GENERAL INFORMATION

Title	**Engineering Mathematics 1**
Code	CHEN 14010
Credit rating	30
Semester	1 & 2
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Lecture Leaders	Paul Grassia (Semester 1 Mathematics), Andrew Masters (Semester 2 Mathematics), Paola Carbone (IT, Semesters 1 and 20
Other Staff	

1. AIMS

To provide the background mathematics and IT skills required for subsequent chemical engineering courses in mathematically oriented topics. Engineering applications are to be introduced where relevant.

2. OUTLINE SYLLABUS

Calculus and Basic Fundamentals; Taylor series.
Partial differentiation – change of variables, stationary points.
Linear Algebra and vectors
Ordinary Differential Equations: Solutions of first order equations and second order linear equations with constant coefficients.
Complex numbers.
Numerical methods: Non-linear equations – iteration, Newton-Raphson and Bisection methods. Linear Equations – Gauss Elimination; Numerical integration, Simpson and Trapezoidal rules.
Information Technology: Use of libraries for information retrieval; use of spreadsheet, mathematical software and Fortran programming.

3. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Differentiate functions of one or more variables.
Solve first and second order ordinary differential equations.
Expand functions in series form.
Perform matrix operations.
Manipulate partial derivatives
Manipulate vectors
Manipulate complex numbers
Obtain numerical solutions to problems in important engineering subject areas.
Use widely available information systems to interrogate library catalogues and databases.
Apply programming skills to solve relevant problems.
Produce tabular and graphical representations as appropriate.

4. ASSESSMENT

20 credits: Semester 1 Exam (50%), Semester 2 Exam (50%)
10 credits: IT assignments (Semester 1 and 2)

5. RECOMMENDED TEXT

Stroud KA, Engineering Mathematics, 5^{th} Edition, Palgrave, 2001. ISBN: 0333919394, Joule Library 510/STR.

James G, Modern Engineering Mathematics, 3rd Edition, Addison-Wesley, 2001. ISBN: 0130183199, Joule Library 510/JAM.
Brian D. Hahn, Essential MATLAB, 2nd ed. Elsevier, 2003
Michael Metcalfe & John Reid, "Fortran 90 Explained", Joule: U: 001.64245/MET
Brian D Hahn, "Fortran 90 for scientists and engineers", (1994, E. Arnold). Joule: U: 001. 64245/HAH

6. STUDY BUDGETS

Lecture hours:	28	Tutorial hours:	29		
Practical work hours:	38	Private study hours:	205	Total study hours:	300

1. GENERAL INFORMATION

Title	**Engineering Chemistry and Thermodynamics**
Code	CHEN 14020
Credit rating	20
Semester	1 & 2
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Lecture Leaders	Peter Gardner, Xue-Feng Yuan
Other Staff	Nick Lockyer

2. AIMS

To give students a basic understanding of physical and organic chemistry, with particular emphasis on atomic and molecular structure, chemical bonding, acids and bases, aqueous equilibria, phase and chemical equilibria, and the fundamentals of processes with heat and work transfer.

3. OUTLINE SYLLABUS

The electronic structure and properties of atoms and molecules.
Chemical bonding: Ionic and covalent, Lewis structures, bond strengths and lengths.
Molecular shape and structure: The VSEPR model, Valence-Bond Theory and Molecular Orbital Theory.
Introductory systematic account of acids and bases.
Equilibria among ions in aqueous solution including precipitation.
PVT properties of gases. Kinetic theory of gases.
The first law: Internal energy, enthalpy, and heat capacity.
Enthalpy of formation and reaction.
Phase diagrams: the phase rule, and PT diagrams for pure substances.
Phase equilibria for mixtures: VLE – Raoult's law, gas solubilities – Henry's law, SLE.
The second law of thermodynamics, entropy and free energy.
Conditions for phase and chemical equilibria.
Chemical equilibria – the influence of pressure, temperature and reactant ratio.
Thermodynamics of steady state systems.
Analysis of simple power and refrigeration cycles.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:

Explain the relationship between atomic/molecular structure and properties.
Draw Lewis Structures for chemical species and determine the ionic/covalent character of chemical bonds.
Use the VSEPR Model, Valance-Bond Theory and Molecular Orbital Theory to predict electron arrangement and molecular shape.
Recognize, rationalize and quantify acid/base behaviour.
Calculate and interpret solubilities.
Explain the development of theories resulting in Arrhenius temperature dependence of reaction rates.
Explain and apply models describing the PVT behaviour of gases.
Explain how energy is stored by molecules.
Analyse closed system and open systems, steady and unsteady process.
Perform basic calculations in thermochemistry, phase and chemical equilibria.
Analyse the performance of heat engines and refrigerators.

ASSESSMENT

Semester 1: 10 Credits Exam on Engineering Chemistry (80%), coursework (20%)

Semester 2: 10 Credits Exam on Engineering Thermodynamics (80%), coursework (20%)

5. RECOMMENDED TEXT

Atkins P and Jones L, Chemical Principles: The Quest for Insight, 3rd Edition, Freeman, 2005, ISBN: 071675701X, Joule Library 540/ATK.
Smith JM, Van Ness HC & Abbott MM, Introduction to Chemical Engineering Thermodynamics, 5th Edition, McGraw-Hill 1996. ISBN: 007059239X, Joule Library 541.36/SMI.
Atkins P and de Paula J, Elements of Physical Chemistry, 4th edition, Oxford University Press, 2005. Main Library 541.02/A53.
Çengel YA and Boles MA, Thermodynamics An Engineering Approach, 4th edition, WCB/McGraw-Hill, 2002. Joule Library 621.4021/CEN.
Atkins P and de Paula J, Physical Chemistry, 7th edition, Oxford University Press, 2002. Joule Library 541/ATK.
Smith JM, Van Ness HC & Abbott MM, Introduction to Chemical Engineering Thermodynamics, 5th Edition, McGraw-Hill 1996. ISBN: 007059239X, Joule Library 541.36/SMI.

6. STUDY BUDGETS

Lecture hours:	42	Tutorial hours:	20		
Practical work hours:		Private study hours:	138	Total study hours:	200

1. GENERAL INFORMATION

Title	**Transport Phenomena**
Code	CHEN 14030
Credit rating	30
Semester	1 & 2
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Members of staff responsible	Grant Campbell, Peter Martin
Other Staff	Nick Lockyer, Peter Gardner, Esther Ventura-Medina

2. AIMS

The programme unit aims to:
To introduce the basic concept of fluid flow and heat transfer with emphasis on practical design and rating calculations.

3. OUTLINE SYLLABUS

Introductory concepts of fluids, units & dimensions, hydrostatics.
Flow, flow regimes, conservation of mass & energy, Bernoulli's equation, flow measurement.
Conservation of momentum, force-momentum balances, forces on pipework, friction in pipe flows, friction factor, The Moody chart, rating & design of pipelines.
Flow around objects: Drag.
Laminar flow, Newton's law of viscosity, Hagen-Poiseuille equation.
Pumps: Types, selection, characteristic curves, NPSH.
Thermophysical properties of materials (esp. water). Temperature-enthalpy diagrams.
Mechanisms of heat transfer: conduction, convection, radiation.
Concept of rate = driving force/resistance, analogy with electrical circuits.
Derivation and application of conduction heat transfer equations.
Correlations for predicting convection heat transfer coefficients.
Applications of heat transfer in process engineering: heat losses, insulation, transient heating and cooling.
Prediction of freezing times.
Introduction to heat exchanger design.

4. INTENDED LEARNING OUTCOMES

By the end of the module the students should be able to:
Explain the working principles of some fluid measurement devices
Apply mass and energy balances (Bernoulli's equation)
Perform simple internal and external force balances
Determine velocity profiles based on shell momentum balances
Perform some simple rating and design calculations
Explain basic fluid flow concepts such as pressure, velocity, friction, flow regimes
Explain the physical phenomena embodied in heat transfer concepts
Give reasoned, quantitative answers to simple heat transfer problems based on application of the general heat transfer equation and thermal resistance concept
Derive conduction heat transfer equations from first principles based on differential energy balances, identify appropriate boundary conditions and solve these equations analytically for simplified cases
Calculate convection heat transfer coefficients from knowledge of the fluid mechanics and geometry of a system via correlations
Apply fundamental heat transfer concepts to obtain design data relevant to selected illustrative industrial problems
Appreciate the safety requirements associated with a particular experiment, as well as the general need for safe working in laboratories
Interpret written instructions
Make appropriate measurements with the equipment provided
Prepare written reports to a specified style

5. ASSESSMENT

20 credits: Semester 1 Exam (40%), Semester 2 Exam (40%), tests / coursework (20%)
10 credits: Laboratory reports, tests and coursework.

6. RECOMMENDED TEXT

Coulson JM & Richardson JF, Chemical Engineering Volume 1, 6th Edition, Butterworth Heinemann, 1999. ISBN:0750644443, Joule Library 660/COU
Holland FA & Bragg R, Fluid Flow for Chemical Engineers, 2nd Edition, Arnold, 1995, ISBN: 0340610581, Joule Library 532/HOL. Electronic version available (Knovel)
Incropera FP and de Witt DP, Introduction to Heat Transfer, 4th Edition, Wiley, 2002. ISBN: 0471386499, Joule Library 536.2/INC.
Ozisik MN, Heat Transfer: A Basic Approach, McGraw-Hill, 1985. ISBN: 0070479828, Joule Library 53602/OZI
Thomson WJ, Introduction to Transport Phenomena, Prentice Hall, 2000. ISBN: 0134548280, Joule Library 660.02 THO

7. STUDY BUDGETS

Lecture hours:	38	Tutorial hours:	25		
Practical work hours:	27	Private study hours:	210	Total study hours:	300

1. GENERAL INFORMATION

Title	**Chemical Engineering Design**
Code	CHEN 14050
Credit rating	40
Semester	1 & 2
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Ted Roberts
Other Staff	Esther Ventura-Medina, Philip Martin, Robin Curtis

2. AIMS

The programme unit aims to:
Provide a basic framework and relevant physico-chemical principles for calculating material and energy balances for various operations and processes. To demonstrate the application of material and energy balances to a complete chemical process. To apply reaction rate kinetics to the design of chemical reactors. To integrate material from first year courses in fluid flow, heat transfer, chemical kinetics and thermodynamics. To provide an introduction to equipment design.

3. OUTLINE SYLLABUS

Introduction to problem solving and group-working skills
Introductory concepts of material balancing
Composition units, gas laws, gaseous mixtures and Dalton's Law. Vapour pressure and vapour / gas mixtures
Material balances on reacting systems including combustion of fuels. Limiting reactant, percentage excess, degree of completion
Material balances on operations involving recycle
Energy balances on physical processes and chemical reactions
Material balances in single stage equilibrium processes (e.g. gas absorption and distillation)
Multistage processes such as evaporation, gas absorption and distillation
Types of reactions, conversions, rate equations, reaction order, rate constants, Arrhenius equation.
Interpretation of batch reaction data: zero, first and second order reactions, reversible reactions.
Complex reactions: analysis of series and parallel reaction sequences.
Types of and design of ideal reactors: CSTR, plug flow, batch, CSTR in series
Design and costing of plant items in detail, e.g. reactors, heat exchangers, distillation columns and pumps.

4. INTENDED LEARNING OUTCOMES

By the end of the module the students should be able to:
Apply the law of conservation of mass to solve material balance problems for multiple–stage process operations, including processes with reaction and/or recycle.
Explain the theories describing processes involving evaporation or condensation of ideal mixtures. Use Dalton's Law and saturated vapour pressure data to solve material balance problems involving evaporation or condensation of ideal mixtures.
Apply the principle of energy conversation and use appropriate thermodynamic data to solve energy balance problems including processes involving a change of phase or chemical reaction.
Solve problems using simultaneous material and energy balance calculations for single stage processes involving reaction.
Explain the meaning of 'equilibrium' when applied to phase change, distillation or gas absorption processes.
Use equilibrium data and material balance calculations to solve problems for multiple-stage processes.
Derive simple differentiated and integrated rate equations for series, parallel and reversible chemical reactions.
Apply quantitative methods to design and size reactors (batch, CSTR, PFR) for simple chemical reaction

schemes.
Determine the order of simple chemical reactions from experimental data.
Identify principal successive steps required in the commencement of a process design.
Explain how the principles of mass and energy balance, fluid flow, heat transfer, thermodynamics, chemical reactors and physical separations are interrelated and combined both in the design of specific pieces of equipment and in a composite plant.
Interact and communicate with his/her peer group when tackling common engineering tasks.
Manage his/her allotted time in order to meet task deadlines.
Begin to demonstrate a capacity for independent critical thought.

5. ASSESSMENT

Semester 1: 10 Credits Exam on Material Balances (80%), test / coursework (20%)

Semester 2: 10 Credits Exam on Energy Balances & Multiple Stage Evaporation &Equilibrium Processes (80%), coursework (20%) (Coursework will include lab reports).
10 Credits Exam on Chemical Reactor Engineering (80%) Coursework (20%)
10 Credits: Design project reports and written test.

