UNIVERSITY OF CAMBRIDGE
Chemical Engineering and Biotechnology

CHEMICAL ENGINEERING TRIPOS

Part IIB

SYLLABUS 2021-22

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General Introduction

Students reading the Chemical Engineering Tripos normally progress as follows:

- 1st year: Part IA Natural Sciences Tripos or Part IA Engineering Tripos
- 2nd year: Part I Chemical Engineering Tripos (CET I)
- 3rd year: Part IIA Chemical Engineering Tripos (CET IIA)
- 4th year: Part IIB Chemical Engineering Tripos (CET IIB)

Progress is dependent on satisfactory performance in the previous year's course – honours standard in CET I is sufficient to do CET IIA. Students are normally required to achieve class II.2 or higher in CET IIA in order to progress to CET IIB.

Please note, this Syllabus document was correct at the time of printing. However, changes may occur during the year due to unforeseen circumstances.

The educational aims of the overall Chemical Engineering Tripos are to:

- give a sound education in the fundamentals of Chemical Engineering;
- develop the skills and confidence necessary for the solution of problems in the chemical, biochemical and allied industries;
- produce graduates of the highest calibre;
- provide an education accredited by the Institution of Chemical Engineers.

Outline of Part I Chemical Engineering Tripos (CET I)

In Part I students gain a broad exposure to the core Chemical Engineering topics.

There are lecture courses on:

- Fundamentals: process calculations; fluid mechanics; biotechnology fundamentals; heat and mass transfer fundamentals
- Process operations: separations; homogeneous reactors; biotechnology operations; heat and mass transfer operations
- Process systems: introductory chemical engineering
- Mathematics: engineering mathematics
- Enabling topics: stress analysis and pressure vessels; mechanical engineering for those who read Natural Sciences in the first year; introductory chemistry for those who read Engineering in the first year

In addition, students are required to undertake classes on:

- Exercises
- Chemical Engineering laboratory
- Engineering drawing: for those who read Natural Sciences in the first year
- Physical chemistry laboratory: for those who read Engineering in the first year

Full details of these courses are provided in the Part I Syllabus Document.

Students for Part I will take four written examination papers. Papers 1-3 will be taken by all students. Paper 4(1) will be taken by students who read Natural Sciences in the first year, and Paper 4(2) will be taken by students who read Engineering in the first year. The format of examinations and weighting of written papers and project work is given in the Form and Conduct Notice published each year by the Chemical Engineering and Biotechnology Syndicate.

Outline of Part IIA Chemical Engineering Tripos (CET IIA)

In Part IIA students continue their study of core chemical engineering topics, both by extending subjects that were introduced in Part I and by being exposed to new topics.

There are lecture courses on:

- Fundamentals: advanced fluid mechanics; equilibrium thermodynamics; radiative heat transfer; corrosion and materials
- Process operations: heterogeneous reactors; separations; bioprocessing; particle processing
- Process systems: process dynamics and control; process synthesis; safety, health and environment
- Mathematical methods: partial differential equations; statistics
- Enabling topics: process design

In addition, students are required to undertake:

- Exercises
- Design project
- Engineering ethics

Full details of these courses are provided in the Part IIA Syllabus Document.

Students for Part IIA will take four written examination papers. These examinations are near the start of Easter term, after which the Design Project takes place. The format of examinations and weighting of written papers and project work is given in the Form and Conduct Notice published each year by the Chemical Engineering and Biotechnology Syndicate.

Rather than staying on for Part IIB, students may graduate with a B.A. degree after successfully completing Part IIA. Students leaving at this stage have not fully completed the academic requirements of the IChemE for becoming a Chartered Engineer.

Outline of Part IIB Chemical Engineering Tripos (CET IIB)

Part IIB is a Master's-level course that gives students a deeper understanding of some fundamental subjects, introduces a range of specialist areas of knowledge, and provides an opportunity for broadening their education.

Topics in Groups A and D are compulsory. Students are required to take a total of six modules from Groups B and C, of which at least two must come from Group B and at least two must come from Group C. Further, at least two of the six modules chosen from Groups B and C should be assessed principally or entirely by written examination.

Group A consists of the following compulsory topics.

