# School of Chemical Engineering

# Study Abroad Module Handbook 2023/24

**Module Title:**From Bench to Market: the Development of Pharmaceutical Drug Products

**Module Code:**18526

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**From the latest technologies used in drug discovery through to post market surveillance activities, this module looks at the stages involved in the multimillion-pound process of drug product development. The module covers the typical 'time-line' of drug product development, including Issues and importance of stages in drug product development; drug discovery; developability; preformulation, primary and secondary manufacturing; quality by design approaches to pharmaceutical manufacturing; pre-clinical studies and clinical studies; the regulatory and quality environment of the pharmaceutical industry; marketing and post marketing activities; patents and protection intellectual property.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LI Process Engineering Fundamentals

**Module Code:**19298

**Semester:**1

**Credits:**10

**Level:**LI

**Module Description:**The module introduces the fundamental aspects of chemical engineering. Dimensional Analysis - engineering units and the concepts of dimensional reasoning, mass and energy balances and their use in plant design and flowsheeting, basics of fluid flow - Bernoulli's theorem, pressure loss and pumps, material handling - solid/gas and solid/liquid interactions, heat transfer, fundamentals of Mass transfer, reaction kinetics & basic reactors.

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**Module Title:**Advanced Transport Processes

**Module Code:**20545

**Semester:**1

**Credits:**20

**Level:**LM

**Module Description:**This module provides in-depth fundamentals of fluids rheology and heat, mass and momentum transfer phenomena in Newtonian and Non-Newtonian fluids. [A] Analysis and development of boundary layers around solid surfaces and drag forces exerted by different type of fluids on large surfaces and particles are discussed. Non-Newtonian fluids are discussed and classified according to their rheological behaviour. Rheometry techniques are described and their theory reviewed. Simple Non-Newtonian flows are solved analytically and visco-elastic fluids are studied using different mechanical models.

[B] The principles of continuum mechanics are introduced to describe mass, momentum and energy transfer. The mechanisms of momentum, mass and energy transfer in flows are discussed and Navier-Stokes equation is solved in a simple geometries. 3D unsteady state momentum, mass and energy balances are introduced and solved in simple geometries. Basic concepts of Computational Fluid Dynamics (CFD) are introduced and applied using Comsol Muliphysics.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**Energy Economics

**Module Code:**21169

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**Given the prominence of how energy is supplied and used globally, the course will examine how economics is shaping the policy agenda, and vice versa, considering the different technologies that will be part of the energy system. The general aim of this module is to introduce students to a range of topics in economics, sufficient to allow them to understand the business and financial pages of a serious newspaper, and to appreciate the commercial context of engineering decisions that they will make in their subsequent careers, and become aware of the main features of government economic policies. The specific aim is to introduce students to economic issues in energy, and in particular to electricity system economics, since this will greatly influence the future success or failure of different low-carbon technologies.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LH Multiphase Systems

**Module Code:**23624

**Semester:**1

**Credits:**20

**Level:**LH

**Module Description:**This module introduces fundamentals enabling understanding of processing of multiphase systems.

Part 1: Colloidal systems and products:

The interaction between colloidal drops/particles such as van der Waals and electrostatic forces are discussed and DLVO model is introduced; colloid stability including gas/liquid and liquid/liquid interfaces are discussed as well as measurements of zeta potential; different mechanisms of droplet break up. Emulsion stabilisation by small molecule emulsifiers and surfactants; steric and charge stabilisation; emulsion stability and destabilisation; rheology and rheology of suspensions; basic properties of suspension microstructure and how they affect rheology, viscoelastic fluids and use of simple viscoelastic models; momentum, mass and energy transfer in dispersed systems.

Part 2: Motion of particles in fluids and gas-liquid flow:

Steady and un-steady state motion of particles/bubbles drag forces, add mass forces, skin friction and form drag are discussed for spherical and non-spherical particles; sedimentation, free and hindered settling as well as gas-liquid flow patterns in vertical and horizontal pipes including flow pattern maps are introduced; pressure drop in two-phase gas/liquid flow and homogeneous flow model, two-phase multipliers and separated flow model are introduced.

Part 3: Fluid/solids systems:

Concept of maximum stable drop size in laminar and turbulent flow in stirred vessel and in pipes is introduced; coalescence and breakage model are discussed and related to dispersion processes; gas-solid fluidisations, pneumatic conveying, powder flow and consolidation are also introduced; stress/strain relationships.

Part 4: Lab:

Generation of an emulsion: evaluation of stability, in particular considering creaming and coalescence over time. Completion of the appropriate report on stability based on measured experimental data (such as the droplet size distribution obtained by microscopy imaging analyses) obtained by all groups of students.

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**Module Title:**Cell Factories

**Module Code:**21317

**Semester:**1

**Credits:**20

**Level:**LM

**Module Description:**This module allows students to understand the principles of the large scale industrial production of a range of molecules, both pharmaceuticals and chemicals, by fermentation and cell culture. The module comprises one week of seminars, tutorials and practical classes and one week in the pilot plant.

Material covered will include: choice of production system based on product (bacterial, yeast, eukaryotic cell); benefits and weaknesses of each system; the way in which each system can be used industrially at a variety of scales; and analytical techniques for monitoring upstream bioprocesses.

The enquiry-based learning module design will allow students to construct their own learning path through the module material and complete a portfolio of coursework that will be assessed to determine whether learning outcomes have been met.