6. RECOMMENDED TEXT

Felder, RM and Rousseau, RW, Elementary Principles of Chemical Processes, 3rd Edition, Wiley, ISBN: 0471534781, Joule Library 660/FEL
Himmelblau DM, Basic Principles and Calculations in Chemical Engineering, 6th Edition, Prentice-Hall, 1996. ISBN: 0133057984, Joule Library 660/HIM
Levenspiel, O, Chemical Reaction Engineering, 3rd edition, Chichester, 1999. ISBN: 047125424X, Joule Library 660.02/LEV.
Fogler SF, Elements of Chemical Reaction Engineering, 4th Edition, Pearson Education, 2006

7. STUDY BUDGETS

Lecture hours:	47	Tutorial hours:	70		
Practical work hours:	59	Private study hours:	224	Total study hours:	400

1. GENERAL INFORMATION

Title	**Process Design & Simulation**
Unit code	CHEN 20001
Credit rating	10
Semester	3
Pre-requisite units	CHEN 10001
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Peter Senior
Other Staff	

2. AIMS

Use of steady state simulator in process design.
Economic considerations provide the framework within which technical decisions must be made.

3. OUTLINE SYLLABUS

The module will be based on the design of a typical continuous process plant and consists of the following components:

- Conceptual design and development of the process flowsheet
- Use of shortcut methods for preliminary designs
- Design of plant items including reactors, separation systems and heat exchangers
- Use of PROII simulations in flowsheet development
- Costing and economic analysis

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Describe and use simulator-based procedures for synthesis of a number of flowsheet subsystems associated with the manufacture of specified product(s).
Integrate these ssubsystems into a composite flowsheet.
Explain the appropriate use of short cut and rigorous methods for screening, analysis and synthesis calculations.
Select and use appropriate thermodynamic methods.
Calculate economic performance using NPV and IRR methods.

5. ASSESSMENT

Students will produce a number of individual pieces of work throughout the semester.		
Coursework		75%
Coursework test		25%

6. RECOMMENDED TEXT

Seider WD, Seader JD, Lewin DR, Process Design Principles, Wiley, New York, 1999
Manual describing and illustrating use of simulator

7. STUDY BUDGETS

Lecture hours:	10	Tutorial hours:			
Practical work hours:	20	Private study hours:	70	Total study hours:	100

1. GENERAL INFORMATION

Title	**Laboratory Projects 2**
Unit code	CHEN 20002
Credit rating	10
Semester	4
Pre-requisite units	CHEN 10002, CHEN 10003
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Paul Grassia
Other staff	

2. AIMS

The programme unit aims to:
Develop skills in problem solving by experimentation.

3. OUTLINE SYLLABUS

Projects such as: batch distillation, gas absorption, thin film evaporator, vapour liquid equilibrium, filtration, cooling tower, boiling/condensation, refrigeration/heat pump, fluidised bed, milling.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Appreciate the importance of familiarity with procedures governing activities being undertaken (transferable skills).
Respond to safety, legal and environmental issues involved in performing laboratory experiments (practical skills, transferable skills).
Plan experiments to solve problems (intellectual skills, transferable skills).
Operate and evaluate laboratory equipment (practical skills).
Analyse experimental results/data using graphical and statistical methods, taking account of error and uncertainty (knowledge and understanding, intellectual skills).
Develop team working skills emphasising the importance of intra-team communication and responsibility to peers (transferable skills, personal qualities).
Interact with team members/peers in a professional manner (transferable skills, personal qualities).
Evaluate and rank the performance of team members in accordance with published sets of assessment criteria, and justify the evaluations/rankings obtained (transferable skills).
Manage time effectively so as to meet deadlines (transferable skills).
Prepare technical reports and/or technical presentations, in compliance with sets of guidelines (intellectual skills, transferable skills).
Appraise a project report/presentation (intellectual skills, transferable skills).

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Lab projects Submission of acceptable experimental plans, target technical learning objectives and permission to work forms are additional course requirements.	Ongoing	100%

6. RECOMMENDED TEXT

A database of resources will be made available to students, which may include: textbooks /articles specific to the project, example risk assessments and / or COSHH forms, equipment technical specifications and / or operating manuals, information on project management procedures, report writing, presentations and data analysis. Further information will be obtained from library database searches and / or other electronic sources.

7. STUDY BUDGETS

Lecture hours:	1	Tutorial hours:	6		
Practical work hours:	8	Private study hours:	85	Total study hours:	100

8. GENERAL INFORMATION

Title	**Transport Phenomena**
Code	CHEN 14030
Credit rating	30
Semester	1 & 2
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Members of staff responsible	Grant Campbell, Peter Martin
Other Staff	Nick Lockyer, Peter Gardner, Esther Ventura-Medina

9. AIMS

The programme unit aims to:
To introduce the basic concept of fluid flow and heat transfer with emphasis on practical design and rating calculations.

10. OUTLINE SYLLABUS

Introductory concepts of fluids, units & dimensions, hydrostatics.
Flow, flow regimes, conservation of mass & energy, Bernoulli's equation, flow measurement.
Conservation of momentum, force-momentum balances, forces on pipework, friction in pipe flows, friction factor, The Moody chart, rating & design of pipelines.
Flow around objects: Drag.
Laminar flow, Newton's law of viscosity, Hagen-Poiseuille equation.
Pumps: Types, selection, characteristic curves, NPSH.
Thermophysical properties of materials (esp. water). Temperature-enthalpy diagrams.
Mechanisms of heat transfer: conduction, convection, radiation.
Concept of rate = driving force/resistance, analogy with electrical circuits.
Derivation and application of conduction heat transfer equations.
Correlations for predicting convection heat transfer coefficients.
Applications of heat transfer in process engineering: heat losses, insulation, transient heating and cooling.
Prediction of freezing times.
Introduction to heat exchanger design.

11. INTENDED LEARNING OUTCOMES

By the end of the module the students should be able to:
Explain the working principles of some fluid measurement devices
Apply mass and energy balances (Bernoulli's equation)
Perform simple internal and external force balances
Determine velocity profiles based on shell momentum balances
Perform some simple rating and design calculations
Explain basic fluid flow concepts such as pressure, velocity, friction, flow regimes
Explain the physical phenomena embodied in heat transfer concepts
Give reasoned, quantitative answers to simple heat transfer problems based on application of the general heat transfer equation and thermal resistance concept
Derive conduction heat transfer equations from first principles based on differential energy balances, identify appropriate boundary conditions and solve these equations analytically for simplified cases
Calculate convection heat transfer coefficients from knowledge of the fluid mechanics and geometry of a system via correlations
Apply fundamental heat transfer concepts to obtain design data relevant to selected illustrative industrial problems
Appreciate the safety requirements associated with a particular experiment, as well as the general need for safe working in laboratories
Interpret written instructions
Make appropriate measurements with the equipment provided
Prepare written reports to a specified style

12. ASSESSMENT

21 credits: Semester 1 Exam (40%), Semester 2 Exam (40%), tests / coursework (20%)
10 credits: Laboratory reports, tests and coursework.

13. RECOMMENDED TEXT

Coulson JM & Richardson JF, Chemical Engineering Volume 1, 6th Edition, Butterworth Heinemann, 1999. ISBN:0750644443, Joule Library 660/COU

Holland FA & Bragg R, Fluid Flow for Chemical Engineers, 2nd Edition, Arnold, 1995, ISBN: 0340610581, Joule Library 532/HOL. Electronic version available (Knovel)

Incropera FP and de Witt DP, Introduction to Heat Transfer, 4th Edition, Wiley, 2002. ISBN: 0471386499, Joule Library 536.2/INC.

Ozisik MN, Heat Transfer: A Basic Approach, McGraw-Hill, 1985. ISBN: 0070479828, Joule Library 53602/OZI

Thomson WJ, Introduction to Transport Phenomena, Prentice Hall, 2000. ISBN: 0134548280, Joule Library 660.02 THO

14. STUDY BUDGETS

Lecture hours:	38	Tutorial hours:	25		
Practical work hours:	27	Private study hours:	210	Total study hours:	300

8. GENERAL INFORMATION

Title	**Chemical Engineering Design**
Code	CHEN 14050
Credit rating	40
Semester	1 & 2
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Ted Roberts
Other Staff	Esther Ventura-Medina, Philip Martin, Robin Curtis

9. AIMS

The programme unit aims to:

Provide a basic framework and relevant physico-chemical principles for calculating material and energy balances for various operations and processes. To demonstrate the application of material and energy balances to a complete chemical process. To apply reaction rate kinetics to the design of chemical reactors. To integrate material from first year courses in fluid flow, heat transfer, chemical kinetics and thermodynamics. To provide an introduction to equipment design.

10. OUTLINE SYLLABUS

Introduction to problem solving and group-working skills
Introductory concepts of material balancing
Composition units, gas laws, gaseous mixtures and Dalton’s Law. Vapour pressure and vapour / gas mixtures
Material balances on reacting systems including combustion of fuels. Limiting reactant, percentage excess, degree of completion
Material balances on operations involving recycle
Energy balances on physical processes and chemical reactions
Material balances in single stage equilibrium processes (e.g. gas absorption and distillation)
Multistage processes such as evaporation, gas absorption and distillation
Types of reactions, conversions, rate equations, reaction order, rate constants, Arrhenius equation.
Interpretation of batch reaction data: zero, first and second order reactions, reversible reactions.
Complex reactions: analysis of series and parallel reaction sequences.
Types of and design of ideal reactors: CSTR, plug flow, batch, CSTR in series
Design and costing of plant items in detail, e.g. reactors, heat exchangers, distillation columns and pumps.

11. INTENDED LEARNING OUTCOMES

By the end of the module the students should be able to:

Apply the law of conservation of mass to solve material balance problems for multiple–stage process operations, including processes with reaction and/or recycle.
Explain the theories describing processes involving evaporation or condensation of ideal mixtures. Use Dalton’s Law and saturated vapour pressure data to solve material balance problems involving evaporation or condensation of ideal mixtures.
Apply the principle of energy conversation and use appropriate thermodynamic data to solve energy balance problems including processes involving a change of phase or chemical reaction.
Solve problems using simultaneous material and energy balance calculations for single stage processes involving reaction.
Explain the meaning of ‘equilibrium’ when applied to phase change, distillation or gas absorption processes.
Use equilibrium data and material balance calculations to solve problems for multiple-stage processes.
Derive simple differentiated and integrated rate equations for series, parallel and reversible chemical reactions.
Apply quantitative methods to design and size reactors (batch, CSTR, PFR) for simple chemical reaction

schemes.
Determine the order of simple chemical reactions from experimental data.
Identify principal successive steps required in the commencement of a process design.
Explain how the principles of mass and energy balance, fluid flow, heat transfer, thermodynamics, chemical reactors and physical separations are interrelated and combined both in the design of specific pieces of equipment and in a composite plant.
Interact and communicate with his/her peer group when tackling common engineering tasks.
Manage his/her allotted time in order to meet task deadlines.
Begin to demonstrate a capacity for independent critical thought.

12. ASSESSMENT

Semester 1: 10 Credits Exam on Material Balances (80%), test / coursework (20%)

Semester 2: 10 Credits Exam on Energy Balances & Multiple Stage Evaporation &Equilibrium Processes (80%), coursework (20%) (Coursework will include lab reports).
10 Credits Exam on Chemical Reactor Engineering (80%) Coursework (20%)
10 Credits: Design project reports and written test.

13. RECOMMENDED TEXT

Felder, RM and Rousseau, RW, Elementary Principles of Chemical Processes, 3rd Edition, Wiley, ISBN: 0471534781, Joule Library 660/FEL
Himmelblau DM, Basic Principles and Calculations in Chemical Engineering, 6th Edition, Prentice-Hall, 1996. ISBN: 0133057984, Joule Library 660/HIM
Levenspiel, O, Chemical Reaction Engineering, 3rd edition, Chichester, 1999. ISBN: 047125424X, Joule Library 660.02/LEV.
Fogler SF, Elements of Chemical Reaction Engineering, 4th Edition, Pearson Education, 2006

14. STUDY BUDGETS

Lecture hours:	47	Tutorial hours:	70		
Practical work hours:	59	Private study hours:	224	Total study hours:	400

8. GENERAL INFORMATION

Title	**Process Design & Simulation**
Unit code	CHEN 20001
Credit rating	10
Semester	3
Pre-requisite units	CHEN 10001
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Peter Senior
Other Staff	

9. AIMS

Use of steady state simulator in process design.
Economic considerations provide the framework within which technical decisions must be made.

10. OUTLINE SYLLABUS

The module will be based on the design of a typical continuous process plant and consists of the following components:

- Conceptual design and development of the process flowsheet
- Use of shortcut methods for preliminary designs
- Design of plant items including reactors, separation systems and heat exchangers
- Use of PROII simulations in flowsheet development
- Costing and economic analysis

11. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Describe and use simulator-based procedures for synthesis of a number of flowsheet subsystems associated with the manufacture of specified product(s).
Integrate these ssubsystems into a composite flowsheet.
Explain the appropriate use of short cut and rigorous methods for screening, analysis and synthesis calculations.
Select and use appropriate thermodynamic methods.
Calculate economic performance using NPV and IRR methods.