- Sustainability in Chemical Engineering
- Energy Technology
- Chemical Product Design

Group B consists of advanced chemical engineering topics.

- Advanced Transport Processes
- Interface Engineering
- Pharmaceutical Engineering
- Adsorption and Advanced Nanoporous Materials
- Fluid Mechanics and the Environment
- Electrochemical Engineering

Group C consists of broadening material topics.

- Optical Microscopy
- Healthcare Biotechnology
- Biophysics
- Biosensors and Bioelectronics
- Foreign Language

The Group D topic is a compulsory project. Each student undertakes a research project, usually in collaboration with another student, supervised by a member of staff.

Full details of these courses are provided in the Part IIB Syllabus Document.

The format of examinations and weighting of written papers and project work is given in the Form and Conduct Notice published each year by the Chemical Engineering and Biotechnology Syndicate.

Students graduate with B.A. and M.Eng. degrees after successfully completing Part IIB. Provided they performed satisfactorily in the design component, they have satisfied the academic requirements of the IChemE for becoming a Chartered Engineer.

Student Workload Statement

It is expected that students will:

- attend and be attentive in all lectures and related classes;
- complete all assignments to a satisfactory standard by the imposed deadlines;
- prepare properly for all College supervisions;
- work in the vacations on consolidation, revision, exam preparation and any coursework.

The normal workload for a typical chemical engineering student is 45 hours each week during term. However, this is not a hard and fast figure. Some students work intensely and can achieve a great deal in an hour. Other students work less efficiently. In an ideal world, students would work on a particular task (problem sheet, lab write-up, exercise report) until the desired learning outcomes have been achieved. That said, students are advised not to spend significantly more time on work than the typical workload on a frequent basis. For supervision work, while it can be useful educationally for a student to battle through a problem to reach a solution (even if it takes a long time), it is perfectly acceptable for a student to “give up” after a decent effort and go on to the next question. One of the roles of supervisions is for students to ask for help on questions that they cannot answer. Question & Answer sessions and demonstrator assistance are also provided for much of the coursework to assist students.

Student Feedback

The Department of Chemical Engineering and Biotechnology has a strong tradition of good relations between staff and students and takes student feedback seriously.

You will be asked to complete a questionnaire on each lecture unit when it finishes. You will also be asked to complete an end-of-year questionnaire on the overall course. Please take time to fill these in. Staff very much value receiving constructive comments.

If there are any problems with teaching in the Department, please tell the lecturer or course organiser. It is a good idea to tell the organiser before the end of the course because it may be possible to rectify the problem. However, if the problem persists, please contact either Rachael Tuley, rlt23@cam.ac.uk or Helen Stevens Smith, hcs24@cam.ac.uk. If you would like to remain anonymous, your name can be removed before passing on to the relevant academic staff.

If there are any problems with College supervisions, then please tell your Director of Studies or Senior Tutor.

A further feedback mechanism within the Department is provided by the Staff-Student Consultative Committee (SSCC). This is the formal forum in which students comment on issues concerning life in the Department. Two student representatives will be elected from each undergraduate year group early in Michaelmas term to serve on this Committee. Meetings are held at least twice a year.

There is also an undergraduate representative on the Chemical Engineering and Biotechnology Syndicate. This is the University body that is responsible for overseeing the running of the Department – it is the equivalent of a Faculty Board. The election of the undergraduate representative to the Syndicate takes place late in Michaelmas term.

Chemical Engineering Tripos: information on plagiarism

The University's website on plagiarism makes the following statement:

> "Plagiarism is defined as submitting as one's own work, irrespective of intent to deceive, that which derives in part or in its entirety from the work of others without due acknowledgement. It is both poor scholarship and a breach of academic integrity."

The open literature, including web-based literature, is available for you to consult. Discussions about continually assessed work with other students, or with demonstrators or supervisors, can be beneficial, and we wish to encourage such discussions. However, any work that you submit for assessment must represent your own knowledge and understanding and not that of someone else. When you draw on the work of others, e.g. words, facts, data, ideas, diagrams, and software, you must acknowledge the source with an appropriate citation.