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**Module Title:**Fermentation and Cell Culture

**Module Code:**26220

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**This module allows students to understand the principles of the large scale industrial production of a range of molecules, both pharmaceuticals and chemicals, by fermentation and cell culture. The module comprises one week of evidence based learning teaching sessions.

Material covered will include: choice of production system based on product (bacterial, yeast, eukaryotic cell); benefits and weaknesses of each system; the way in which each system can be used industrially at a variety of scales; and analytical techniques for monitoring upstream bioprocesses.

The enquiry-based learning module design will allow students to construct their own learning path through the module material and complete a portfolio of coursework that will be assessed to determine whether learning outcomes have been met.

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**Module Title:**Fuel Cell Technologies

**Module Code:**37607

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**The module will cover the Fuel Cell & Hydrogen technologies and their science:

Electrochemistry/thermodynamics/energy analysis tools, applications of fuel cells and hydrogen, hydrogen generation, processing & storage, hydrogen as energy storage vector, low temperature fuel cells, materials, designs, fuels, and systems, high temperature fuel cells, materials, designs, fuels, and systems hydrogen and fuel cell safety issues, environmental analysis, market introduction, economy, and policy framework.

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**Module Title:**Introduction to Electrochemistry

**Module Code:**26223

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:**The module with cover the basics of modern electrochemistry, including:

Equilibrium electrochemistry/thermodynamics, dynamic electrochemistry & kinetics, Faradaic vs Galvanic electrochemistry, common experimental techniques, illustrative case studies.

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**Module Title:**Advanced Electrochemical Applications

**Module Code:**26226

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module will cover the theories and applications of electrochemistry and will be divided into six parts:

(i) Principles of Electrochemistry inc. Electron-Transfer Kinetics, Nernst, Electrode Reactions, Butler-Volmer, Overpotentials, Cell Voltages

(ii) Electroanalytical Methods & Techniques (Voltammetry/Amperometry/Chrono/RDE/RRDE/RCE,Tafel,EIS)

(iii) Battery Technologies

(iv) Fuel Cell Technologies

(v) Electrolysis and Electroplating

(vi) Corrosion: Introduction to Corrosion of Metals in Aqueous Environments & Corrosion of PEMFC BPPs

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**Module Title:**LM Thermal Energy - conversion, storage and applications

**Module Code:**31272

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module will cover the following aspects:

Fundamental concept of thermal energy, generation of thermal energy, thermal energy conversion processes, thermal energy transmission/transportation, thermal energy storage, applications of thermal energy. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Sustainability in the Food Industry

**Module Code:**26437

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**Sustainability and the need to address environmental issues is a significant driver in the food industry. From 'Farm to Fork' the Food Industry uses significant amounts of resources in agriculture, production, transport and other sectors; in addition, it generates many types of wastes. This module provides an overview of the main issues facing the food industry, including the economic, legislative and political contexts which influence the options available to industry to manage and minimise its environmental impact. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Food Control

**Module Code:**26443

**Semester:**1

**Credits:**20

**Level:**LM

**Module Description:**An Introduction to Food Control in the EU, using the UK as the main example. The module will focus on how the member states try and ensure consumers can access safe food. The main food hygiene legislation will be reviewed and put in the context of premises inspection and enforcement including imported food. Approaches taken by other member states and important trading partners such as the USA, Australia and Canada will be compared to the UK. Problems such as fraud in the food industry will be considered, as will key issues and events which demonstrate learning points for enforcement.

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**Module Title:**Process Systems and Principles of Process Control

**Module Code:**28467

**Semester:**1

**Credits:**20

**Level:**LI

**Module Description:**Part A of the module:

Introduces students to modelling, process dynamics and practical process monitoring and control. The importance of control for process operation will be explained, and the structure of modern plant-wide control systems will be described. The module will discuss typical process monitoring devices for common variables (pressure, temperature, level, flow, etc.), and show how signals are generated by these and transduced, transmitted and, if necessary, transformed for use in the control system. The fundamentals of open- and closed-loop control will be discussed and controller actions outlined. A review of process modelling and its basic procedures will be used to explain the concept of dynamic behaviour of processes. Methodologies for solving the differential equations resulting from unsteady-state balances over selected process examples will be given, in particular for linear, second-order differential equations. Practical examples will also be given of processes and instruments demonstrating common types of dynamic behaviour.

Part B of the module:

This builds upon and covers the basic principles of analysis and design of process level control systems, and the appropriate mathematical tools. Topics discussed include transfer functions, ideal dynamic systems, classical PID controllers, feedback control block diagram analysis, stability concept and analysis, structure and components of modern control loops, and practical aspects of industrial process control.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**Petrochemical Engineering

**Module Code:**26504

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**The module covers some of the main unit operations of crude oil refineries, from crude oil to gasoline. It involves pre-treatment, crude distillation, catalytic cracking, hydrocracking, hydroprocessing, hydrotreating.

Calculation work involves crude distillation products, mass and energy balances on catalytic cracking and mass balance of reforming. It focuses on the engineering aspects that offer comprehensive applications to the chemical engineering process principles that they learnt during the First and Second Years. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Energy Systems and Policy

**Module Code:**31267

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**The aim is to give students an overview of the demand for and supply of energy, the technologies involved, and the main economic and policy issues.

The topics covered are: The demand for energy, fossil fuels, electricity generation (conventional, nuclear and renewable), hydrogen, electricity networks, electricity markets, investment decisions, energy security, energy and the environment, and energy policy.