12. ASSESSMENT

Students will produce a number of individual pieces of work throughout the semester. Coursework Coursework test		 75% 25%

13. RECOMMENDED TEXT

Seider WD, Seader JD, Lewin DR, Process Design Principles, Wiley, New York, 1999
Manual describing and illustrating use of simulator

14. STUDY BUDGETS

Lecture hours:	10	Tutorial hours:			
Practical work hours:	20	Private study hours:	70	Total study hours:	100

1. GENERAL INFORMATION

Title	**Laboratory Projects 2**
Unit code	CHEN 20002
Credit rating	10
Semester	4
Pre-requisite units	CHEN 10002, CHEN 10003
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Paul Grassia
Other staff	

5. AIMS

The programme unit aims to:
Develop skills in problem solving by experimentation.

6. OUTLINE SYLLABUS

Projects such as: batch distillation, gas absorption, thin film evaporator, vapour liquid equilibrium, filtration, cooling tower, boiling/condensation, refrigeration/heat pump, fluidised bed, milling.

7. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Appreciate the importance of familiarity with procedures governing activities being undertaken (transferable skills).
Respond to safety, legal and environmental issues involved in performing laboratory experiments (practical skills, transferable skills).
Plan experiments to solve problems (intellectual skills, transferable skills).
Operate and evaluate laboratory equipment (practical skills).
Analyse experimental results/data using graphical and statistical methods, taking account of error and uncertainty (knowledge and understanding, intellectual skills).
Develop team working skills emphasising the importance of intra-team communication and responsibility to peers (transferable skills, personal qualities).
Interact with team members/peers in a professional manner (transferable skills, personal qualities).
Evaluate and rank the performance of team members in accordance with published sets of assessment criteria, and justify the evaluations/rankings obtained (transferable skills).
Manage time effectively so as to meet deadlines (transferable skills).
Prepare technical reports and/or technical presentations, in compliance with sets of guidelines (intellectual skills, transferable skills).
Appraise a project report/presentation (intellectual skills, transferable skills).

7. ASSESSMENT

Assessment task	Length	Weighting within unit
Lab projects Submission of acceptable experimental plans, target technical learning objectives and permission to work forms are additional course requirements.	Ongoing	100%

8. RECOMMENDED TEXT

A database of resources will be made available to students, which may include: textbooks /articles specific to the project, example risk assessments and / or COSHH forms, equipment technical specifications and / or operating manuals, information on project management procedures, report writing, presentations and data analysis.
Further information will be obtained from library database searches and / or other electronic sources.

8. STUDY BUDGETS

Lecture hours:	1	Tutorial hours:	6		
Practical work hours:	8	Private study hours:	85	Total study hours:	100

1. GENERAL INFORMATION

Title	**Professional and Career Development**
Unit code	CHEN 20003
Credit rating	5
Semester	3
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Mike Sutcliffe
Other staff	John Richardson, Careers Service

2. AIMS

The programme unit aims to:
Provide an intensive two day course to develop the personal skills necessary to achieve success in subsequent careers.

3. OUTLINE SYLLABUS

Employment opportunities in chemical engineering, job searching, curriculum vitae and application forms, interviews and assessment centres, identification of personal skills, action planning, team working skills, project management and time management.

4. INTENDED LEARNING OUTCOMES

By the end of the module the students should be able to:
Write a Curriculum Vitae.
Develop an action plan.
Produce a personal portfolio.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Curriculum Vitae, action plan, personal portfolio. Coursework	Ongoing	100%

6. STUDY BUDGETS

Lecture hours:	4	Tutorial hours:	7		
Practical work hours:	0	Private study hours:	39	Total study hours	50

1. GENERAL INFORMATION

Title	**Mathematical Methods 2**
Unit code	CHEN 20004
Credit rating	10
Semester	3
Pre-requisite units	Mathematics Methods 1
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Dr Sam de Visser

2. AIMS

The programme unit aims to:
Provide an introduction to the methods of solution of ordinary differential equation systems arising from the mathematical modelling of chemical engineering applications.

3. OUTLINE SYLLABUS

Formulation of ordinary differential equations and boundary conditions describing physical and chemical processes. Review of analytical solutions of 1^{st} and 2^{nd} order ordinary differential equations.
Application of double-, triple and multiple integrals.
Functions of a complex variable; Cauchy's theorem. Sturm-Liouville theory. Gamma, Bessel and Legendre functions.
Eigenvalues and Eigenvectors.
Eigenvalue problem and application to solution of simultaneous homogeneous linear differential equations.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Explain how both differential equations and integration can arise in the process of setting up mathematical models.
Approximate solutions of a differential equation.
Compare different methods.
Appreciate the accuracy and limitation of solutions.
Apply the ideas and concepts to systems of differential equations.
Apply techniques to an engineering problem.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	100%

6. RECOMMENDED TEXT

Stephenson G, Mathematical Methods for Science Students, 2^{nd} Edition, Longmans, 1973, ISBN 0582444160, Joule Library 510 STE
Kreyzsig E, Advanced Engineering Mathematics, 8^{th} Edition, Wiley, 1999, ISBN 047133328X, Joule Library, 517 KRE

7. STUDY BUDGETS

Lecture hours:	21	Tutorial hours:	4		
Practical work hours:	0	Private study hours:	75	Total study hours:	100

1. GENERAL INFORMATION

Title	**Chemical Reaction Engineering**
Unit code	CHEN 20005
Credit rating	10
Semester	3
Pre-requisite units	CHEN 14020
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Aline Miller
Other Staff	Arthur Garforth, Andrew Masters

2. AIMS

The programme unit aims to:
Provide an introduction to the design of process reactors for homogeneous systems.

3. OUTLINE SYLLABUS

Volumetric efficiency of batch, plug flow, completely mixed flow and recycle reactors.
Effect of reactor type on product distribution in multiple reactions.
Design of adiabatic and non-adiabatic reactors.
Optimum temperature progression for reversible exothermic reactions.
Reactor stability, pressure effects, feed composition effects, reactor safety.
Examples will demonstrate the use of these principles on process and bioprocess engineering.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Explain and derive mass and heat balance equations for the main types of industrial reactors (batch, PFR, CSTR).
Explain the main drivers in economic and safe reactor design.
Design appropriate reactor configurations for simple and complex reaction chemistries.
Apply simple techniques for assessing and abating process hazards (eg exothermicity and toxicity).
Use numerical and computer methods for calculating results.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	80%
Coursework	Ongoing	20%

6. RECOMMENDED TEXT

Levenspiel O, Chemical Reaction Engineering, 3rd Edition, Wiley, 1998, ISBN 047125424X, Joule library 660.02 LEV
Fogler HS, Elements of Chemical Reaction Engineering, 3rd Edition, Prentice Hall, 1998, ISBN 0135317088, Joule library 660.02 FOG

7. STUDY BUDGETS

Lecture hours:	14	Tutorial hours:	16		
Practical work hours:	0	Private study hours:	70	Total study hours:	100

8. GENERAL INFORMATION

Title	**Solid Fluid Systems**
Unit code	CHEN 20006
Credit rating	10
Semester	3
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Esther Ventura-Medina

9. AIMS

The programme unit aims to:
Introduce the fundamental concepts and application of equations describing particle-fluid interactions and particle motion to model physical systems within the context of industrial applications aiming to design solid-fluid separation processes.

10. OUTLINE SYLLABUS

Particle characterisation.
Gas cyclones and Particle classification.
Motion of particles in a fluid.
Sedimentation, Hindered Settling and Thickening.
Fluid flow through packed beds.
Filtration.
Fluidisation.
Multiphase flow.

11. INTENDED LEARNING OUTCOMES

Category of outcome	*By the end of the module the student should be able to:*
Knowledge and understanding	Outline and describe different solid-liquid separation techniques. State the formulae and describe the physical meaning of dimensionless numbers. Describe the basic concepts related to particle-fluid motion. Apply relevant equations to a given physical situation. Solve solid-fluid separation problems and perform basic design calculation for separation equipment.
Intellectual skills	Solve problems by using relevant subject knowledge and appropriate strategies. Appraise the validity of the solutions obtained. Search relevant information required in the solution of problems. Discern by relevance available data.
Practical skills	Use electronic and on-line resources.
Transferable skills and personal qualities	Apply subject knowledge to specific physical situations. Use electronic and on-line resources. Communicate technical information at appropriate level both orally and in writing.

12. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	100.00%

13. RECOMMENDED TEXT

Holdich R, Fundamentals of Particle Technology, Midland Information Technology and Publishing, 2002, ISBN: 0954388100, Joule Library 660.0049/HOL
Rhodes, M.J. Introduction to Particle Technology, Chichester: New York, John Wiley, 1998. ISBN: 047198483.
Coulson JM & Richardson JF, Chemical Engineering Volume 2, 5th ed, Butterworth-Heinmann, 2002, ISBN:075064451, Joule library 660/COU.
Rushton, A, Solid-liquid Filtration and Separation Technology, John Wiley and Sons Ltd Wiley-VCH, 2000, ISBN: 3527296042 .
Svarovsky L, Solid-Liquid Separation, 4th edition, Butterworth and Heinemann, 2000, ISBN: 0750645687, Joule Library 660.022/SVA.

14. STUDY BUDGETS

Lecture hours:	20	Tutorial hours:	10		
Practical work hours:	10	Private study hours:	60	Total study hours:	100

1. GENERAL INFORMATION

Title	**Distillation and Absorption**
Unit code	CHEN 20007
Credit rating	10
Semester	4
Pre-requisite units	CHEN 10007
Co-requisite units	CHEN 20009
School responsible	Chemical Engineering
Member of staff responsible	Colin Webb

2. AIMS

The programme unit aims to:
Develop a basic competence in making mass transfer and hydraulic calculations for binary distillation and absorption.

3. OUTLINE SYLLABUS

Batch distillation: Rayleigh distillation and batch rectification for ideal mixtures.
Continuous distillation: Revision of McCabe-Thiele construction, total and partial reboilers and condensers, plate efficiencies.
Non-ideal mixtures: material and enthalpy balances, Ponchon-Savarit construction, operating characteristics, link with McCabe-Thiele construction.
Column hydraulics: Characteristics of plates and packings, flooding, flooding correlations and sizing of columns, column control strategies.

4. INTENDED LEARNING OUTCOMES

Category of outcome	*By the end of the module the student should be able to:*
Knowledge and understanding	Know the principles of vapour liquid equilibria and various phenomena associated with mixtures of components having different volatilities or solubilities. Understand the basics of binary mixture separation by distillation and absorption methods.
Intellectual skills	Apply stagewise balance equations to make preliminary design calculations for a wide range of binary distillation and absorption applications. Use knowledge of a number of design methods, selecting the appropriate approach for a range of new situations.
Practical skills	Use graphical methods to represent balance equations.
Transferable skills and personal qualities	Integrate knowledge and understanding of distillation and absorption column design with that for other equilibrium stage processes

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination Coursework	1.5 hours Ongoing	90% 10%

6. RECOMMENDED TEXTS

Coulson JM & Richardson JF, Chemical Engineering Volume 2, 5th Edition, Butterworth-Heinemann, 2002, ISBN 0750644451, Joule Library 660 COU
McCabe WL, Smith JC, Unit Operations of Chemical Engineering, 5th Edition, McGraw Hill, 1993, ISBN 0070448442, Joule Library 660.02 MMC
Treybal RE, Mass Transfer Operations, 3rd Edition, McGraw Hill, 1980, ISBN 0070651760, Joule Library 660.02 TRE
Smith BD, Design of Equilibrium Stage Processes, McGraw Hill, 1983, Joule Library 660.022 SMI

7. STUDY BUDGETS

Lecture hours:	17	Tutorial hours:	8		

Practical work hours:	0	Private study hours:	75	Total study hours:	100

1. GENERAL INFORMATION

Title	**Heat Transfer and Process Integration**
Unit code	CHEN 20008
Credit rating	10
Semester	3
Pre-requisite units	CHEN 10002, CHEN 10004
Co-requisite units	CHEN 20010
School responsible	Chemical Engineering
Member of staff responsible	Simon Perry

2. AIMS

The programme unit aims to:
Provide an introduction to the design of industrial heat exchangers and heat exchanger networks.

3. OUTLINE SYLLABUS

Heat exchanger types.
Shell-and-tube heat exchanger configurations.
Heat transfer coefficients, pressure drops and temperature differences in shell-and-tube heat exchangers. Condensers and reboilers.
Energy targets for processes.
Composite curves and the problem table algorithm.
The heat recovery pinch, grid diagram , pinch design method, stream splitting.
Multiple utility targeting.
Threshold problems.

4. INTENDED LEARNING OUTCOMES

Category of outcome	*By the end of the module the student should be able to:*
Knowledge and understanding	Knowledge and understanding of the theory of heat exchanger design for two stream heat exchangers, and energy targeting and the design of heat exchanger networks for multiple streams.
Intellectual skills	Apply theories to different heat exchanger arrangements and networks of heat exchangers.
Practical skills	Analyse industrial examples of heat exchanger and heat exchanger network problems and develop solution strategies.
Transferable skills and personal qualities	Integrate knowledge and understanding of heat transfer processes to equipment and network design for the efficient use of energy in process engineering.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination Coursework	1.5 hours Ongoing	80% 20%

6. RECOMMENDED TEXT

Smith R, 2005, Chemical Process Design and Integration, John Wiley, ISBN 0-471-48681-7, Joule Library 660 COU.
Coulson JM & Richardson JF, 1999, Chemical Engineering Volume 6, 3rd Edition, Butterworth-Heinemann, ISBN 0750641428, Joule Library 660 COU.
ESDU Heat Transfer Data Items, University Library Intranet.