Any attempt to pass off the work of others as your own is a serious offence. If plagiarism (which includes unauthorised collusion) is detected, the Examiners will award a mark which reflects the underlying academic merit and extent of a candidate's own work. Further, the case may be referred to the Senior Proctor, the University Advocate, or taken to the University's Court of Discipline, depending on the nature of the offence.

Moreover, as well as not copying the work of others, you should not allow another person to copy your work. If you allow another person to copy your work, you may be found guilty of assisting an attempt to use unfair means.

Some continually assessed work is designed to be carried out individually, and some in collaboration with other students. The specifications regarding the manner of working and reporting are shown in the Student Collaboration Table below.

Information about the University's policy and procedures on plagiarism can be found at http://www.admin.cam.ac.uk/univ/plagiarism/

The University Library provides a Guide on Good Academic Practice and Avoiding Plagiarism here: https://libguides.cam.ac.uk/plagiarism

Plagiarism Quiz
At the start of the academic year, you will be asked to complete the Plagiarism Quiz on Moodle. Links will be provided to all cohorts at the start of term. All students must take the quiz. Successful completion of the quiz confirms that you have read and understood the policies and procedures of the Department and the University on plagiarism.

Student Collaboration Table 2021/2022

Level	Course	Instructions
CET I	Exercises	You must work as an individual.
CET I	Chemical Engineering Laboratory	You normally work in a group of two. You may collaborate with the other member or members of your group in conducting experiments and theoretical investigations, but your reports must be written independently.
CET I	Engineering Drawing	You must work as an individual.
CET I	Physical Chemistry Laboratory	You normally work in a group of two. You may collaborate with the other members of your group in conducting experiments and theoretical investigations, but your reports must be written independently.
CET IIA	Engineering Ethics	You must work as an individual.
CET IIA	Exercises	You must work as an individual.
CET IIA	Design Project	Because the projects are carried out in groups, cooperation between members of each group is essential. However, collaboration between different groups, and exchange of information, drawings, text, calculations and computer files, other than that which takes place at office hours and seminars, is prohibited. The report and associated calculations must represent the work only of the members of the group.
CET IIB	Chemical Product Design	Because some of the work is carried out in groups, cooperation between members of each group is essential. However, collaboration between different groups, and exchange of information, drawings, text, calculations and computer files, other than that which takes place during and following workshops and seminars, is prohibited. All individual reports must be written individually.
CET IIB	Research Project	You normally work in pairs, in which case you may collaborate with your partner in conducting experiments and theoretical investigations, but your reports must be written independently. If you work with a research group, you may collaborate with members of the group on experimental and theoretical investigations. However, your report must be written independently, and you should clearly state the assistance provided by other members of the research group.
CET IIB	Foreign Language	You must work as an individual.
CET IIB	Biosensors and Bioectronics	You must work as an individual when specified. When it is specified that you should work in a group, you may collaborate with the other members of your group in conducting experiments, theoretical investigations, and design exercises but your reports must be written independently.

Unit

Sustainability in Chemical Engineering

Level	***Term***	***Duration***
CET IIB	LT 2022	12 lectures

Background

Achieving the state of sustainability is seen as a critical societal challenge. It is a major factor in decision making in most industries employing chemical engineering graduates. This course will examine the foundation principles of sustainability, sustainability challenges in specific application areas and the role of chemical engineering in attaining the goals of sustainable development.

Aims

This course provides an overview of sustainability in a chemical engineering context. The aim is to establish the conceptual framework and apply quantitative methods to the analysis of chemical engineering technology with respect to its impact on sustainability.

Learning Outcomes

After completing this course and the associated problem sheets, students should be able to:

- Understand the concept of sustainability as a system's problem
- Understand basic concepts of general systems theory in application to technology systems
- Understand basic principles of environmental ecology; understand interaction of technological and environmental systems and their interconnections
- Describe principles of life cycle thinking; practically apply life cycle analysis to simple chemical processes
- Use thermodynamic analysis of simple chemical systems; be able to calculate exergy of chemical processes and use it to evaluate process efficiency.
- Describe the water-energy-food nexus – an example of a system's problem.

Assumed Knowledge

Material	*Source*
Thermodynamics	CET I Process calculations CET IIA Equilibrium thermodynamics

Connections To Other Units

This course builds on material taught in CET I and CET IIB.