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**Module Title:**LM Advanced Energy Technology

**Module Code:**39214

**Semester:**1

**Credits:**20

**Level:**LM

**Module Description:**This module provides a significant proportion of the module's fundamental engineering concepts, specifically relating to thermodynamics and power generation processes, in addition to the impact that each generation process can have on the environment and wider economy.

The syllabus will include: the laws of thermodynamics, conventional power generation processes, renewable power generation processes, the current mix of generation processes in the UK (and wider global market) and how this is changing over time as a result of improving technology (and how distributions change as a function of geography and raw materials), the needs of a developed economy in terms of heat and power, climate change processes and climate change modelling.

Further material on how the provision of energy to non-electrical systems ties into the UK energy demand is important here. For example, heat networks and the emergence of transportation operating via non-ICE drivers. The supply of such systems should be set in context with the demand for such. Other modules may look at how supply and demand could change with time, but AET should be able to show how demand can be satisfied at any particular time, and the module will also include an overview of general energy systems such that students can understand this process.

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**Module Title:**LM Project Management (Business Strategy Delivery)

**Module Code:**31634

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**The module links directly with engineering and business strategy development, demonstrating how programmes and projects are derived from a business intent. Describes the ontology and structure of projects and develops the role of a project manager in planning and delivering the required benefits for the enterprise.

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**Module Title:**LM Non Ideal Materials

**Module Code:**34538

**Semester:**1

**Credits:**20

**Level:**LM

**Module Description:**This module provides an in depth study of the world of non-ideal materials, particularly colloidal systems and their industrial importance. The course will concentrate on three main systems, namely suspensions, emulsions and foams and in particular will concentrate on how the interparticle forces control the structure of the colloidal system. The course will start defining colloidal systems and explain their classification. The module will describe how surfactant molecules can be used to modify the surface tension and form micelles and their importance in the industry as detergents and lubricants.

How capillary forces are important in the process of wetting will be considered in some detail. The stability of colloidal suspensions will be discussed in the terms of the balance of repulsive and attractive forces and the various microstructures that can be obtained when one force dominates over the other. In particular how these forces can be manipulated by the careful addition of pH, salt or polymers will be presented. The measurements of zeta potentials as a means of characterising and magnitude of the interparticle forces will be discussed in detail. The contacts between small particles and their role in adhesion and cohesion will be explored. The use of sols and gels in the manufacture of glasses, ceramics, coatings and catalysts will be explored in terms of fundamental interactions, particular attention will be paid to silica gelation. Freeze casting of porous filters, coating gelation and rapid gelation techniques will also be covered. The emerging technologies of gel casting will be covered. The industrial importance of emulsions especially in the food industry will be presented.

Finally foams will be discussed. This module will also describe how chemistry and interfacial phenomena create structure in complex fluids, specifically emulsions creams and gels which occur in many consumer products. The module describes measurement methods which can be used to infer structural properties and determine the process conditions (history of shear, time and temperature) which cause structure to break down. These measurements are based on the rheological behaviour of the fluids and the module introduces the concept of rheology and provides an in depth description of the different types of fluid which exist (Newtonian and non-Newtonian and Viscoelastic). The different types of equipment used to perform rheological measurements and different measurements methods of rotational viscometry and oscillatory rheology are described.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LM Frontiers in Tissue Engineering

**Module Code:**32433

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module defines the area of tissue engineering from an interdisciplinary viewpoint and explains key concepts that are important for those working within the healthcare technology and formulation engineering disciplines. A focus is placed on the latest research and technological advances in the field, however suitable introductory material is covered to enable students new to the topic to digest this material. This module aims to explain how engineers have and will continue to contribute a central role to this exciting and flourishing field.

The fundamentals of cell biology, immunology, organogenesis and regenerative medicine will be covered to equip the student with the necessary knowledge and language to understand key concepts within tissue engineering. Structure function relationships of materials will be discussed in the context of regenerative applications and important approaches and tools to engineer tissue will be presented using examples from the literature. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Applied Synthetic Biology

**Module Code:**32444

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module covers the application of systems and synthetic biology for the design and development of microbial systems for the production of varied molecules such as biofuels, platform and fine chemicals, pharmaceuticals and neutraceuticals from varied biological feedstocks.

The fundamentals of synthetic biology and systems biology are introduced and their relevance to the biochemical and formulation engineer considered. Through the use of examples from the recent research literature, the development of organisms that are capable of producing varied molecular products from a range of feedstocks is explored.

Students work in teams to design organisms that are able to generate specified molecules from specified feedstocks. The plans are presented in group oral presentations, and feedback is given that students are able to refine their approaches and develop their written reports.

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**Module Title:**Food Structure for Performance

**Module Code:**36358

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**Food manufacturers are under constant pressure to provide 'healthy' and functional processed foods, while maintaining flavour and desirability. In order to achieve this, food products need to be understood and specifically designed to tackle problems. This module will introduce the fundamental structures that make up the majority of modern processed foods, and explore how processing and formulation affects the developed structure and subsequent texture and flavour. Fundamental information on emulsion science, crystallisation, heat/mass/momentum transfer, and standard measurement techniques will be provided through an online environment and will be needed to form the basis of the main content delivered during contact week. This core knowledge will then be applied to case studies of current research within the food structure research area. As a research led module it will develop student's understanding of current formulation, processing, characterisation and evaluation methods being employed to develop future food products.

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**Module Title:**LM Advanced Therapeutic Medicine Products

**Module Code:**32445

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module will cover the area of Advanced Therapeutic Medicine Products (ATMPs) within Healthcare Technologies encompassing how interdisciplinary Bioscience and Medicine can be influenced by Chemical Engineering technologies.