7. STUDY BUDGETS

Lecture hours:	18	Tutorial hours:	7		
Practical work hours:	0	Private study hours:	75	Total study hours:	100

15. GENERAL INFORMATION

Title	**Chemical Thermodynamics**
Unit code	CHEN 20009
Credit rating	10
Semester	3
Pre-requisite units	CHEN 14020, CHEN 14030
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Leo Lue

16. AIMS

The programme unit aims to:
Develop the laws of thermodynamics into working equations relating phase compositions for equilibrium systems and to apply these to separation and chemical processes.

17. OUTLINE SYLLABUS

Phase behaviour for binary and ternary systems: V-L, L-L, S-L and V-L-L equilibria.
Conditions for phase and chemical equilibrium: the Gibbs-Duhem equation, activity coefficient models, quantitative prediction of phase behaviour.
Equations of state: fugacities and fugacity coefficient evaluation, residual properties.
Chemical equilibria for real mixtures.

18. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Interpret, qualitatively, vapour-liquid (V-L), liquid-liquid (L-L), vapour-liquid-liquid (V-L-L), gas-liquid (G-L), and solid-liquid (S-L) phase diagrams for binary and tertiary mixtures.
Predict quantitatively the phase behaviour of V-L, L-L, V-L-L, G-L, S-L binary and tertiary systems involving either ideal or real liquids; to apply knowledge of these systems to separation processes.
Explain the theoretical basis of corrections to the ideal gas law required for real gases (including fugacity, equations of state).
Apply equations of state for computation of real fluid properties.
Devise appropriate procedures for calculating dew points, bubble points and flash points for multi-component systems involving real or ideal liquids and real or ideal gases.
Determine chemical equilibria for real mixtures.

19. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	100.00%

20. RECOMMENDED TEXT

Smith JM & Van Ness HC, Abbott M, Introduction to Chemical Engineering Thermodynamics, 7th Edition, McGraw-Hill, 2004 ISBN 0073104450, Joule Library 541.36 SMI
Daubert TE, Chemical Engineering Thermodynamics, McGraw-Hill, 1986 ISBN 0070154139, Joule Library 541.36 DAU
Denbigh KG, The Principles of Chemical Equilibrium: With Applications in Chemistry and Chemical Engineering, 4th Edition, Cambridge, 1981 ISBN 0521281504, Joule Library 541.36 DEN

21. STUDY BUDGETS

Lecture hours:	18	Tutorial hours:	10		

Practical work hours:	0	Private study hours:	72	Total study hours:	100

22. GENERAL INFORMATION

Title	**Momentum, Heat and Mass Transfer**
Unit code	CHEN 20010
Credit rating	10
Semester	4
Pre-requisite units	CHEN 14020, CHEN 14030
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Leo Lue

23. AIMS

The programme unit aims to:
Develop a physical and mathematical picture of transport processes and the implications of turbulence.

24. OUTLINE SYLLABUS

Differential balances: development of conservation equations for momentum, energy, and mass.
Diffusive transport: Newton's law of viscosity, Fourier's law, and Fick's law, solution of steady state transport problems.
Turbulence: description of turbulent motion and mechanism of transport, fluctuations and time averaging, Reynolds stresses, transfer equations in terms of eddy diffusivities, and universal velocity profile.
Boundary layer theory: von Karman integral analysis, calculation of transfer coefficients.
Interfacial mass transfer: film model, controlling resistance, penetration model.
Similarities in transport: Reynolds, Prandtl, von Karman and Colburn analogies.
Simultaneous heat and mass transfer: wet bulb and adiabatic saturation temperature, psychometric ratio; simplification for air-water system, enthalpy, heat flux expression, and application to cooling tower calculations.

25. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Solve steady state diffusive transport problems.
Describe the similarities among the three transfer processes, including the roles of molecular and turbulent transport
Make appropriate calculations for molecular and turbulent transport.
Define and calculate transfer coefficients.
Make calculations for humidification/dehumidification processes.

26. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	100.00%

27. RECOMMENDED TEXT

Holland FA & Bragg R, Fluid Flow for Chemical Engineers, 2nd Edition, Arnold, 1995, ISBN 0340610581, Joule Library 532 HOL, Electronic version available (Knovel)
Bennett CO & Myers JE, Momentum, Heat and Mass Transfer, McGraw-Hill, 1982, ISBN 0070661804, Joule Library 660.02 BEN
Welty J, Wicks CE, Rorrer GL, Wilson RE, Fundamentals of Momentum, Heat and Mass Transfer, 5th Edition, Wiley 2008

28. STUDY BUDGETS

Lecture hours:	18	Tutorial hours:	10		
Practical work hours:	0	Private study hours:	72	Total study hours:	100

1. GENERAL INFORMATION

Title	**Introduction to Biotechnology**
Unit code	CHEN 20011
Credit rating	5
Semester	4
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering & Analytical Science
Member of staff responsible	Mike Sutcliffe, Ferda Mavituna

2. AIMS

The programme unit aims to:
Provide students with an introduction to biotechnology and bioprocesses
Provide examples of scientific and engineering bases of biotechnology.

3. OUTLINE SYLLABUS

Introduction to the applications of biotechnology, emphasising the multidisciplinarity of this field and the role of chemical engineers.
Cells and cell culture. Cell structure, composition and behaviour. Microbial growth kinetics. Design of culture systems.
Introduction to enzymes: functions and kinetics. Exploitation of enzymes in biotechnology.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
- Appreciate basic biotechnology and the role of the chemical engineers in this field.
- Undertake further training in biotechnology.
- Apply mathematical analysis to define microbial growth and enzyme kinetic parameters
- Use graphical methods to describe the behaviour of enzymes and the growth kinetics of cells
- Appreciate how enzyme structure underpins function.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination Coursework	1 hour Ongoing	80% 20%

6. RECOMMENDED TEXT

Voet, D & Voet, J.G. "Biochemistry" 3rd Edition (2005). Wiley Higher Education. ISBN: 0-471-19350-X. Joule Library, 612.015/VOE
Madigan, MT, Martinko, JM, Brock, TD. "Brock biology of microorganisms 11th ed. Pearson Prentice Hall, 2006. ISBN 0131443291/ 0131968939. Main library, 579/BRO
Price, N.C. & Stephens, L. "Fundamentals of Enzymology" 3rd Edition (1999). Oxford University Press. ISBN 0-198-50229-X. Main Library, 572.7/PRI
Glazer, A.N. & Nikaido, H. "Microbial Biotechnology" 2nd Edition (2007). W.H. Freeman and Co. ISBN 0-716-72608-4. Joule Library, 663.1/GLA
Ratledge C, Basic Biotechnology, 2nd Edition, Cambridge University Press, 2001, ISBN 0521779170, Joule Library 663.1/RAT
Branden, C & Tooze, J "Introduction to Protein Structure" 2nd Edition (1999). Garland. ISBN 0-815-32304-2. Main Library, 572.633/BRA

7. STUDY BUDGETS

Lecture hours:	9	Tutorial hours:	3		
Practical work hours:	0	Private study hours:	38	Total study hours:	50

1. GENERAL INFORMATION

Title	**Introduction to Environmental Technology**
Unit code	CHEN 20012
Credit rating	5
Semester	4 & 6
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Adisa Azapagic

2. AIMS

The programme unit aims to:
Provide students with an introduction to sustainable development and its relevance for chemical engineers.
Provide an overview of engineering approaches and technologies that can be used to contribute to sustainable development.

3. OUTLINE SYLLABUS

Introduction to Sustainable Development
Life Cycle Thinking and Life Cycle Assessment
Water Systems
Energy Systems
Waste Management Systems

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Understand the concept and importance of sustainable development
Understand the concept of life cycle thinking and how it can be applied to engineer more sustainable technologies and activities
Apply scientific and engineering principles to providing sustainable solutions for society, with a particular application to water, energy and waste systems

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1 hour	70%
Coursework	Ongoing	30%

6. RECOMMENDED TEXT

Azapagic, A., S. Perdan and R. Clift (eds.) (2004). *Sustainable Development in Practice: Case Studies for Engineers and Scientists*. John Wiley & Sons, Chichester, pp437.

7. STUDY BUDGETS

Lecture hours:	12	Tutorial hours:	0		
Practical work hours:	0	Private study hours:	38	Total study hours:	50

1. GENERAL INFORMATION

Title	**Introduction to the Process Industries**
Unit code	CHEN 20013
Credit rating	5
Semester	4
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Mike Briggs

2. AIMS

The programme unit aims to:
Provide an understanding of the business drivers operating on products in the process industries and the role of the chemical engineer.

3. OUTLINE SYLLABUS

Process Industries Overview – Context, Size, Markets, Business Drivers, Role of Chemical Engineer.
Seeing the Whole Business – Value & Supply Chains, Corporate Financing & Investment Decisions.
Getting the Product to Market – Innovation & Marketing Strategies, Running Projects, Right Pricing
Sourcing the Product – Optimising Sourcing, Location & Scale Factors, Capacity & Complexity
Procuring the Raw Materials – Buying Strategy, Flexible Formulations, Cost & Price Modelling.
Human Factors – Roles & Responsibilities, Organisation, Driving Performance, Communications, Professionalism, Individual & Corporate Ethics, Impact of Chemical Engineers.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Explain key issues and techniques in financing and organising product innovation and on-going production in the process industries.
Interpret business organisations, behaviour and trends in the industry.
Explain the role of the chemical engineer in analysis, decision-making and project execution.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1 hour	75%
Coursework	Ongoing	25%

6. RECOMMENDED TEXT

Handling Uncertainty – Mike Briggs – IChemE, Rugby - ISBN 0 85295 432 8
The Chemical Engineer, The Economist, The Financial Times.

7. STUDY BUDGETS

Lecture hours:	9	Tutorial hours:	3		
Practical work hours:	0	Private study hours:	38	Total study hours:	50

29. GENERAL INFORMATION

Title	**Systems Measurement and Optimisation**
Unit code	CHEN 20014
Credit rating	10
Semester	4
Pre-requisite units	CHEN 10006, CHEN 20004
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Patricia Scully & Richard Holmes

30. AIMS

The programme unit aims to:

Introduce Chemical Engineers to the concepts of measurement systems and their relevance and importance to safe and efficient process control – utilizing a component level description of the essential elements of a measurement instrument, from user interface to transducer. This will require a degree of electronics comprehension.

31. OUTLINE SYLLABUS

The syllabus for this course will include:-

- Measurement systems, accuracy, precision, and quantification,
- Process monitoring and intrinsic safety,
- Instrumentation and measurement components,
- Data Acquisition and Amplification,
- Operational Amplifiers (Op-Amps),
- Basic Analogue Electronics,
- Optoelectronics,
- Basic Digital Electronics including data transmission,
- Analogue to Digital Conversion,
- Signal Processing, Sampling and Filtering,
- Noise, Feedback and Calibration,
- Control Systems and Process Management in Chemical Engineering,
- Virtual Instrumentation, and Computer Control.

32. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:

- Understand the requirements and limitations of measurement systems in a chemical engineering context.
- Determine the effect noise may have on a measurement signal, and methods that may be used to minimize this.
- Appreciate the complexity of a measurement process and the methods in which measurements may be recorded and utilized.
- Design a simple measurement schematic for a basic chemical process plant, incorporating signal processing, digital monitoring and feedback loops to monitor and control a dynamic system.
- Recognize the importance of intrinsically safe design features and their use in hazardous environments.
- Explain the differences between Analogue, Digital and Opto-electronic measurement systems giving examples of their uses in chemical engineering.
- Conceive of situations where virtual instrumentation may be utilized in process measurement
- Identify a variety of process measurement instrumentation systems and the inherent advantages and disadvantages.

33. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination Coursework	1.5 hours Ongoing	80% 20%

34. RECOMMENDED TEXT

Texts for supplementary reading will be recommended during the course.

J. Bentley. Principles of Measurement Systems. 4th Edition. 2004. ISBN13: 9780130430281 ISBN10: 0130430285

J.A. Skoog & D.A. Leary: Principles of Instrumental Analysis - 4th Edition (1992)
ISBN: 0-03-075398-8

35. STUDY BUDGETS

Lecture hours:	24	Tutorial hours:	12		
Practical work hours:	0	Private study hours:	65	Total study hours:	100

1. GENERAL INFORMATION

Title	**Design Project 3**
Unit code	CHEN 30001
Credit rating	30
Semester	6
Pre-requisite units	All previous courses
Co-requisite units	CHEN 30004
School responsible	Chemical Engineering
Member of staff responsible	Peter Senior
Other Staff	Grant Campbell, Peter Martin, Ferda Mavituna, Severino Pandiella, Ted Roberts, Flor Siperstein, Esther Ventura-Medina, Jin Kuk-Kim, Colin Webb, Dave Cresswell, Aruna Manipura

2. AIMS

The programme unit aims to:
Give a detailed knowledge of the design of a process from the conceptual stage through to detailed design. Apply chemical engineering skills acquired from other courses.
Encourage a creative approach to design.
Gain the experience of working in a team.
Gain experience of the presentation of technical material in extended written reports.
Meet the IChemE requirements for accreditation.
Act as a showcase for the University of Manchester course and students to the industrial sponsors.

