lectures, tutorials and group meetings will provide training in the techniques and tools required to carry out the design project, applying appropriate design concepts and computational tools. The module also develops the following transferable skills: teamwork, presentation, written communication and project management.			
Learning Outcomes:	On completion the students will be expected to: - Understand the importance of identifying the objectives and context of the design in terms of: the business requirements; the technical requirements; sustainable development; safety, health and environmental issues; appreciation of public perception and concerns. - Understand that design is an open-ended process, lacking a pre-determined solution, which requires: synthesis, innovation and creativity; choices on the basis of incomplete and contradictory information; decision making; working with constraints and multiple objectives; justification of the choices and decisions taken. - Be able to deploy chemical engineering knowledge using rigorous calculation and results analysis to arrive at, and verify, the realism of the chosen design. - Be able to take a systems approach to design appreciating complexity; interaction and integration. - Be able to work in a team and understand and manage the processes of: peer challenge; planning; prioritising and organising team activity; the discipline of mutual dependency. - Be able to communicate effectively to: acquire input information; present the outcomes of the design clearly, concisely and with the appropriate amount of detail, including flowsheets and stream data; explain and defend chosen design options and decisions taken.			
Synopsis:	Chemical engineering design is the creation of a system, process, product, or plant to meet an identified need and serves to: • Develop an integrated approach to chemical engineering. • Encourage the application of chemical engineering principles to problems of current and future industrial relevance including sustainable development, safety, and environmental issues. • Encourage students to develop and demonstrate creative and critical powers by requiring choices and decisions to be made in areas of uncertainty. • Encourage students to take a broad view when confronted with complexity arising from the interaction and integration of the different parts of a process or system. • Encourage the development of transferable skills such as communication and team working. • Give students confidence in their ability to apply their technical knowledge to real problems			
Textbooks:	As recommended for the particular project.			

General:
Towler, G., Sinnott, R.K., Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design, 2nd ed., Elsevier, 2013.
Sinnott, R.K., Coulson & Richardson's Chemical Engineering, Vol 6, 4th ed., Butterworth Heinemann, 2005.
McCabe, W.L., Smith, J.C., Harriott, P., Unit Operations of Chemical Engineering", 7th ed., McGraw-Hill, 2005.
Kirk-Othmer Encyclopedia of Chemical Technology, 5th ed., Wiley & Sons, 2007.
Ullmann's Encyclopedia of Industrial Chemistry, 2nd ed., Wiley & Sons, 2002
Yaws, C.L., Yaws' Handbook of Thermodynamic Properties for Hydrocarbons and Chemicals, 2nd ed., Gulf Professional Publishing, 2015.

Hazop and Safety Integrity Analysis
Center for Chemical Process Safety, Pilot Plant Operation Phase: An Illustration of the HAZOP Study Method, in: Guidelines for Hazard Evaluation Procedures, 3rd ed., John Wiley & Sons, 2008.
Kletz, T., Hazard identification and assessment, in: HAZOP AND HAZAN: Identifying and assessing process industry hazards, 4th ed., Institution of Chemical Engineers, 1999.
Kletz, T., Hazard and operability studies (Hazop), in: HAZOP AND HAZAN: Identifying and assessing process industry hazards, 4th ed., Institution of Chemical Engineers, 1999.
Lees, F., Lees' loss prevention in the process industries: hazard identification, assessment, and control, 4th ed., Elsevier, 2012.
Marzal, E.M., Scharpf, E.W., Safety Integrity Level Selection - Systematic Methods Including Layer of Protection Analysis, ISA, 2011.

P&ID development:
Hall, S., Rules of thumb for chemical engineers, Elsevier, 5th ed., 2012, pp 291-295, 337-346.
Mayer, F. A., A P&ID standard: What, why, how?, ISA transactions, 41 Issue 4, 2002, pp 389-394.

Process Control:
Ponton J.W., Degrees of freedom analysis in process control, Chemical Engineering Science, Vol. 49, No. 13, 1994, pp 2089 – 2095.
Pham, Q.T. Degrees of freedom of equipment and processes, Chemical Engineering Science, Vol. 49, No. 15, 1994, pp 2507 – 2512.
Gorak, A., Schienmakers, H., Distillation Control, in: Distillation: Operation and Applications, Academic Press, 2014.
Luyben, W.L., Chemical Reactor Design and Control, AlChe, Wiley, 2007.

Detailed Unit Design:
Gildert, G., Gildert., J., Specifying a catalyst bed, CEP Magazine, August 2016, AIChE.
Karmarkar, M., How to design a reactor,The Chemical Engineer. Dec2016/Jan2017, Issue 906/907, p44-49.
Wankat. P.C., Separation Process Engineering: Includes Mass Transfer Analysis, 3rd ed., Prentice-Hall, 2011.

Contact Time: Meeting with supervisor every two weeks

Coursework: 45% Project work - Group
45% Project Work - Individual

Examination: 0%

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Module Code:	CENG0052	Module Title	Advanced Process Design Principles
Weighting:	15 credits 7.5 ECTS	Pass mark:	50%
Year of Study:	MSc (L7)	Level:	L7 - Compulsory MSc Chemical Process Engineering, design route only
Teaching Staff:	**Prof E S Fraga**, Dr Richard Porter		
Aims:	• To provide an introduction to process design, bringing together elements of process analysis and detailed process phenomena and preparing the students for the main design project (CENG0043). • To develop skills in the use of computational modelling and optimisation tools.		
Learning Outcomes:	Upon completion of this module students should: • understand what design entails and how to apply this to both new and existing process designs • understand the use of modelling, simulation and optimisation tools in design • understand the connection between the technologies, the phenomena and overall processes.		
Synopsis:	• Introduction to design: processes, economics, flowsheeting • Flowsheet design: heuristic, algorithmic • Heat exchanger network design • Case studies: reactor system design, separation sequencing, recycles This is a Masters level (level 7) version of the module CENG0013 Process Design Principles but will have a stronger focus on unseen, and more open ended, problem solving, including a design project.		
Textbooks:	Biegler, L.T., I.E. Grossmann and A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall International Series, 1997. Towler, G. and R. Sinnott, Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 2nd rev. ed., Butterworth-Heinemann, 2012.		
Contact Time:	20 hours lectures and problem classes		
Coursework:	100% (40% coursework, 60% project)		
Examination:	0%		

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