Taking concepts from the laboratory through preclinical evaluation and on to clinical trials, this module will cover how interdisciplinary researchers are advancing regenerative medicine technologies. Areas covered within the module will include personalised medicines, cell therapies, manufacture & classification, and cell delivery. Examples from the Healthcare Technologies Institute will include skin and bone restructuring as well as technologies being developed for tissue regeneration. The module will also discuss finding new methods of detecting injuries and cancers early, improving scar reduction at different body sites and the development of innovative, bespoke medical devices and cell-based therapies. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Hydrogen and Hydrogen-based Fuels

**Module Code:**36871

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**The module will cover the production and storage of hydrogen as a fuel for fuel cells and for decarbonising industry and the overall energy system. The topics covered include:  
• An Introduction to Hydrogen  
• Hydrogen production from fossil energy sources  
• Hydrogen production by the electrolysis of water at temperatures below 100ºC  
• High temperature water electrolysis  
• Hydrogen production using nuclear energy and solar thermo-chemical cycles  
• Renewable hydrogen, non-electrolysis and natural (geologic) hydrogen   
• Separation and Purification of Hydrogen  
• Hydrogen Storage  
• On-board storage  
• Infrastructure, supply chain, transport, dispensing   
• Power to Gas technologies

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LM Food Safety Management Systems

**Module Code:**32830

**Semester:**1

**Credits:**20

**Level:**LM

**Module Description:**This module is an examination of the systems used to manage food safety hazards including HACCP, allergen risk assessment & management principles and quality assurance systems. The module sets these systems within both the legal and food safety context and thus considers the application of these systems from the food industry and relevant food safety enforcement bodies. The module also covers the pre-requisite systems required to support food safety management, including, Pest Management, Cleaning, personnel policies and maintenance.

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**Module Title:**LH Advanced Reactors and Thermodynamics

**Module Code:**33126

**Semester:**1

**Credits:**20

**Level:**LH

**Module Description:**The module will cover key aspects of chemical thermodynamics, with particular emphasis on how this information is used in practice. With attention to equations of state, vapour-liquid equilibria and other phase equilibria, chemical potential and use in single and multicomponent systems, concept of fugacity and it links to chemical potential, activity coefficients, phase separation and chemical reaction. Moreover, it will cover the formulation of catalysts and some products based on catalytic processes (such as syngas, synthetic fuels, methanol), the impact of non-ideal conditions within reactors. Complex reactions will be covered, to include reactions in series, in parallel and series-parallel, and the concepts of yield and selectivity explored in detail. An introduction to catalyst design, manufacture and characterisation will be given, to incorporate extrusion of pastes, calcining and metal impregnation, characterisation of pore structure, modelling of catalyst pore structures, and determination of adsorption behaviour using Fourier Transform Infrared Spectroscopy and Gas Chemisorption. Other key focus will be on Equilibria Residence time distributions in ideal vessels will be covered including CSTR, PFR, compartment models, combinations and systems thereof, and non-ideal flow in reactor systems to diagnose flow problems and deviations from ideal reactor behaviour, such as bypassing and dead zones.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LI Reactors Catalysis and Thermodynamics

**Module Code:**32470

**Semester:** 2

**Credits:**10

**Level:**LI

**Module Description:**This module teaches the fundamentals of thermodynamics and its application in reactor design. It will begin with a revision of reactors covered in 1RET such as CSTR, plug flow and batch. It will cover reaction equilibria and criteria to decide if a reaction is reversible and has reached equilibrium. The design of reactors to overcome mass transfer resistances will include liquid mixing equipment, e.g. stirred vessels and static mixers types and how they operate, mixing in single phase chemical reactors' mixing mechanism and thermodynamics; Students will understand how to generate a well-mixed reactor: influence of mixing length to include micro, meso and macro mixing in chemical reactors nature and boundaries of phenomena; mixing set up and power consumption in high viscosity and non-Newtonian fluids. Revision of first and second law of thermodynamics will lead on to cover phase change, internal energy enthalpy and specific heats, energy analysis of steady flow system. The relevant mixing theory will cover powder mixing in gas fluidised bed fundamentals of fluidisation, effect of critical parameters in mixing, calculation of minimum fluidisation velocity; residence time distribution in ideal reactors application and experimental determination.

The module will give students the necessary skills to undertake Advanced Reactors and Thermodynamics in Year 3.

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**Module Title:**LM Food Chain Security

**Module Code:**23638

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**A consideration of food security as defined by the WHO. Aspects of insecurity and the mechanisms to manage them will be addressed including, for example: Deliberate contamination, Infrastructure issues, Food safety management systems, Global sourcing. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Product Design Exercise

**Module Code:**17128

**Semester:**2

**Credits:**10

**Level:**LI

**Module Description:**The module is intended to emphasise the creative aspects of process engineering, and as such contrasts with other modules, which concentrate on numerical and technical skills. It delivers the message that imagination and responsibility are essential attributes for successful professional engineers who are required to interface with many other business sectors. Working in groups, students use brainstorming techniques to generate ideas for new products and/or processes, while considering ethical, economic, and societal implications of proposed innovations. Each group then filters these ideas and develops one or more to the point of producing a business/development plan for its realisation. Groups are required to give attention to both commercial and ethical aspects of the project, and the engineering and process technology involved. As well as experiencing group operation in a broad, open-ended ideas generating environment, the students written and oral presentational skills and ethical reasoning capabilities are enhanced and tested.   
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**Module Title:**LH Processing for Formulation