3. OUTLINE SYLLABUS

Industrial panel specifies design objectives, usually manufacture of given tonnage of a nominated chemical. Detailed objectives are agreed between module leader and sponsoring company selected in rotation from the industrial panel. Students, working individually and in groups, are supervised by academic 'project managers' who assist in definition of the task(s) to be confirmed.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Working as a group:
Communicate effectively within a group and as a group; synthesise a flowsheet for the manufacture of a defined quantity of specified product(s) via an established overall route; evaluate the consequences of uncertainty of data, equipment performance and applicability of the rigorous calculation procedures; evaluate alternatives on an economic basis; evaluate process safety; evaluate environmental impact; report the results against a deadline; present the results to an industrial panel orally.
Working Individually:
Synthesise a complex unit operation or subsystem required by the flowsheet; communicate results to the group for integration within the overall design; report the results against a deadline; defend the chosen design in oral examination.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Oral Examination		10%
Coursework	Ongoing	90%

6. RECOMMENDED TEXT

Douglas JM, Conceptual Design of Chemical Engineering Processes, McGraw-Hill, 1988 ISBN 0070177627, Joule Library 660.013 DOU
Scott D & Crawley F, Process Plant Design and Operation: A Guide to Safe Practice, IChemE, 1992 ISBN 0852952783, Joule Library 660.013 SCO
Seider WD, Seader JD, Lewin DR, Process Design Principles, Wiley, 1999 ISBN 0471243124, Joule Library

660.013 SEI

7. STUDY BUDGETS

Lecture hours:	10	Tutorial hours:	20		
Practical work hours:	135	Private study hours:	135	Total study hours:	300

36. GENERAL INFORMATION

Title	**Laboratory Projects 3**
Unit code	CHEN 30002
Credit rating	15
Semester	5
Pre-requisite units	CHEN 20002, CHEN 20007, CHEN 20008
Co-requisite units	CHEN 30003
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Leo Lue
Other Staff	Xue-Feng Yuan

37. AIMS

The programme unit aims to:
Address an advanced practical problem as a member of a team and gain both practical and transferable skills from implementing a solution for the problem.

38. OUTLINE SYLLABUS

Case study projects are carried out on an experiment, such as:
(1) Refrigeration
(2) Tomography in a Mixing Tank
(3) Flotation tanks
(4) Liquid ring pump
(5) Tank level control
(6) Thermosiphon reboiler
(7) Mixing

39. INTENDED LEARNING OUTCOMES

Category of outcome	*By the end of the module the student should be able to:*
Knowledge and understanding	Recognise and respond to any risk or safety aspects relevant to performing laboratory experiments conforming to legal and environmental issues. Identify, describe and illustrate relevant background information and physical models relating to the case study. Apply quantitative tests to verify the accuracy of experimental results.
Intellectual skills	Review critically experimental results and compare them with those predicted by physical models. Critically evaluate and synthesise relevant information from the literature. Investigate a problem and plan and conduct experimental work towards the solution of the problem
Practical skills	Prepare Risk assessment and COSHH forms for experimental work. Evaluate and safely operate laboratory equipment. Write a report following a set of guidelines. Make a clear, interesting and well-constructed oral presentation as part of a team.
Transferable skills and personal qualities	Demonstrate group-working and self-assessment skills, emphasising the importance of intra and inter group communication, task allocation, reporting on meetings and recording progress in a responsible manner. Demonstrate the ability to gather, summarise and organise relevant information relating to the case study.

40. ASSESSMENT

Assessment task	Length	Weighting within unit
Seminar		10%
Self-assessment		10%
Project management		10%
Technical Report		70%

41. **RECOMMENDED TEXT**

A collection of resources will be made available to students, including literature references specific to the problem, COSSH, risk assessment and hazard data sheets, equipment specifications and operating manuals. Further information must be obtained from the library databank searches and the internet.

42. **STUDY BUDGETS**

Lecture hours:	5	Tutorial hours:	0		
Practical work hours:	30	Private study hours:	115	Total study hours:	150

1. GENERAL INFORMATION

Title	**Safety**
Unit code	CHEN 30003
Credit rating	5
Semester	5
Pre-requisite units	
Co-requisite units	
School responsible	Chemical Engineering
Member of staff responsible	Stuart Holmes
Other Staff	John Cuffe

2. AIMS

The programme unit aims to:
Provide an introduction to process plant safety.

3. OUTLINE SYLLABUS

Management Aspects: COSHH and risk assessment, permits to work.
Hazards: fire, explosion, toxins.
Methodology: HAZOP, HAZAN.
Case Studies

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Describe the major hazards associated with process plant.
Identify and avoid common hazards using general technical knowledge together with techniques such as HAZOP.
Quantify simple hazards (e.g. flammability limits).
Explain the management issues involved in the safe operation of plant.
Have a proper level of fear of plant.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	100%

6. RECOMMENDED TEXT

Relevant Literature
Laboratory Handbook

7. STUDY BUDGETS

Lecture hours:	13	Tutorial hours:	0		
Practical work hours:	0	Private study hours:	37	Total study hours:	50

1. GENERAL INFORMATION

Title	**Catalytic Reaction Engineering – Industrial Experience**
Unit code	CHEN 30004
Credit rating	10
Semester	5
Pre-requisite units	CHEN 20004, CHEN 20005, CHEN 20010
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Arthur Garforth
Other Staff	

2. AIMS

The programme unit aims to:
Learn and understand the chemical reaction engineering fundamentals of catalytic gas-solid reactors.
Design simple tubular fixed-bed reactors.
Evaluate catalytic performance from laboratory testing.

3. OUTLINE SYLLABUS

Adsorption and surface reaction kinetics.
Mass transfer, diffusion and reaction in catalyst pellets.
Simple tubular reactor design.
Parametric sensitivity of catalytic fixed-bed reactors.
Catalyst tyre, design, testing and evaluation

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Appreciate how surface reactions interact with mass transfer.
Explain how the reaction rate and heat transfer govern reactor behaviour and safety.
Diagnose results from laboratory test archetypes.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	95%
Class and on-line tests (5)	1 h	5%

6. RECOMMENDED TEXT

Bartholomew CH and Farrauto RJ, 2nd Edition, Fundamentals of Industrial Catalytic Processes, 2006, Fogler HS, Elements of Chemical Reaction Engineering, 3rd Edition, Prentice Hall 1998, ISBN 0135317088 Joule Library 660-02 FOG
Review several refereed journal papers.

7. STUDY BUDGETS

Lecture hours:	12	Tutorial hours:	5	On-line tests	5
Practical work hours:	18	Private study hours:	60	Total study hours:	100

8. GENERAL INFORMATION

Title	**Catalytic Reaction Engineering**
Unit code	CHEN 30005
Credit rating	10
Semester	5
Pre-requisite units	CHEN 20004, CHEN 20005, CHEN 20010
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Arthur Garforth
Other Staff	

9. AIMS

The programme unit aims to:
Learn and understand the chemical reaction engineering fundamentals of catalytic gas-solid reactors.
Design simple tubular fixed-bed reactors.
Evaluate catalytic performance from laboratory testing.

10. OUTLINE SYLLABUS

Adsorption and surface reaction kinetics.
Mass transfer, diffusion and reaction in catalyst pellets.
Simple tubular reactor design.
Parametric sensitivity of catalytic fixed-bed reactors.
Catalyst tyre, design, testing and evaluation

11. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Appreciate how surface reactions interact with mass transfer.
Explain how the reaction rate and heat transfer govern reactor behaviour and safety.
Diagnose results from laboratory test archetypes.

12. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	80%
Class and on-line tests (5)	1 h	5%
Coursework	Ongoing	15%

13. RECOMMENDED TEXT

Bartholomew CH and Farrauto RJ, 2nd Edition, Fundamentals of Industrial Catalytic Processes, 2006, Fogler HS, Elements of Chemical Reaction Engineering, 3rd Edition, Prentice Hall 1998, ISBN 0135317088 Joule Library 660-02 FOG
Review several refereed journal papers.

14. STUDY BUDGETS

Lecture hours:	12	Tutorial hours:	5	On-line tests	5
Practical work hours:	18	Private study hours:	60	Total study hours:	100

1. GENERAL INFORMATION

Title	**Process Fluid Dynamics**
Unit code	CHEN 30006
Credit rating	10
Semester	5
Pre-requisite units	CHEN 10006, CHEN 10009
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Severino S. Pandiella

2. AIMS

The programme unit aims to:
Provide a basic competence in making simple flow calculations for compressible flow, non-Newtonian flow and gas-liquid two-phase flow.

3. OUTLINE SYLLABUS

Compressible flow: energy equation; subsonic flow with friction in pipes, flow rate–pressure drop relationships, choking, sonic speed. Isentropic flow through convergent and convergent-divergent nozzles; flow regimes, critical pressure ratio, flow rate.
Non-Newtonian flow: Classification of non-Newtonian behaviour, elementary viscometry and non-Newtonian flow calculations. Rabinowitsch-Mooney analysis: true shear rate at wall, application to flow rate – pressure drop calculations for laminar flow in pipes. Shear stress – flow characteristic curves and flow calculations.
Two-phase flow: generalized Reynolds number, turbulent flow regime maps. Flow in pipes; general momentum equation. Homogenous model; momentum equation, friction factors, two-phase multiplier. Separated flow models; momentum equation, empirical correlations.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Describe the nature of compressible flow through pipes and nozzles under various conditions and make flow rate calculations.
Identify various forms of non-Newtonian behaviour and the types of materials exhibiting such behaviour. Make basic viscometric calculations. Obtain laminar velocity profiles for non-Newtonian fluids.
Describe the main characteristics of gas-liquid two-phase flow. Calculate flow rate – pressure drop relationships for two-phase systems. Use empirical models to describe air-water flows in pipes.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 Hours	85%
Coursework	Ongoing	15%

6. RECOMMENDED TEXT

Holland FA & Bragg R, Fluid Flow for Chemical Engineers, 2nd Edition, Arnold, 1995 ISBN 0340610581, Joule Library 532 HOL, Electronic version available (Knovel)
Shapiro AH, The Dynamics and Thermodynamics of Compressible Fluid Flow, Volume 1, Ronald Press Company, New York

7. STUDY BUDGETS

Lecture hours:	17	Tutorial hours:	8		
Practical work hours:	0	Private study hours:	75	Total study hours:	100

1. General Information

Title	**Advanced Mass Transfer Methods**
Unit code	CHEN 30007
Credit rating	10
Semester	6
Pre-requisite units	CHEN 20007, CHEN 20009
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Jin-Kuk Kim

2. Aims

The programme unit aims to:
Develop students' understanding of and skills for conceptual design of separation processes.

3. Outline Syllabus

Basic distillation design: Vapour-liquid equilibrium, vapour-liquid separations, binary distillation, multi-component distillation, short-cut distillation design, choice of operating parameters
Distillation sequencing: Sequencing simple distillation columns, complex distillation configurations, distillation sequencing with complex columns
Separation of homogenous mixtures: Absorption, adsorption, extraction, crystallisation
Separation of heterogeneous mixtures: centrifugal separation, filtration, drying, settling

4. Intended Learning Outcomes

Category of outcome	By the end of the module the student should be able to:
Knowledge and understanding (K)	Develop and demonstrate knowledge and understanding of: • The principles of design and operation of separation processes • Conceptual design of distillation processes • Design for energy-efficient distillation and its sequencing
Intellectual skills (I)	• Apply conceptual design methods for simple and complex distillation columns • Apply short-cut and rigorous models for distillation analysis and design • Design distillation processes and sequences for improving energy efficiency
Practical skills (P)	• Conceptual decision for selection and design of separation processes • Apply heuristics for distillation sequencing synthesis • Use computer software (e.g. ProII, Excel) to solve distillation design and sequencing problems
Transferable skills and personal qualities (T)	• Demonstrate problem-solving skills and competence in the use of chemical engineering software • Understand and apply models for process design and integration

5. Assessment

Assessment task	Length	Weighting within unit
Examination	1.5 hours	85 %
Coursework	Ongoing	15 %

6. Recommended Texts

Seader JD & Henley EJ, Separation Process Principles, Wiley, 1998, ISBN 0471586269, Joule Library 660.022
Smith R, Chemical Process Design and Integration, Wiley, 2005, ISBN 0471486817, joule Library 660.013

7. Study Budgets

Lecture hours	17	Tutorial hours	8		
Practical work hours	0	Private study hours	75	Total study hours	100

1. GENERAL INFORMATION

Title	**Fine Chemicals Production**
Unit code	CHEN 30008
Credit rating	10
Semester	3 & 5
Pre-requisite units	CHEN 10007, CHEN 20005
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Aline Miller

2. AIMS

The programme unit aims to:
Give an understanding of the culture and nature of fine and effect chemicals production.
To introduce chemistry and engineering aspects of product design.