Self Assessment

Exercises within lectures and additional exercises made available to students for self study and self assessment. Interactive sessions during the scheduled sessions also include elements of self-assessment and peer assessment.

Assessment

The material from this unit is assessed by coursework.

Prepared	***Approved***	***Subject Grouping***
AAL 9/2021	AJS	Group A: Compulsory Topics

Unit	*Staff*
Sustainability	Prof. A.A. Lapkin

Synopsis

1. Sustainability as a system' science
   Three pillars of sustainability
   Mathematical definitions of sustainability
   General systems theory and its application to sustainability

2. Life cycle thinking
   Principles of LCA
   LCA of chemical processes

3. Thermodynamics-based evaluation of process efficiency
   2^{nd} Law efficiency
   Exergetic efficiency of chemical processes

4. Water-food-energy nexus

Teaching Materials

References to original and review papers for background reading and discussion will be mentioned during lectures and deposited in Moodle.
The following books may be useful:

- B.R. Bakshi, Sustainable Engineering. Principles and Practice, Cambridge University Press, 2019.
- M. Robertson, "Sustainability Principles and Practice", Routledge, 2014.
- S.A. Moore (editor), "Pragmatic Sustainability. Theoretical and Practical Tools", Routledge, 2010.

Unit

Energy Technology

Level	*Term*	*Duration*
CET IIB	MT 2021	20 lectures

Background

The future of society in the 21st century depends hugely on developments in Energy Technology. Most large-scale methods for converting energy from one form into another, including generation of electricity, depend on chemical engineering principles. It is useful for students to revise chemical engineering principles by seeing how they can be applied in the field of energy technology.

Aims

The aim of the course is to use chemical engineering principles to perform calculations of relevance to the energy industries. The courses includes combustion science, the fundamentals of nuclear energy, renewable energy processes, and energy storage.

Learning Outcomes

On completing this course and the associated problem sheets, students can:

- describe and perform calculations on gas-phase combustion reactions.
- explain stages and reactions involving radicals.
- describe and perform calculations on liquid-phase combustion reactions.
- describe and perform calculations on combustion of solids.
- describe the principles of energy storage.
- describe and perform calculations on wind turbines.
- describe and perform calculations on hydroelectric turbines.
- describe and perform calculations involving solar energy
- describe and perform calculations involving fuel cells
- describe the physical principles behind radioactivity and nuclear reactions
- describe and perform calculations on radioactive decay
- describe and perform calculations on nuclear reactor design
- describe and perform calculations on poisoning of fission nuclear reactors

Assumed Knowledge

Material	*Source*
Chemical Engineering principles	CET I and CET IIA

Connections To Other Units

This course is designed to revise and build upon key chemical engineering topics covered in previous years.

Self Assessment

Three examples sheets will be issued during lectures.
This course was given for the first time in 2014-15. The past exam questions are CET IIB 2015-2018, 2020 / Paper A1 / questions 1 and 2, and CET IIB 2019 / Paper A1 / question 1

Assessment

The material from this unit is assessed by written examination.

Prepared	*Approved*	*Subject Grouping*
EJM 29/09/2021	AJS	Group A: Compulsory Topics

Unit Energy	***Staff*** Dr Ewa J. Marek

Synopsis

The topics of the course will not necessarily be given in the order presented here.

1) Electricity and energy storage

2) Combustion processes
   - Introduction: combustion; heating values; types of flame
   - Combustion of gases: temperature in a flame; equilibrium; flame propagation; reactions involving radicals;
   - Combustion of liquids: heating time; mass transport, energy transport and combining Equations;
   - Combustion of solids: coal; biomass. Rate of reaction and limiting factors.

3) Nuclear energy
   - Fundamentals of nuclear physics: atomic structure; binding mass energy; nuclear stability of isotopes; radioactive decay;
   - Nuclear reactor physics: nuclear reactions; nuclear fusion; nuclear fuel; nuclear power plants; handling of nuclear wastes;

4) Renewable energy processes
   - Wind energy: wind turbines; power coefficient; Betz limit; force on turbine; turbine blade design; power output for a steady wind; wind speed distribution; siting of wind turbines;
   - Hydropower: introduction; impulse and reaction turbines; Euler's turbine equation;
   - Solar energy: semiconductors, p-n junction and diode, characteristics of PV cells, other solar technologies (briefly).