**Module Code:**23627

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**The course will be taught by case study, developing understanding of product development, technological issues, process decisions and implementation. Product evaluation and characterisation methods are introduced. The studies will be based around the processing of zirconia (allowing the development of materials processing routes, phase control (phase diagrams), mechanical properties and the evaluation of microstructure). Catalyst extrusion (alumina supports, exploring sol-gel technologies and soft solids processing routes). The development of plastic recycling and recyclable plastics is covered in the circular economy. Bio fuel production via thermochemical routes is covered. The final bio processing case study will concentrate on magnetic fishing. Starting from basic first principles the development of powerful magnetic techniques for bioprocessing will be described. Using examples, the properties required of magnetic adsorbents and magnetic separator equipment will be described, the ways in which magnetic bioprocesses can be operated, modelled and optimised will be demonstrated, and future prospects of magnetic fishing technology within the bioprocess industries will be highlighted. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Chemical Contamination of Food and Water

**Module Code:**26439

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**The students will learn about the importance and effects of the major classes of chemical contamination in food and drinking water. Additionally, students will be made aware of a) sources of contaminants, b) methods of treatment of food and water and c) the importance of contaminants in food relative to other uptake pathways. Legally accepted chemical additives will also be considered in this module. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Plant Optimisation

**Module Code:**26506

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**The manufacturing sector is rapidly changing to adjust to a range of complex and often conflicting needs while aiming to maximize a range of benefits. This module will equip students with the tools necessary to undertake these tasks as well as present their use in a range of manufacturing sectors of interest to chemical engineers. The module will introduce the students to setting up optimization problems; optimization of unconstrained/constrained objective functions; optimization of linear and non linear problems. Elements of design of experiments will be also introduced including full and fractional factorial. Speakers from the various industrial sectors will expand on the use of these methods. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Chemical Nanoengineering

**Module Code:**26512

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**Nanotechnology is increasingly moving from a research curiosity to actual product application, bring increased demands for nanoengineering. Nanotechnology is described generally as ‘the manipulation of matter with at least one dimension sized from 1 to 100 nanometres’ and more specifically can be thought of as assembling products at atom by atom, or molecule by molecule, so as to harness the unique properties of matter at the nanoscale.

Here we will introduce the fundamental concepts of nanotechnology, discuss methods for characterising and fabricating at the nanoscale and look at application in the Chemical Engineering arena, together with consideration of the ethical and economic impacts of this new field.

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**Module Title:**LM Principles of Nutrition

**Module Code:**27443

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**The WHO Global Strategy on Diet, Physical Activity and Health and the Publication of the 2004 Government White Papers' Choosing Health: Making Healthy Choices' Easier and 'Choosing a Better Diet', have heightened public and professional awareness of the importance of nutrition and healthy eating. The government is now turning to the food industry to help improve the nation's diet.

The aim of this module is to equip students' with knowledge and understanding of the principles of good nutrition and healthy eating and to ensure they are able to apply these principles in a practical and responsible way whilst working in the food industry and /or government organizations e.g. food product development, setting nutrition standards. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Module Title:**LM Water and Health

**Module Code:**29680

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**The module considers the main health hazards associated with water used as a food or ingredient, including the typical control methods used in the UK to ensure safety of supply. Recreational use of water in public swimming pools will also be considered. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Energy Systems Modelling

**Module Code:**31268

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module will give students a thorough grounding in the modelling of both engineering processes and energy networks. In order to understand how the UK delivers variable amounts of power in response to changing demand, students must understand the mathematics and engineering behind both the generation of energy and its distribution via the energy networks (some of which material is taught in other modules) and be able to build mathematical models that can describe these processes. As such, the syllabus will entail:

a) Thermodynamics of conventional power generation and energy distribution networks.

b) Use of CFD software (Comsol) to investigate the behaviour of process units, e.g. heat exchangers.

c) Use of Matlab and Simulink software for numerical modelling, network modelling and frequency response modelling.

d) Use of flowsheeting techniques to model overall power plant cycles and heat networks

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**Module Title:**LM Business and Strategy Development

**Module Code:**31632

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**The module links directly with engineering and project management giving a business and enterprise context.

Following a natural entrepreneurial flow, it considers the critical aspects of turning a commercial idea or a concept into a business. Looking at how consumer trends and globalisation impact strategy, and how companies turn their strategies into programmes and projects to deliver them. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Renewable Energy Systems

**Module Code:**31566

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module covers the operating principles, characteristics, and classifications of energy storage solutions and their integration within a whole energy system.

In addition, this module covers the operating principles, characteristics, and interactions of distributed heat and power generation technologies (for example, wind power systems, photovoltaic systems, biomass-derived systems), their technical and environmental benefits, their planning, operating, and grid integration challenges, complexities, remedies, charging mechanisms in a distribution energy business, and standards.

Finally, the integration of such technology into energy networks will be studied from a standpoint of demand; specifically how such technology can be utilised both to satisfy realtime demand as a function of grid load change and to accommodate increased future energy demand. This latter consideration is also important when considering the increasing energy demand in developing nations.

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**Module Title:**LM Food Standards

**Module Code:**31692

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**The module covers compositional and marketing standards for foods. In addition it includes the mandatory requirements relating to information provided to consumers including labelling and packaging that allow them to make informed choices.