3. OUTLINE SYLLABUS

Nature of fine, speciality and effect chemicals production.
Comparison with bulk/commodity chemicals.
Flexible and multiproduct plant.
Product life cycles.
Relationship between process and chemistry.
Recipes.
Cycle times and occupation.
Gantt charts.
Capacity increase. Influence of operation time variability.
Crystallisation.
Green process technologies.
Property prediction.
Converting chemicals into products.
Influence of polymer and colloid science.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Estimate capacities and processing times in batch manufacture.
Optimise kinetic and diffusional processes in batch chemical reactions.
Problem solve in systems involving two phase chemical reactions.
Assess issues relating to solvent usage in batch process.
Awareness of emerging green processing technologies and its impact on the fine chemicals industry.
Predict simple physical properties.
Optimise crystallisation and filtration steps in a batch process.
Design a simple product.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	80%
Coursework – group presentation 20%	Ongoing	20%

6. STUDY BUDGETS

Lecture hours:	20	Tutorial hours:	10		
Practical work hours:	0	Private study hours:	75	Total study hours:	100

43. GENERAL INFORMATION

Title	**Process Control**
Unit code	CHEN 30009
Credit rating	10
Semester	5
Pre-requisite units	
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Dr Jhuma Sadhukhan

44. AIMS

The programme unit aims to: Introduce the principles of chemical process control in terms of the range of control strategies employed for chemical processes. The understanding and modeling of process dynamics into practical implementation of control strategies will be presented.

45. OUTLINE SYLLABUS

Introduction to process control, feedback and feed forward control strategies, understanding process dynamics and modeling, adoption of control strategies, complex chemical process dynamic modeling and control, synthesis of controllers

Use of MATLAB-Simulink for process control

46. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:

Explain the need for control for achieving process objectives and safety.
Understand dynamics of chemical processes and how to model
Develop practical control strategies for chemical processes
Indicate types of controllers and design them.

47. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	75%
Coursework	Ongoing	25%

48. RECOMMENDED TEXT

Chemical Process Control by George Stephanopoulos

49. STUDY BUDGETS

Lecture hours:	16	Tutorial hours:	6		
Practical work hours:	14	Private study hours:	64	Total study hours:	100

1. GENERAL INFORMATION

Title	**Advanced Mathematical Methods**
Unit code	CHEN 30010
Credit rating	10
Semester	
Pre-requisite units	
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Nick Goddard

2. AIMS

The programme unit aims to:

To provide the basic statistical and error analysis techniques needed for chemical engineers. The topics are taught as practical methods to be applied to real data. The underlying mathematical justification is generally only mentioned briefly, as these are covered in more detail in other courses. The assumptions made in deriving the methods are covered in more detail. The conditions under which the statistical methods covered may fail to give a valid result are also emphasised.

3. OUTLINE SYLLABUS

Introduction to statistics.
Classification of data
Classification of errors
Types of noise
Introduction to sampling: sampling design and protocols.
Sampling theory
Applications to the sampling of heterogeneous material
Random Sampling procedures and protocols
Design of experiments.
Estimating the number of experiments and measurements required for given accuracy and precision
Measures of central tendency
Measures of dispersion
Confidence limits and standard error
Parametric/non-parametric statistics.
Propagation of errors
Composite measurements and associated errors
Distributions.
Skewness, Kurtosis
Tests for Normality
Central limit theorem.
Statistical tests: F and t tests.
Rejection of data: outliers, Chauvanet's criterion, Grubb's test, Dixons Q test.
Linear regression analysis: correlation coefficient.
Limits of detection
Background signals
Weighted regression analysis.
Non-linear regression.
Analysis of Variance (ANOVA)
One way ANOVA
Two way ANOVA
Statistics software.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Apply the appropriate statistical methods/tests to his/her data.
Understand the limitations and assumptions inherent in the statistical methods used.
Understand the concept of probability and confidence levels.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	90%
Coursework	Ongoing	10%

6. RECOMMENDED TEXT

Miller, J. N. and Miller J. C., "Statistics and chemometrics for analytical chemistry" Prentice Hall, 2005, ISBN 0131291920
Otto, M., "Chemometrics – Statistics and Computer Application in Analytical Chemistry", Wiley-VCH, 2007, ISBN 3527314188
Gilbert R.O., "Statistical Methods for Environmental Pollution Monitoring" Van Nostrand Reinhold, ISBN 0442230508
Carr-Brion K.G. and Clarke, J.R.P., "Sampling systems for process analysers" Butterworth Heinemann, 1996, ISBN 0750612479.
McBean EA & Rovers FA, Statistical Procedures for Analysis of Environmental Monitoring Data and Risk Assessment, Volume 3, Prentice Hall, 1998 ISBN 0136750184, Joule Library 363.7 MCB

7. STUDY BUDGETS

Lecture hours:	12	Tutorial hours:	8		
Practical work hours:	0	Private study hours:	80	Total study hours:	100

50. GENERAL INFORMATION

Title	**Sustainable Development and Industry**
Unit code	CHEN 30017
Credit rating	10
Semester	6
Pre-requisite units	CHEN 2 0012 (Introduction to Environmental Technology)
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Adisa Azapagic

51. AIMS

The programme unit aims to:
-To introduce students to the concept of corporate sustainability and to various approaches to it
-To learn what companies can do at the practical level to become more sustainable

52. OUTLINE SYLLABUS

Introduction to sustainable development
Legislative framework
Strategies for corporate sustainability
Application of corporate sustainability strategies
Sustainability assessment tools
Life Cycle Assessment
Sustainable process design

53. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
- understand the concept of corporate sustainability
-apply various sustainability tools and approaches to corporate sustainability
-understand and apply the concept of life cycle thinking and Life Cycle Assessment
-design more sustainable chemical processes

54. ASSESSMENT

Assessment task	Length	Weighting within unit
Coursework I: Corporate sustainability strategy Coursework II: Life cycle assessment of packaging Coursework III: Designing sustainable chemical plants		25% 35% 40%

55. RECOMMENDED TEXT

Azapagic, A., S. Perdan and R. Clift (2004). Sustainable Development in Practice: Case Studies for Engineers and Scientists. John Wiley & Sons, Chichester, pp446. (ISBN: 0-470856092)

56. STUDY BUDGETS

Lecture hours:	18	Tutorial hours:	6		
Practical work hours:	6	Private study hours:	70	Total study hours:	100

7. GENERAL INFORMATION

Title	**Fundamentals of Life Sciences**
Unit code	CHEN 30018
Credit rating	10
Level	BEng, MEng
Pre-requisite units	
Co-requisite units	
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Dr Baier, Dr de Visser and Professor Mavituna

8. AIMS

The unit aims to:
1) Provide fundamentals of cell biology within the context of bioprocessing
2) Provide fundamentals of macromolecular structure and function
3) Familiarise students with the integration and regulation of metabolism
4) Introduce concepts in systems biology.

9. BRIEF DESCRIPTION OF THE UNIT

The unit will be composed of a series of lectures, and tutorials covering the following topics:
1) Introduction to cell structure and molecular composition relevant to bioprocessing (FM).
2) Different cell types and cell morphology. (FM).
3) Protein structure, function and kinetics (SdV)
4) Overview of genetic engineering tools (SdV)
5) Overview of metabolic processes and metabolic regulation (GB)

10. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should be able to:*
Knowledge and understanding	Understand basics of Life Sciences and be able to apply the knowledge to problems in biotechnology/biochemical engineering.
Intellectual skills	To work effectively at the boundaries between biological and engineering disciplines. Develop skills in problem solving.
Practical skills	Develop a good appreciation of skills utilized in biotechnology. Develop skills in information retrieval.
Transferable skills and personal qualities	Ability to communicate across disciplinary boundaries and to begin to apply existing engineering skills to problems in the life sciences.

11. LEARNING AND TEACHING PROCESSES

This module will be composed of a combination of lectures and tutorials. This module requires that the students learn a large breadth of material encompassing many different aspects of Life Sciences, and will be supported by handouts and recommended reading. Assessed coursework exercises will be used to reinforce the material taught and to prepare for examinations.

6. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Assessed coursework		15%
Written examination	2 hours	85%

Date of current version	09/07/2009

GENERAL INFORMATION

Title	**Environmental Law and Regulation**
Unit code	CHEN 30112
Credit rating	10
Semester	6
Pre-requisite units	None
Co-requisite units	None
Member of staff responsible	Dr Philip Martin

2. AIMS

Aims
To introduce the student to the key elements of international, EU/US and UK environmental law.
To describe mechanisms of regulation of industrial activities.

3. UNIT OUTLINE

Unit Outline
The objectives of international EU/US and UK environmental law will be described and the mechanisms of enforcement and prosecution introduced. Mechanisms of regulation will be discussed, including permitting, economic instruments and inspection.

4. INTENDED LEARNING OUTCOMES

Learning Outcomes	*After studying the Unit a students should be able to:*
Knowledge and understanding	Understand the objectives of environmental laws at the international, regional and national levels. Understand the processes of approximation between the tiers of environmental law and regulation Describe good practice in the operation of regulation Apply basic knowledge to the solution of problems in the environmental management and regulation of industry
Intellectual skills	Analyse the environmental regulatory requirements for a case study Explain the purpose and features of a regulatory system.
Practical skills	Use the internet for finding environmental regulatory information
Transferable skills and personal qualities	

5. LEARNING AND TEACHING PROCESSES

The principal mode of learning is through private study, supported by web based materials. The project based coursework encourages the student to carry out his or her own personal research beyond the core materials provided. Seminar sessions are used to enhance aspects of the web based materials and tutorial sessions are used to develop the students understanding of the more challenging aspects of the unit. Seminar sessions are thematically grouped into study weeks whilst tutorials are conducted either as on-line fora or as face to face class room sessions.

6. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Examination	2hours	50%
Project based coursework	23hours	50%

1. GENERAL INFORMATION

Title	**Research Proposal and Dissertation**
Unit code	CHEN 40001
Credit rating	50
Semester	7 & 8
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Dr Grant Campbell
Other Staff	All academic staff acting as supervisors and/or second markers

2. AIMS

The programme unit aims to:
Develop students' skills in the preparation of a research proposal.
Encourage students to engage deeply with the literature relevant to the subject of their research project.
Develop students' understanding of the methods of research through the execution and reporting of an appropriate research project in a chosen subject area.

3. OUTLINE SYLLABUS

Most projects in industry, academia and elsewhere are preceded by a proposal, explaining the motivation and rationale for the project, its resource requirements and its benefits, in order to obtain approval or funding to carry out the project. Thus, in this activity, the student will prepare a research proposal containing the necessary elements to allow a senior person (played here by the student's research project supervisor) to give the project approval to go ahead. The proposal will include reference to appropriate background literature to give the context and motivation for the proposed project and its specific objectives. It will outline the approach that would be taken to achieve those objectives, the required timescales and resource requirements, and the benefits that would result if the project were undertaken. In common with most project applications, the proposal will be subject to strict length limitations, requiring a conciseness of style resulting from a maturity of understanding of the subject. In order to gain this maturity of understanding, a separate literature review will be undertaken, which will receive feedback in order to enhance the quality of the subsequent proposal, but which will not itself form part of the assessment. (A more detailed literature survey is assessed later within the final dissertation. A mature engagement with the literature at this early stage will benefit the quality of the final dissertation, as well as enhancing the research proposal.)

The research proposal and literature review will be submitted towards the end of Semester 7.

The project involves an extensive research study, commencing with a proposal (described in Part a) and concluding with a final formal report (the dissertation) on the work undertaken. Students choose a research topic from a selection of laboratory-based and computational projects offered by different academic supervisors, and often work closely with a postgraduate or postdoctoral researcher or industry.
Following the submission of a research proposal described above, the research programme is undertaken from the middle of Semester 7 for the remainder of the module, and the Research Dissertation is submitted towards the end of Semester 8. In addition, students submit a four-page research paper, and make and discuss a poster presentation of their research work.

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:

Prepare a research proposal containing the elements necessary for approval of the proposed project.
Explain the purpose of each element of a research proposal.
Perceive the information requirements of those considering research proposals and, in the light of this perception, supply that information appropriately and persuasively.
Carry out literature search using library and IT facilities.
Undertake a literature review as a basis for identifying potential research areas, presenting the justification for the proposed research, and formulating objectives arising as a logical consequence of the literature review.
Formulate a workplan suitable to address identified objectives, and budget the time and resource requirements to execute the workplan.
Identify the benefits and beneficiaries of a proposed project.