5) Other topics
   - Energy storage;
   - Hydrogen economy;
   - H_2 combustion in fuel cells – principles and fundamental calculations, Nernst equation.

Teaching Materials

Recommended textbook with an appropriate approach (though not always sufficient detail) is:
- J. Andrews and N. Jelley: "Energy Science" (3rd ed., Oxford University Press, 2017).

Detailed approach to combustion fundamentals and energy supply topics can be found in:
- S. R. Turns: "An Introduction to Combustion: Concepts and Applications" (3rd ed. or earlier, Mc Graw-Hill, 2012)
- David Rutledge: "Energy: Supply and Demand" (Cambridge University Press, 2019)

A suitable textbook on the nuclear energy part of the course is:
- R.L. Murray and K.E. Holbert: "Nuclear Energy" (7th ed., Butterworth-Heinemann, 2014)
- J.S. Goldstein and S.A. Qvist: "A Bright Future: How Some Countries Have Solved Climate Change and the Rest Can Follow, (New York, PublicAffairs, 1st ed, 2019)

Unit

Chemical Product Design

Level	*Term*	*Duration*
CET IIB	LT 2022	8 × 2 hr classes plus assessments

Background

Chemical and biochemical product design is an important activity for many companies, and chemical engineers need to understand the principles of product design. An important aspect is sustainable design that addresses significant current global challenges.

Aims

To prepare students for the increasingly diverse range of challenges faced by chemical engineers in industry, in particular the increasing emphasis on design of the product in addition to the process.

Learning Outcomes

On completing this course, students should be able to:

- apply fundamental chemical engineering principles to design chemical and biochemical products at a level suitable to make an initial assessment of their viability/functionality/feasibility;
- demonstrate confidence in data/parameter estimation such that a pragmatic level of design can be carried out;
- make pragmatic assumptions about processes and products such that an initial level of design can be carried out;
- summarise succinctly and report both orally and in writing key information relating to their designs;
- demonstrate an understanding of the design and manufacture of pharmaceutical products.

Assumed Knowledge

Material	*Source*
Chemical engineering principles	CET I and CET IIA
Biotechnology and bioprocess engineering	CET I and CET IIA

Connections To Other Units

This course builds upon, and extends, design philosophies gained in CET IIA process design.

Self Assessment

Assessment

This course is assessed by coursework, which may include written reports, oral presentations and/or recorded videos. Group and individual work will be included in the assessment. An element of peer assessment may be used in marking.

Prepared	*Approved*	*Subject Grouping*
GDM 10/9/2021	AJS	Group A: Compulsory Topics

Unit	*Staff*
Chemical Product design	Professor Geoff Moggridge

Synopsis

Chemical engineering shares with other engineering disciplines a tradition of courses in design. In these courses, students use what they have learned to come up with new solutions to relevant problems. Normally, these problems have centered on chemical processes. For example, students can design an ammonia synthesis plant, or a cryogenic distillation unit for air separation.

This design experience has been a mainstay of the profession for over fifty years. It has successfully prepared students to work for large multi-national companies which make commodity chemicals. It has served the profession well.

However, over recent decades, fewer students have gone to work for these commodity chemical companies. Increasing numbers take jobs in specialty chemicals, consumer products, and biomedical industries. Some of these jobs are in start-up companies. For students anticipating this type of career, process design is not as relevant, but there is and will be in the future, more emphasis on the design and manufacture of high added value products.

The focus of this course is on product, not process design. An example of such products, which chemical engineers are involved in designing, is pharmaceuticals. In a special edition of this course, in recognition of the key role vaccine development has played in tacking the SARS-CoV-2 pandemic, the course this year will focus primary on how to develop, scale up and distribute medical products. This will be delivered in collaboration with an industrial partner.

Topics discussed will include:

- Regulatory framework
- Reactor design and scale up for vaccines
- Separation design and scale up for vaccines
- Delivery methods
- Evolution of disease and vaccines
- Product to person
- Economics of a vaccine
- The broader context of the pharmaceutical industry

Classes will be organized into short sections of lectures interspersed with interactive group or individual tasks. These sessions will provide the basis for pieces of continually assessed work, by written report, oral presentation and/or recorded videos. Effective group working is an essential part of the course and assessment.