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**Module Title:**Mass, Heat and Momentum Transport

**Module Code:**17125

**Semester:**1

**Credits:**20

**Level:**LI

**Module Description:**This module covers the critical theoretical material for mass and heat transfer. It extends the introductory material taught in Introduction to Transport Phenomena and Thermodynamics. This includes a general energy balance for conduction and common simplifications for symmetrical 2-D and 1D problems. The lumped capacitance method is discussed, as well as heat transfer from extended surfaces. Engineering processes such as membrane separations and adsorption are described. In addition, the critical theoretical material for momentum transport is discussed and addresses viscous and turbulent flows between solid boundaries. The principle of similitude is applied to the design and analysis of pumped flow systems and cost optimisation is applied to the design of pipelines. Engineering applications such as complex pipe networks and combined pipe-pump systems are analysed. The heat transfer material covered is further extended to cover internal/external convection and radiation. Computer based methods of solution of heat and mass transfer problems are introduced and applied to some process examples.

Typical content would include:

Use of lumped capacitance method to calculate temperature distributions and heat flux in transient cooling/heating problems, simplified general energy balance to describe specific problems (2D or 1D simplifications) and definition of appropriate initial/boundary conditions, calculation of heat flux from finned surfaces, description of how diffusion influences the operation of absorption, adsorption and membrane systems, description of the two film model and application of this concept in selected mass transfer problems;

an analysis of the flow of real fluids between solid boundaries, application of the arguments for friction and energy conservation to calculate pumping requirements for complex pipe systems, selection of appropriate pump types, and design pipelines economically, an analysis of the flow over a flat plate and around cylinder/sphere, compare hydrodynamic and thermal boundary, and physical interpretation of Nusselt, Reynolds and Prandtl numbers, calculation of heat transfer rate by radiation, understanding of the concepts of black/grey bodies and radiation of gases, description of the qualitative heat transfer during boiling/condensation, completion of the appropriate momentum and heat balances and calculation of transfer coefficients based on measured experimental data.

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LH Engineering of Food

**Module Code:**32469

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**In the engineering for food, the principles of chemical engineering are applied to edible starting materials, the ingredients, to create an often quite complex composite. The quality of the final product as presented to the consumer on supermarket shelves frequently deteriorates over time due to a non-equilibrium state of the processed ingredient as well as because of abuse, mostly temperature, during storage.

In order to engage with design concepts for high quality processed foods that are healthy, sustainable, functional and yet tasty in fourth year optional modules, this module introduces the established principles of processing a selection of complex foods including chocolate, ice cream, snack products, The traditional lecture style delivery will be accompanied by seminars on ‘what’s hot’ and a seminar on the UK importance of the food and drink sector and the role of the chemical engineer.

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**Module Title:**LH Efficient Use of Energy

**Module Code:**32463

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**This module will provide students with a firm and hands-on understanding of the science and engineering behind effective and efficient use of energy technologies, particularly related to conventional energy (e.g. fossil fuels). It will consider how resources can be minimised by reducing energy consumption, specifically by increasing efficiency of use. This will be underpinned by coursework and experimental work in which the students will attempt to reduce their own home energy use by 70%. In doing so they will be instructed on energy technology, the economic environment they operate in and also the socio-political issues such as tackling energy poverty.

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**Module Title:**LI Computing for Chemical Engineers

**Module Code:**33607

**Semester:**2

**Credits:**10

**Level:**LI

**Module Description:**The module develops students' skills in using tools such as MATLAB and Excel, and introduces students to other advanced computer-based design tools such as SIMSCI PRO/II. It is intended that students will use these tools in concurrent and subsequent modules, particularly the modules Product Design Exercise (Year 2) and the Design Project (Level M; Year 3 or 4). It is presumed that the students are familiar with MATLAB and Excel from Year 1 Modelling Concepts and Tools, if not earlier experiences. The demonstration of these design tools requires production of an outline process engineering design of a unit operation as a vehicle on which to practise the work.

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**Module Title:**LM Energy Storage

**Module Code:**32458

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**This module covers the integration of energy storage solutions within a whole energy system, and a detail of the practical considerations at a local level.

In addition, some of the wider implications for energy storage are explored e.g. Potential of pumped hydro storage in the UK, Recycling/re-use of batteries, Hybrid/distributed solutions, EVs use as stationary storage, storage at charge points, Solar + storage in the home.

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**Module Title:**LH Introduction to Healthcare Technologies

**Module Code:**32465

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:**This module aims to provide an introduction to the field of healthcare technologies which encompasses biomaterials, tissue engineering and regenerative medicine.

The module will introduce the most commonly used materials in the field of healthcare technologies, their properties and how they are selected within healthcare technologies.

The latest fabrication technologies used within the field will be discussed, including the use of advanced technologies such as electrospinning, and 3D printing. The influence of structure, functionalisation and biological loading of devices and scaffolds will be discussed in terms of functionality. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Future Engineering of Food

**Module Code:**33110

**Semester:**1

**Credits:**10

**Level:**LM

**Module Description:**The engineering of food is not stood still, new processes and processing paradigms are continuously been researched. The purpose of this module is to introduce novel developments, some of which not yet establish widely in practice, hence the module title: ‘Future’ Engineering of Food. Lectures and seminars will be given by experts in the field. The students will prepare a piece of coursework on a novel process in advance, supported by tutorials, and grouped together at the beginning of the module week to prepare a short group presentation/ .