Undertake and report on a substantial piece of project work.
Present a critical assessment of published literature appropriate to the area of research.
Formulate objectives for the work, logically relating these to previous work and its context.
Analyse a scientific or technological problem and develop or select and apply appropriate methods to investigate the problem.
Describe the methods and procedures by which the objectives of the problem were addressed.
Produce, report and analyse results, and draw appropriate conclusions.
Discuss the significance of the work and its outcomes in the context of previous work.
Summarise a complex piece of work and its subcomponents.
Structure the presentation of a complex written report appropriately, including appropriate use of summaries and linkages.
Communicate the work and its outcomes in a variety of formats – report, poster and academic paper.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Literature review (feedback given, but not assessed)	Around 20-30 pages	
Research proposal	6 pages	10%
Short paper	4 pages	20% altogether for short paper and poster
Poster	1 A0 poster	
Dissertation	Of an appropriate length	70%

6. RECOMMENDED TEXT

As recommended by supervisors

7. STUDY BUDGETS

Lecture hours:	5	Tutorial hours:	25		
Practical work hours:	220	Private study hours:	250	Total study hours:	500

1. GENERAL INFORMATION

Title	**Interface and Colloid Science of Multiphase Products**
Unit code	CHEN 40005
Credit rating	10
Semester	8
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Sven L.M. Schroeder

2. AIMS

The programme unit aims to:
Introduce the science underlying colloidal and interfacial phenomena
Show how the interface in heterogeneous mixtures are of importance to understanding structure, stability and transfer processes
Discuss examples of such systems through student team projects/presentations
Improve transferable skills, particularly literature research, abstracting and presentation skills

3. OUTLINE SYLLABUS

Thermodynamic properties of fluid-fluid and fluid-solid interfaces; adsorption at interfaces, capillarity, Laplace equation, Ostwald ripening, contact angles, interfacial instabilities.
Surfactant and polymer solution thermodynamics, molecular structure and phase diagrams/mesophases.
Mechanical and transport properties of interfaces, mesophases, colloids and powders.
Nucleation and crystallisation phenomena
Behaviour of complex systems involving interfaces and adsorbed surfactant layers: foams, emulsions (and microemulsions); solid in liquid dispersions, porous media.
Rheology

4. INTENDED LEARNING OUTCOMES

Category of outcome	*By the end of the module the student should be able to:*
Knowledge and understanding	Have an overview over important industrial products that are based on colloidal systems or interfacial interactions Explain the similarities and differences in molecular, thermodynamic and mechanical properties of interfaces, mesophases and colloidal systems. Apply these principles to the design of complex multiphase processes and products
Intellectual skills	Identification of relevant scientific concepts in the context of a complex industrial product Evaluation of the relevance of available information in the context of a practical problem
Practical skills	Literature research in the published scientific literature Self-learning from latest (non-textbook) available information Presentation of outcomes of literature research to peers Abstracting and summarising of complex information
Transferable skills and personal qualities	Independent evaluation Judgment and decision-making based on limited available information Public speaking Team work & peer assessment

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	1.5 hours	50%
Coursework (presentations/reports for peers)	Ongoing	50%

6. RECOMMENDED TEXT

Israelachvili J, Intermolecular and Surface Forces, 2nd Edition, Academic, 1991 ISBN 0123751810
Jonsson B, Lindman B, Holberg K and Kronberg B, Surfactants and Polymers in Aqueous Solution. Wiley 2000 ISBN 0471896985
Stokes RJ and Fennel Evans D, Fundamentals of Interfacial Engineering, Wiley, 1997 ISBN 0471186473
Evans D and Wennerstrom H, The Colloidal Domain, 2nd edition, Wiley, 1999 ISBN 0471242470

7. STUDY BUDGETS

Lecture hours:	15	Tutorial hours:	5		
Practical work hours:	15	Private study hours:	70	Total study hours:	100

1. GENERAL INFORMATION

Title	**Adsorption and Ion Exchange**
Unit code	CHEN 40006
Credit rating	15
Semester	7
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Flor Siperstein

2. AIMS

The programme unit aims to:
Instruct students on design procedures and calculation methods for the separation of multi-component mixtures by adsorption and ion-exchange.

3. OUTLINE SYLLABUS

Fluid-solid interactions leading to adsorption phenomena.
Porous materials and their use in adsorption.
Experimental methods for surface characterisation and acquisition of design data.
Development of isotherm relationships: thermodynamic and kinetic models.
Mass and heat transfer effects in fluid-solid batch and continuous systems.
Examples and applications will be drawn from temperature and pressure swing adsorption, ion exchange and chromatograph separations.

4. INTENDED LEARNING OUTCOMES

Category of outcome	*By the end of the module the student should be able to:*
Knowledge and understanding	Know the principles of separation by fluid/solid interactions in physical adsorption. Understand the requirements for loading and kinetic data for design of adsorption/desorption processes.
Intellectual skills	Apply theories for the design and operation of fixed bed sorption systems. Use knowledge to analyse experimental data to provide design information.
Practical skills	Appraise critically theories to the analysis of loading data and breakthrough curves. Mathematical modelling of heterogeneous heat and mass systems, and application of numerical techniques to find solutions
Transferable skills and personal qualities	Tackle relevant industrial design and operational problems of sorption systems.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
2 problem sheets, paper review and a project using software		
Examination	1.5 hours	80%
Coursework	Ongoing	20%

6. RECOMMENDED TEXT

Yang RT, Gas Separation by Adsorption Processes, World Scientific Publishing Co., 1997 ISBN 1860940471, Joule Library 660.022/YAN
Ruthven DM, Principles of Adsorption and Adsorption Processes, Wiley, 1984 ISBN 0471866067, Joule Library 660.02 RUT
Chi Tien, Adsorption calculations and modelling, Butterworth-Heinemann, 1994 ISBN 0750691212
J. U. Keller and R. Staudt , Gas Adsorption Equilibria: Experimental Methods and Adsorptive Isotherms, Springer Science + Business Media, Inc., 2005, ISBN 9780387235981

Slater MJ, Principles of Ion Exchange Technology, Butterworth-Heinemann, 1991 ISBN 0750611154

7. STUDY BUDGETS

Lecture hours:	20	Tutorial hours:	20	Group Project	35
Practical work hours:	0	Private study hours:	75	Total study hours:	150

8. GENERAL INFORMATION

Title	**Book Exam**
Unit code	CHEN 40015
Credit rating	10
Semester	7
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Dr Grant Campbell
Other Staff	All academic staff acting as supervisors and/or second markers

9. AIMS

The programme unit aims to:
Allow students the opportunity to develop in-depth knowledge in a subject area of their choice, closely or loosely related to their research project or more broadly to chemical engineering, through reading and mastering a book on the subject.
Develop an appreciation of the unique features of books as communication media, and to give students the skills and inclination to engage with books as the basis of lifelong learning and ongoing education.

10. OUTLINE SYLLABUS

Books give access to an in-depth understanding of a subject in a way that other communication media do not; books convey a uniquely strong coherence and sophistication of thought and idea. This part of the module will therefore focus on the student choosing a suitable book, in consultation with their supervisor and the Module Leader, reading it, mastering its content, and preparing themselves to sit an examination on the subject. (Two shorter books, or selected chapters of a longer book, may be read as an equivalent alternative to a single book, depending on the interests of the student and the agreement of the supervisor and module leader.) The student will be supported through this activity through discussion groups and supporting lectures. The examination will include both generic questions about books as communication media and their relevance to professional chemical engineers, and specific questions related to the chosen book. Coursework components will include a review of the chosen book and participation in discussion groups. The book will either be closely related to the student's research project, facilitating the development of a mature understanding of the subject and enhancing the quality of the research proposal; or will be more generally related to chemical engineering, helping to put the research proposal in the wider context.

The book review will be submitted towards the end of Semester 7. The book examination will take place in January.

11. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Describe, insightfully and engagingly, the content, merits and significance of a selected book.
Demonstrate mastery of the subject matter of a selected book and understanding of its context within the discipline and practice of chemical engineering.
Communicate an appreciation of the advantageous and disadvantageous features of books, compared with other communication media.

12. ASSESSMENT

Assessment task	Length	Weighting within unit
Book review Book examination, covering generic and specific elements	1 page 2.5 hours	10% 90%

13. RECOMMENDED TEXT

Books selected either in agreement with Research project supervisor or from a generally available pool.

14. STUDY BUDGETS

Lecture hours:	3	Tutorial hours:	2		
Practical work hours:	0	Private study hours:	95	Total study hours:	100

GENERAL INFORMATION

Title	**Fundamentals of Biochemical Engineering**
Unit code	CHEN 40016
Credit rating	15
Semester	7
Pre-requisite units	
Co-requisite units	
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Dr R Curtis, Dr S S Pandiella and Professor F Mavituna

1. AIMS

The unit aims to:
1) Introduce framework for modelling of biological systems by giving the tools needed for setting-up and solving the modelling problems.
2) Provide thermodynamic treatment to describe solutions containing small biomolecules and biocolloids.
3) Apply kinetics of biological processes and concepts of fluid flow, heat transfer and mass transfer to the design and operation of homogeneous and heterogeneous bioreactor systems.

2. BRIEF DESCRIPTION OF THE UNIT

The unit will be composed of a series of lectures, tutorials, and computer workshops. The following topics will be covered
1) Overview of bio-modelling. Rate and balance equations, thermodynamic relations. Parameters versus variables. Definition of control volume. Biological constraints.
2) Solution thermodynamics of small bio-molecules (organic acids, antibiotics, amino acids).
3) Biocolloids. Protein-protein interactions (DLVO theory and beyond) protein phase behaviour and crystallization.
4) Bioreaction engineering of homogeneous systems. Reaction kinetics and stochiometric relations. Design equations for batch, chemostat, fed-batch reactors. Recycle systems.
5) Bioreaction engineering of heterogeneous systems. Immobilized cells/enzymes. Solid-state and sludge fermentation processes.
6) Rheology, mixing, mass transfer and foaming conditions. Physiological parameters and scale up/scale down analysis.
7) Case studies of the application of biochemical engineering principles in bionanotechnology and in high-throughput, miniaturization technology (microbioreactors, lab on a chip).

3. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should be able to:*
Knowledge and understanding	Apply thermodynamics, reaction kinetics, and heat and mass transfer to biological problems for bioreactors and in other bioprocessing operations.

Intellectual skills	Be able to set-up and evaluate models to describe biological systems.
Practical skills	Analyze and interpret experimental data from biosystems, design further experiments and predict biosystem behaviour. Compare and contrast various bioreactor designs.
Transferable skills and personal qualities	Integrate knowledge and apply biochemical engineering principles with generic design principles to the analysis and performance of bioprocesses and biosystems. Be able to use mathematical software to solve modelling problems.

4. LEARNING AND TEACHING PROCESSES

This module will be composed of a combination of lectures, literature search and either problem-based tutorials or computer workshops. This module requires that the students learn a large breadth of material encompassing many different aspects of biochemical engineering, develop problem solving and analytical skills. This module will be supported by handouts and recommended reading. Assessed coursework exercises will be used to reinforce the material taught and to prepare for examinations.

5. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Coursework		15%
Computational project		15%
Written examination	2 hours	70%

Date of current version	09/07/09

GENERAL INFORMATION

Title	**Biorefinery Engineering**
Unit code	CHEN 40017
Credit rating	15
Semester	7
Pre-requisite units	
Co-requisite units	
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Professor Colin Webb

1. AIMS

The unit aims to:
Understand topical issues regarding the development, design and operation of biorefinery systems for the production of non-food products from agricultural raw materials.

2. BRIEF DESCRIPTION OF THE UNIT

The unit will be composed of a series of lectures, tutorials, and case studies. The following topics will be covered
1) Context – environmental and political drivers for the development of biorefineries.
2) Biorefinery Process Integration.
3) Raw materials for biorefineries (Crop production, Land utilisation, Genetic engineering of crops).
4) Fractionation, Extraction and Fermentation – Basic biorefinery processes.
5) Production of Biofuels (Biodiesel from oilseeds, Bioethanol from cereals)
6) Biomass Gasification and Biogas production.
7) Life Cycle Analysis for Biorefineries

3. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should/will (please delete as appropriate) be able to:*
Knowledge and understanding	Describe the contributions of cereals and other agricultural crops to the world's non-food needs. Describe the required technologies for the establishment of biorefineries and discuss their justification.
Intellectual skills	Apply quantitative modelling approaches to formulate descriptions of selected biorefinery processes.
Practical skills	Make balanced judgements regarding the production and use of important renewable natural resources.
Transferable skills and personal qualities	Describe the purpose and basis of Life Cycle Analysis in the context of the sustainable development of biorefineries and apply these principles to other sustainable industries in general.

4. LEARNING AND TEACHING PROCESSES

Seventy-five percent of the contact hours in this module will be lectures and the remainder will be in the form of either problem-based tutorials or case studies. These students will be assessed with coursework including a short essay and an exam containing problems and short answer essay questions.

5. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Coursework/essay Written examination	ongoing 2 hours	20% 80%

Date of current version	20/03/09

GENERAL INFORMATION

Title	**Bioprocessing**
Unit code	CHEN 40018
Credit rating	15
Semester	8
Pre-requisite units	
Co-requisite units	
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Dr R. A. Curtis

1. AIMS

The unit aims to:
1) Give students an overview of the different operations and analytical methods used in bioseparations.
2) Train students to be able to establish, operate, and analyze bioprocesses that meet safe/quality control guidelines.
3) Train students to integrate bioprocesses, in part, by using case studies of insulin and of monoclonal antibodies.