Teaching Materials

The following books are recommended:

- K.T. Ulrich and S.D. Eppinger, "Product Design and Development", McGraw-Hill, 5th ed. 2011.
- E.L. Cussler and G.D. Moggridge, "Chemical Product Design", Cambridge University Press, 2nd ed. 2011.

Unit

Advanced Transport Processes

Level	*Term*	*Duration*
CET IIB	LT 2022	16 lectures

Background

Transport processes is one of the fundamental topics that helps define the chemical engineering discipline. The ability to model transport processes in different situations, such as in porous solids, in packed beds, in the presence of reaction and so on, is an important part of a chemical engineer's training.

Aims

The overall aim is to enable students to formulate solutions to unfamiliar transport problems occurring in chemical engineering. The course will emphasise the tackling of problems by applying fundamentals to produce a solution.

Learning Outcomes

After completing this course and associated problem sheets, students should be able to:

- perform calculations on advective and diffusive fluxes in binary systems
- describe diffusion in multicomponent systems, and understand the limitations of Fick's law
- apply the Stefan Maxwell to multicomponent transfer and understand its derivation
- calculate the rate of transfer between gas and liquid phases when the gas reacts with the liquid at a finite rate
- set up and use models for time-dependent transport problems
- set up and use models for how fluid disperses as it travels through an open tube or a packed bed
- tackle problems concerning the stability of reactions undertaken in industrial-scale stirred reactors.

Assumed Knowledge

Material	*Source*
Core chemical engineering topics	CET I and CET IIA

Connections To Other Units

This course builds on the knowledge gained in the CET I Transport Processes lectures, and the applications in CET I and CET IIA.

Self Assessment

There will be five problem sheets. Fully documented solutions will be available 10 days after each problem sheet is issued.
The following examination papers indicate the level of achievement expected:
CET IIB 2013-2021 Paper B1, *except* questions on high-rate coefficients of
heat and mass transfer, not now part of the syllabus.

Assessment

The material from this unit is assessed by written examination.

Prepared	*Approved*	*Subject Grouping*
JSD 9/2021	AJS	Group B: Advanced Chemical Engineering Topics

Unit	Staff
Advanced Transport	Professor J.S. Dennis

Synopsis

1. Mass and Energy Transport in a Binary System.
    - understanding advective and diffusive fluxes in binary systems.
2. Multicomponent Diffusion – Stefan-Maxwell Equations.
    - derivation of equations, including a consideration of non-equilibrium thermodynamics.
    - to understand what happens in a diffusing system when there are more than two components and there are significant changes in concentration, as in a practical catalyst. Limitations of Fick's Law.
3. Interphase Mass Transfer: Gas-Liquid Mass Transfer
    - how to calculate the rate of transfer between a gas and liquid when the gas reacts with the liquid at a finite rate. Time-dependent aspects of gas absorption.
4. Time-Dependent PDEs – Revision and Extension
    - an extension of material covered in Part IIA PDEs to allow solution of time-dependent transport problems.
5. Reaction and Dispersion
    - how fluid disperses as it travels through a packed or open tube. Understanding tracer measurements on packed beds. How to formulate the correct boundary conditions for a packed bed reactor.
6. Dynamic Stability of CSTRs
    - how to determine if a reaction undertaken in a CSTR will be stable or will undergo oscillations.

Teaching Materials

Advice on suitable background reading will be given in lectures.

It is expected that one or two revision lectures will be given in the Easter Term, depending on demand.

Unit

Interface Engineering

Level	***Term***	***Duration***
CET IIB	LT 2022	16 lectures

Background

Interfaces exist everywhere in nature. Interfaces between solid, liquid and vapour phases have always been important in chemical engineering as chemical engineers have always worked with multi-phase systems. Interfaces are becoming increasingly important as more materials are manufactured with smaller scale features and in smaller devices. An understanding of interfacial phenomena means that surfaces can be designed to promote desired behaviours and new processes evaluated.