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**Module Title:**LM Sensor Systems in Medicine

**Module Code:**33111

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:**Sensor systems are used throughout medicine as a means to both monitor and diagnose patients. In recent years, our growing knowledge of the mechansms underpinning disease have opened up a new range of target molecules that can be used for early diagnosis. Many of these molecules have required novel sensing systems to enable detection at sufficient resolution and with reliability to make a success diagnosis. This module will outline the principles behind existing sensor systems used in medicine and will feature specialists in the development of new sensing modalities who will provide seminars to the students on their latest research.

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**Module Title:**LI Reactors or Catalysis and Thermodynamics

**Module Code:**34767

**Semester:**2

**Credits:**10

**Level:**LI

**Module Description:**This module will introduce the properties of catalysts and will build upon kinetics covered in 1RET (or equivalent in home institution) to include derivations of kinetic models based on chemisorption. The effects of diffusion in catalysis including Thiele modulus, effectiveness factor and external diffusion resistances will be covered so that students can make decisions as to whether a reaction is controlled by kinetics or mass transfer.

These will be applied to the calculation of heat balances in ideal reactors such as batch and continuous stirred tank reactors including isothermal and adiabatic cases.

Application areas will include the design of some specific classes of reactor, for example extend ideal reactors covered in 1RET to cover design of fixed bed and fluidised bed reactors; biochemical reaction kinetics and design of bioreactors.

The module will give students the necessary skills to undertake Advanced Reactors and Thermodynamics in Year 3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Bioseparations

**Module Code:**19768

**Semester:**2

**Credits:**20

**Level:**LM

**Module Description:**The following topics are covered in the module:General downstream processing, Recombinant protein hosts, Cell disruption strategies, Aggregation, Fractional precipitation, Centrifugation and centrifuges, Conventional filtration, Membrane separations. Introduction to process chromatography.Principles and theories of chromatography, Chromatography: adsorption & adsorption models; resolution & zone broadening; three phase strategies & linking steps; process development; development of media; scale-up & optimisation. Alternatives to chromatography including Expanded bed adsorption & Magnetic separations. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Industry 4.0 and Big Data

**Module Code:**34534

**Semester:**2

**Credits:**20

**Level:**LM

**Module Description:**The use of technology and data within industry is being considered as a new form of industrial revolution. This is now commonly called Industry 4.0. This module introduces the key concepts that are required to understand the benefits and challenges of this use of technology and data within the process and related industries.

During the module the key concepts around (i) Interconnection, (ii) Information transparency, (ii) Technical assistance and (iv) Decentralised decisions will be introduced. A series of case studies from relevant industry will then present the key challenges and potential impact of the changes provided by the technology and data. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Research Project

**Module Code:**20546

**Semester:**Full Term

**Credits:**40

**Level:**LM

**PRE REQ:** Students must have completed A level H Design in order to take this module.

**Module Description:**A research project spanning both terms. Students are arranged into groups of 2 or 3 and assigned projects from a list of proposals, on the basis of their stated preferences. Projects are intended to have some industrial relevance. The format of the project can vary considerably (experimental, theoretical, literature-based), but in all cases, research is carried out by the project group. This is under the supervision of a member of staff (and other advisors as appropriate), but the students are expected to show initiative and self-direction. Before commencing the project work, students meet their supervisors and prepare a brief, pre-project report, to include a plan of their proposed research and a literature survey of the field. At the end of semester 2 a final report covering literature survey and experimental/theoretical results of the research is required. The reports are individual (i.e., one per student) and are marked by 2 independent academics. There is a short viva voce examination for each student, where they defend their final report. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LM Measurement, Sensors and Design of Experiments

**Module Code:**34536

**Semester:**2

**Credits:**20

**Level:**LM

**Module Description:**The ability to collect relevant information from processes and then analyse and make use of the information underpins a lot of process development, both within research and in industry.

Design of Experiment methodologies are presented to understand how to collect relevant data, with then a series of relevant case studies looking at research and industry process measurement, sensors and data acquisition and then analysis and use of the collected data. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**Process Integration and Unit Operations

**Module Code:**17126

**Semester:**2

**Credits:**20

**Level:**LI

**Module Description:**This two-semester module (part A in semester 1, Part B in semester 2) introduces the methodologies for the synthesis of a new process and discusses the factors governing process selection.

Process Integration and Unit Operations Part A first introduces problem-solving approaches reflecting current trends in process integration (efficient material and energy usage and emissions reduction). Pinch technology is introduced and used to develop heat exchanger networks, with a number of tutorials designed for students to practice the application of the taught approach.

Subsequently, the module proceeds to consider equilibrium stage-wise process design, and starting with the unit operations of absorption, distillation and liquid-liquid extraction, students will be introduced to the concepts of stage to stage calculations and diagrammatic problem solving techniques. They are also introduced to novel processing routes, including a case study on supercritical fluids.

In Process Integration and Unit Operations Part B, the interactions and interdependency between different process units are further developed via case studies. The module builds on these principles by introducing a core set of unit operations (including drying, crystallization, and membrane separations) with particular emphasis on the selection of the appropriate methods to meet process requirements. Elements of process design for each of these unit operations are also discussed. More specifically, mass and energy balances are used together with simplified models of each operation, in order to calculate specific processing parameters (e.g. flow rates) and/or unit-specific characteristics (e.g. unit volume).