2. BRIEF DESCRIPTION OF THE UNIT

The unit will be composed of a series of lectures and tutorials covering
1) Survey of traditional operations (precipitation, solids removal, ultrafiltration, cell disruption)
2) Principles of chromatography (affinity, ion exchange, hydrophobic interaction, SEC)
3) Analysis of chromatographic processes
4) Novel bioseparation technologies
5) Process scale-up
6) Analytical methods for quantifying product quality and for quality control
7) Protein formulation and effect of excipients on protein stability
8) Integration of unit operations and bioprocess heuristics
9) Flow diagrams and process economics
10) Case study of insulin production and purification
11) Case study for purification of monoclonal antibodies

3. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should/will (please delete as appropriate) be able to:*
Knowledge and understanding	Understand the basic science that governs the separation behaviour.
Intellectual skills	Be able to evaluate quantitatively the performance of bioprocessing operations
Practical skills	Select appropriate analytical methods for evaluating and

	monitoring process operation. Be able to select a sequence of operations to achieve a protein purification.
Transferable skills and personal qualities	Apply knowledge to novel separation methods/strategies.

4. LEARNING AND TEACHING PROCESSES

This module requires in part both analytical skills and knowledge/understanding of the basic science in bioprocesses. Consequently, the assessment will include coursework problems, which will be associated with tutorials in which the problem-solving skills are practiced. In addition, a short technical essay will be assigned to test the student's knowledge and their critical evaluation skills. The exam will include a combination of short essay questions and some problem solving.

5. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Problems Essay Written examination to include problem based questions and essay	 2 hours	15% 15% 70%

Date of current version	03/07/09

Title	**Computer Aided Process Design**
Unit code	**CHEN 40019**
Credit rating	**15**
Level	
Pre-requisite units	**None**
Co-requisite units	**None**
School responsible	**Chemical Engineering and Analytical Science**
Member of staff responsible	**Nan Zhang**

Aims

To introduce the students to the concepts of process modelling using computational techniques. Students will learn how to set up and validate mathematical models in order to solve real engineering problems, including the implementation of models in a structured programming language, and obtaining numerical results. They will also learn how to construct and simulate process flowsheets. Furthermore optimisation theory will be introduced including various optimisation algorithms for continuous and integer parameters. They will learn how to apply optimisation techniques for parameter estimation and for the optimal synthesis and design of chemical processes.

Unit Outline

Advances in chemical process design in recent years have required the construction of detailed process models for efficient system design, scale-up and optimisation. Such models should contain an adequate number of parameters that can be exploited for optimal operation and control purposes. Chemical systems' models are often based on sets of non-linear equations. Furthermore, chemical systems often exhibit interesting dynamic behaviour and Ordinary Differential Equation (ODE) based models are needed in order to capture system dynamics. Also, in order to model phenomena such as mass and energy transfer, convection, etc., Partial Differential Equations (PDE) need to be employed.

The aim of this course is to teach students the numerical techniques needed to model both linear and non-linear chemical processes based on algebraic equations as well as on ODEs and PDEs. The non-linear dynamic behaviour of chemical process systems will also be examined. Furthermore, the essentials for the optimisation of chemical processes will be presented, such as basic principles of optimisation, necessary and sufficient conditions of optimality, various optimisation algorithms including the simplex method for linear problems, gradient methods and Newton type methods for non-linear problems, and branch and bound methods for integer problems. The basics of stochastic optimisation will also be given.

Learning Outcomes	*After studying the Unit a student should be able to:*
Knowledge and understanding	• Understand the need for models in engineering and in particular chemical process design • Evaluate methods for constructing models, experimental design and parameter estimation • Evaluate and apply numerical techniques for computer-aided solving of linear and nonlinear models • Evaluate and apply optimisation methods, for linear, non-linear and mixed-integer problems
Intellectual skills	• use, build and evaluate models for chemical process design. • implement models, in a structured programming language and to obtain numerical solutions. • Use MATLAB as a programming language. • formulate optimisation problems and how to apply optimisation techniques using computational tools such as GAMS and What's Best.
Practical skills	• demonstrate fluency in developing algorithms and solving numerically nonlinear mathematical models through a number of MATLAB-based assignments and workshops. • use advanced mathematical methods and specialised software, such as GAMS and What's Best, to solve linear nonlinear and mixed-integer optimisation problems. • Solve problems through homework assignments and workshops will involve examples from practical chemical and biochemical processes.
Transferable skills and personal qualities	• Ability to use information and communications technology • To be able to manage time and workloads effectively • Ability to communicate efficiently and effectively orally and in writing

Recommended Text

Introduction to Engineering Programming: C, MATLAB, Java, M. Austin and D. Chancogne
Introduction to Applied Mathematics, G. Strang
Introduction to Partial Differential Equations with MATLAB, J. M. Cooper
Linear Algebra with applications, S.J. Leon
Matrix computations, G.H. Golub, C.F. VanLoan
Steven H. Strogatz Nonlinear dynamics and chaos : with applications to physics, biology, chemistry, and engineering, Cambridge Mass 2000
Edgar,T.F. and Himmelblau,D.M., Optimization of Chemical Processes, McGraw-Hill, 1988
Williams, H.P., Model Building in Mathematical Programming, J.Wiley, 1993

Reklaitis,G.V., Ravindrau,A. and Ragsdell,K., Engineering Optimization, Wiley, 1983.

Assessment task	Length	Weighting within unit (if relevant)
Lectures	30 hours	
Practical Based Coursework	50 hours	25%
Private Study	68 hours	
Examination	2 hours	75%

1. GENERAL INFORMATION

Title	**Aqueous Systems Technology**
Unit code	CHEN 40102
Credit rating	15
Semester	8
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Alastair Martin

2. AIMS

The programme unit aims to:
Develop the student's understanding of water and wastewater treatment processes and their underlying design and operating principles.

3. OUTLINE SYLLABUS

Wastewater treatment operations: physical and chemical oxidisation and reduction; biological treatment; sedimentation; precipitation and flocculation; filtration and membrane processes. Coursework design project addressing various aspects of waste and waste water treatment technologies

4. INTENDED LEARNING OUTCOMES

By the end of the module the student should be able to:
Explain the function of unit processes in water and wastewater treatment.
Implement generic protocols in design scoping studies.
Apply chemical engineering principles to the analysis of process units and to the development of appropriate models.
Develop sound strategies for the treatment of diverse wastewater streams.
Assess critically appropriate technologies for the treatment of wastewater arising from particular industries.

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination	2 hours	50%
Coursework project	Approximately 30 hours	50%

6. RECOMMENDED TEXT

Eilbeck WJ & Mattock G, Chemical Processes in Waste Water Treatment, Ellis Horwood, 1987 ISBN 0853127913, Joule Library 628.54 EIL
Horan NJ, Biological Waste Water Treatment Systems: Theory and Operation, Wiley, 1990 ISBN 0471922587, Joule Library 628.351 HOR

7. STUDY BUDGETS

Lecture hours:	20	Tutorial hours:	5		
Project work hours:	50	Private study hours:	75	Total study hours:	100

GENERAL INFORMATION

Title	**Eco-Design and Green Chemistry**
Unit code	CHEN 40112
Credit rating	10
Level	4
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Stuart Holmes

2. AIMS

The unit aims to:
Introduce and discuss the concepts of eco-design and green chemistry

3. UNIT OUTLINE

This unit comprises a mixture of web based teaching material combined with seminars and tutorials. The seminars are thematically grouped into study weeks. The web based material supports the student's private study and project coursework. Either on-line or face to face tutorials are used to extend the student's understanding of the material.

The unit defines "eco-design" and the contribution made by green chemistry to achieving environmental and sustainability objectives.
Resource efficiency is discussed and design tools developed to address the "green and sustainable" agendas.
Energy efficiency is addressed through the "pinch" concepts and method.
The water resource is considered through the development of the "pinch" concepts.
Raw materials efficiency is considered through the introduction of optimisation principals and techniques
Project management for sustainable outcomes is discussed in the context of objective, timely decision making and consideration of the "design team" composition.

4. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should be able to:*
Knowledge and understanding	Describe the objectives of Eco-design Understand the role of green chemistry in achieving environmentally sound process designs Describe a range of technical and managerial tools appropriate to Eco-design
Intellectual skills	Apply a range of technical and managerial tools to example scenarios relevant to Eco-design. Critically analyse Eco-design problems and select appropriate tools to resolve the issues. Evaluate example design tools and determine their suitability as part of an Eco-design solution.
Practical skills	Evaluate a design team and identify skill shortages relevant to achieving environmental and sustainability objectives.
Transferable skills and personal qualities	Deploy a range of managerial tools in the pursuit of environmental objectives.

5. LEARNING AND TEACHING PROCESSES

The principal mode of learning is through private study, supported by web based materials. The project based coursework encourages the student to carry out his or her own personal research beyond the core materials provided. Seminar sessions are used to enhance aspects of the web based materials and tutorial sessions are used to develop the students understanding of the more challenging aspects of the unit. Seminar sessions are thematically grouped into study weeks whilst tutorials are conducted either as on-line fora or as face to face class room sessions.

6. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Examination	2hours	50%
Project based coursework	23hours	50%

Revision	**Notes**	**Date**
0.0	Original	Jan 2007

1. GENERAL INFORMATION

Title	**Solid Waste Management and Valorisation**
Unit code	CHEN 40121
Credit rating	15
Semester	7
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering
Member of staff responsible	Alastair Martin
Other Staff	Stuart Holmes

2. AIMS

The programme unit aims to:
Develop the students' understanding of solid waste and its management.

Introduce the students to the concepts and issues of waste valorisation

Develop the students' knowledge if solid waste management and valorisation techniques

Introduce the students to a methodical approach for the identification and evaluation of valorisation opportunities and management techniques.

3. OUTLINE SYLLABUS

Hierarchy of waste Waste disposal in landfill, Energy from waste, Tools to identify opportunities to recycle waste, Examples of waste valorisation techniques, Relevant EU and UK legislation.

4. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should be able to:*
Knowledge and understanding	Understand both the environmental and regulatory issues associated with solid waste management. Describe the technical requirements for the construction and management of a land fill site Describe a range of example waste valorisation technologies and understand the environmental and sustainable benefits arising from their implementation.
Intellectual skills	Deploy a range of tools to analyse an example manufacturing scenario and synthesise waste management and valorisation opportunities for it. Apply a range of tools to analyse the benefits of a range of waste management and valorisation opportunities
Practical skills	Employ a systematic approach to the identification of waste management and valorisation opportunities.
Transferable skills and personal qualities	Structure and present a satisfactory technical report critically analysing waste production and management scenario

5. ASSESSMENT

Assessment task	Length	Weighting within unit
Examination (answer 2 questions from 3) Coursework	2 hours Approximately 50 hours	50% 50%

6. RECOMMENDED TEXT

None

7. STUDY BUDGETS

Lecture hours:	20	Tutorial hours:	5		
Project work hours:	5	Private study hours:	75	Total study hours:	100

GENERAL INFORMATION

Title	**Aerial Emissions Avoidance and Abatement**
Unit code	CHEN 40131
Credit rating	10
Level	4
Pre-requisite units	None
Co-requisite units	None
School responsible	Chemical Engineering and Analytical Science
Member of staff responsible	Dr Philip Martin

2. AIMS

The unit aims to:
Develop the students' understanding of aerial emissions and their impact on the local, regional and global environments.

Develop the students' knowledge of techniques to avoid aerial emissions and a methodical approach to their application

Develop the students' knowledge of techniques to abate the impact of unavoidable emissions

3. UNIT OUTLINE

This unit comprises a mixture of web based teaching material combined with seminars and tutorials. The seminars are thematically grouped into study weeks. The web based material supports the student's private study and project coursework. Either on-line or face to face tutorials are used to extend the student's understanding of the material.

The unit characterises aerial emissions with respect to particle size, molecular composition, environmental impact and contribution to sustainability. Emissions of dust, VOCs, SO_x, NO_x, "ozone depleters" (CFCs etc.) and "global warmers" (CO_2 etc.) will be critically examined for their impacts at the local, regional and global levels.

Methods for the assessment and avoidance of material emissions are discussed and evaluated including auditing, mass balance reconciliation, exclusion, and zero tolerance management.

Methods for abatement of impact are critically evaluated for their net benefit including adsorption and absorption, destruction and sequestration.

4. INTENDED LEARNING OUTCOMES

Category of outcome	*Students should be able to:*
Knowledge and understanding	Describe the impact of a range of aerial emissions and understand the scales relevant to the type of emission. Understand the concepts and principals behind emission avoidance techniques Understand the design principals of a range of abatement technologies and the limitations to their application
Intellectual skills	Critically analyse example scenarios and deduce the environmental impacts and contribution to sustainability arising from their aerial emissions Synthesise strategies to eliminate or minimise impacts arising from aerial emissions Synthesise process configurations to abate aerial emissions
Practical skills	Specify aerial emissions avoidance and abatement technologies
Transferable skills and personal qualities	Structure and present a satisfactory technical report critically analysing an aerial emissions scenario

5. LEARNING AND TEACHING PROCESSES

The principal mode of learning is through private study, supported by web based materials. The project based coursework encourages the student to carry out his or her own personal research beyond the core materials provided. Seminar sessions are used to enhance aspects of the web based materials and tutorial sessions are used to develop the students understanding of the more challenging aspects of the unit. Seminar sessions are thematically grouped into study weeks whilst tutorials are conducted either as on-line fora or as face to face class room sessions.

6. ASSESSMENT

Assessment task	Length	Weighting within unit (if relevant)
Examination	2hours	50%
Project based coursework	23hours	50%

Revision	**Notes**	**Date**
0.0	Original	Jan 2007