Aims

The aim of this module is to explain the principles involved with interfaces between two fluids, and between two fluids and a solid. The approach will be quantitative, in 1-D where possible, so that students can construct simple models of surface-tension driven phenomena. The focus will be on continuum phenomena. The relationship to nanoscience and current research topics will be flagged.

Learning Outcomes

On completing this course and the associated problem sheets, students should be able to tackle problems involving

- surface tension, surface energy, contact angle and spreading
- fluid statics, including the shape of interfaces and buoyancy/surface tension effects
- simple fluid flows with surface tension boundary conditions
- disturbances leading to instabilities (though not detailed perturbation analysis)
- the effect of surface structure and composition
- surfactants

Assumed Knowledge

Material	*Source*
Fluid mechanics	CET I and CET IIA
Thermodynamics	CET I and CET IIA
Equation solving, ODEs, integral calculus, 1 and 2D coordinates	Part IA

Connections To Other Units

Surface tension is mentioned in CET I Heat and Mass Transfer and CET IIA Reactors. The material covered in these lectures may complement other CET IIB modules.

Self Assessment

Three problem sheets will be provided with introductory problems as well as problems approaching Tripos level. Worked examples will be provided on Moodle, and the solutions to all three problem sheets are provided on Moodle.
Past examination papers: CET IIB: 2017 Paper B7, 2018 Paper B7, 2019 Paper B7

Assessment

The material from this unit is assessed by written examination.

Prepared	***Approved***	***Subject Grouping***
DiW 9/2021	AJS	Group B: Advanced Chemical Engineering Topics

Unit Interface Engineering	***Staff*** Professor D.I. Wilson

Synopsis

1 Introduction and basic concepts
- 1.1 Surface tension, surface energy and simple fluids
- 1.2 Wetting, contact lines and contact angles
- 1.3 Spreading

2 Surface tension in fluid mechanics
- 2.1 Governing equations for flow
- 2.2 Stress balance equations
- 2.3 Governing equations in dimensionless form
- 2.4 Curvature, κ

3 Static or quasi-static fluid applications
- 3.1 Simple menisci
- 3.1.1 Capillaries
- 3.1.2 Kelvin equation
- 3.2 Wetting of walls
  - 3.2.1 The long wall
  - 3.2.2 The Wilhelmy plate
  - 3.2.3 Partially immersed bodies
  - 3.2.4 Froth flotation
  - 3.2.5 Pilkington float glass process
- 3.3 Liquid bridges and cohesion
  - 3.3.1 Simple analysis of liquid bridges between particles
  - 3.3.2 Real liquid bridges
  - 3.3.3 Viscous forces in liquid bridges
  - 3.3.4 The science of sandcastles

4. Surface tension in flow
- 4.1 Rise in a capillary – the Washburn equation
- 4.2 The water bell
- 4.3 Droplet spreading
- 4.4 Jet breakup
  - 4.4.1 Cylindrical jet behaviour
  - 4.4.2 Region II: the Plateau-Rayleigh instability
  - 4.4.3 Rayleigh instability: formal treatment

5. Surfaces, surfactants and surface energies
- 5.1Thermodynamic origin of ELV
- 5.2 Surface energies of solids
- 5.3 Surface morphology
  - 5.3.1 Rough surfaces – the Wenzl model
  - 5.3.3 Contact line hysteresis and pinning
- 5.4. Surfactants
  - 5.4.1 Soluble surfactants: the Gibbs adsorption isotherm
  - 5.4.2 Insoluble surfactants
- 5.5 Marangoni forces and flows

Links to the questions on the examples papers will be provided in lectures.

Teaching Materials

Lecture notes are provided as a series of booklets and will be available on Moodle.

In 2020-21 the lectures will be delivered via the web and links will be available on Moodle.

Supervisions will be advertised by e-mail and sign-up sheets provided.

There is no set text for this module: books with relevant sections will be mentioned. Papers from journals will be referred to and copies will be put on Moodle if copyright allows.

Unit

Pharmaceutical Engineering

Level	*Term*	*Duration*
CET IIB	LT 2022	16 lectures

Background

The pharmaceutical industry contributes a key part to the UK economy and it stands out as one of the nation's largest manufacturing exporters. There are ample opportunities for chemical engineers to contribute their expertise in this sector. The industry is a major energy consumer and manufacturing practice sometimes lags behind other process industries (such as food) even though product quality is critical.