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**Module Title:**Design Project

**Module Code:**17133

**Semester:**Full Term

**Credits:**40

**Level:**LM

**Module Description:**In this important module, students work in groups (generally of around 5-6 students) to produce group and individual reports concerning the design of an industrially relevant chemical, biochemical or minerals process. They also deliver formal and informal oral presentations. All reports and presentations are to be to a commercial, professional standard. The design work is supported by frequent classes and seminars, and if possible, a site visit. In most cases, a manufacturing /commercial organisation will provide background material and data, and the supporting involvement of staff from such organisations is encouraged. The output is a complete chemical process design that meets certain technical and commercial specifications while also taking into consideration safety, health and environmental factors; the requirements and interests of the work force; the community; national and local government; other statutory / regulatory authorities and standard setting agencies. The project is entirely student lead with each student group reporting to a 'Board' (group of supervising academic staff). The projects are open ended with many possible solutions. The students are given a very high level brief which, over the course of the project, they close down to a single concept and final design through informed decision taking facilitated by their own literature research and appropriate questions to the Board. The role of staff is to offer guidance where appropriate, administer the project, supervise its progress, ensure the welfare of the design teams and grade submissions.

The Design Project exploits much prior learning, being the culmination of the students' learning. It is this module above all that requires a holistic approach to chemical engineering. It is necessary to pass the individual components of this module to fulfil the taught design requirement of the Institution of Chemical Engineers, for subsequent achievement of Chartered Engineer status. The nature of the tasks to be undertaken, and the learning to be achieved, justify this module being at Level M. However, most students will take the project in Year 3. Students who have taken Year 3 out of the University without completing the equivalent of a Design Project in their host Institution must generally do this module in Year 4. (This is necessary to obtain exemption from IChemE examinations, for example.) It is desirable that students on this module have taken Year 2 Computing for Design and the Product Design Exercise, although these are not prerequisites. However, any student wishing to take this module without Computing for Chemical Engineers and the Product Design Exercise will be advised to complete additional guided learning to ensure they are familiar with design software and shortcut design methods. Exchange students will need to have prior approval to be added to Design Project to prove they meet the pre-requisites.

More detail is provided in the Project Manual (pdf document) and on Canvas. Individual projects have specific Canvas section where relevant information is posted as appropriate. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Module Title:**LI Sustainable Process Engineering

**Module Code:**31633

**Semester:**1

**Credits:**20

**Level:**LI

**Module Description:**The module focusses on the following main areas, supplemented by topical issues: 1. Grand challenges for sustainability faced by the manufacturing, transport and energy industries achieving the transition from fossil based, energy intensive to renewable (carbon neutral) and efficient processes over the coming decades.

2. Sustainable materials and the circular economy. Introduces the technology associated with recycling including recovery, sorting and reuse. Established technologies such as metal, paper and glass recovery will be contrasted with newer approaches. Consideration will be given to product designs that utilise recycled material while also facilitating recyclability.

3. Life cycle assessment and Integrated Pollution Prevention and Control Regulations. The concept of sustainable development is discussed and tools for quantitative assessment of our approach to sustainability are introduced. For example, lifecycle analysis is covered according to the principles of ISO14000, including use of commercial software (eg GABI). Introduction is given to the principles and practice of environmental legislation within the UK and the EU.

4. In the context of the above, topics and case studies may include (but will not be limited to):

a. Cellulosic fibres

b. Strategic and critical materials

c. Fuel cell technologies

d. Energy storage including battery technology

e. Decarbonisation of energy supply

f. Reduction in use of solvents (in coatings industry for example)

g. Waste water treatment including recovery of organics.

h. Carbon capture and storage. Including carbon (and other emissions) trading

i. Global resources (e.g. UN Report March 2019)

*This module cannot be taken by students on Semester 1 only exchange.*

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**Module Title:**LI Reactors, Catalysis and Thermodynamics

**Module Code:**32470

**Semester:**2

**Credits:**20

**Level:**LI

**Module Description:**This module teaches the fundamentals of thermodynamics and its application in reactor design. It will begin with a revision of reactors, such as CSTR, plug flow and batch. It will cover reaction equilibria and criteria to decide if a reaction is reversible and has reached equilibrium. It will introduce the properties of catalysts and will build upon kinetics covered in 1RET to include derivations of kinetic models based on chemisorption. The effects of diffusion in catalysis including Thiele modulus, effectiveness factor and external diffusion resistances will be covered so that students can make decisions as to whether a reaction is controlled by kinetics or mass transfer. The design of reactors to overcome mass transfer resistances will include liquid mixing equipment, e.g. stirred vessels and static mixers types and how they operate, mixing in single phase chemical reactors mixing mechanism and thermodynamics; Students will understand how to generate a well mixed reactor: influence of mixing length to include micro-, meso- and macro mixing in chemical reactors nature and boundaries of phenomena; mixing set up and power consumption in high viscosity and non-Newtonian fluids.

Revision of first and second law of thermodynamics will lead on to cover phase change, internal energy enthalpy and specific heats, energy analysis of steady flow system. These will be applied to the calculation of heat balances in ideal reactors such as batch and continuous stirred tank reactors including isothermal and adiabatic cases. Application areas will include the design of some specific classes of reactor, for example extend ideal reactors covered in 1RET to cover design of fixed bed and fluidised bed reactors; biochemical reaction kinetics and design of bioreactors. The relevant mixing theory will cover powder mixing in gas fluidised bed fundamentals of fluidisation, effect of critical parameters in mixing, calculation of minimum fluidisation velocity; residence time distribution in ideal reactors application and experimental determination. The module will give students the necessary skills to undertake Advanced Reactors and Thermodynamics in Year 3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_