Aims

This course aims to give students an understanding of the fundamentals of pharmaceutical engineering. It introduces the subject and builds on established concepts from general chemical engineering to highlight specific applications and requirements of this industrial sector.

Learning Outcomes

On completing this course and the associated problem sheets, students should be able to:

- Understand the complex requirements set by pharmacological efficacy, formulation, primary and secondary manufacturing as well as the regulatory framework that govern this global industry
- Have an appreciation for the cultural differences between the R&D and manufacturing environments
- Understand the different type of dosage forms manufactured by the industry (solids, semi-solids and liquids)
- Know the major unit operations currently in place for batch production
- Understand the barriers that prevent further improvements to the quality of medicines using present manufacturing technologies
- Understand the state of the art in the drive towards continuous production, quality-by-design and process analytical technology

Assumed Knowledge

Material	*Source*
Chemical thermodynamics; reaction kinetics	CET I and CET IIA
Heat and mass transfer	CET I

Connections To Other Units

Pharmaceutical engineering is an extension to the general chemical engineering principles that the students have become familiarised with throughout CET I and IIA.

Self Assessment

Problem sheets will be issued during the lectures.
This course was taught for the first time in 2015-16. Past exam papesrs:
CET IIB 2016-19 Paper B3.

Assessment

The material from this unit is assessed by written examination.

Prepared	*Approved*	*Subject Grouping*
JAZ 9/2021	AJS	Group B: Advanced Chemical Engineering Topics

Unit	***Staff***
Pharmaceutical Engineering	Professor J.A. Zeitler

Synopsis

1) The Pharmaceutical Industry
2) Design of Solid Dosage Forms
   a. Physicochemical properties
   b. Pharmacokinetics
3) Immediate Release Tablets
   a. Formulation
   b. Processing
4) Current Trends in Pharmaceutical Processing
   a. Quality by Design (QbD)
   b. Multivariate Analysis
   c. Process Analytical Technology (PAT)
   d. Microstructure Engineering
   e. Continuous Manufacturing
      - Real time release testing
      - Regulatory requirements
      - Example of continuous process
      - Advanced process control
5) Modified Release Technology
   a. Concepts
   b. Drug Release Behaviors
      - Diffusion barriers
      - Matrix technology
      - Osmotic drug delivery control
   c. Processing
      - Tablet film coating
      - Extrusion and spheronisation
      - Pellet film coating
6) Outlook
   a. Other Dosage Forms
   b. Personalised Medicine

Teaching Materials

The following textbooks are useful:

- D.J. am Ende (ed.), “Chemical Engineering in the Pharmaceutical Industry”, Wiley, 2011.
- M.E. Aulton and K.M.G. Taylor (eds.), “Aulton's Pharmaceutics”, Elsevier, 4th ed., 2013.
- P.J. Sinko (ed.), “Martin's Physical Pharmacy and Pharmaceutical Sciences”, Wolters Kluwer, 6th ed., 2011.
- Y. Qiu *et al.* (eds.), “Developing Solid Oral Dosage Forms”, Academic, 2009.

Unit

Adsorption and advanced nanoporous materials

Level	*Term*	*Duration*
CET IIB	MT 2021	16 lectures

Background

Traditional materials such as zeolites and activated carbons have been used for decades in industrial applications. Their main applications are related to adsorption (storage and separation of molecules) and catalysis. Besides, the more recent developments in materials science, synthetic chemistry and chemical engineering allow for the design and manufacture of new families of porous materials such as metal-organic frameworks.

Aims

This unit aims to provide chemical engineer students with a better understanding of the fundamental knowledge on adsorption processes and catalysis, and how they are modelled in chemical industries. It involves the understanding of different adsorption theories and equations for single- and multi-component gases. It also brings the novelties of these fields in terms of materials properties and industrial applications.

Learning Outcomes

On completing this course, the students should be able to:

- demonstrate familiarity with adsorption and porosity terminology;
- identify and describe the main characteristics of different adsorption phenomena based on the properties of different porous materials;
- learn about the techniques and challenges involved in the evaluation of porosity in terms of adsorption performance and surface area;
- develop the capability to model adsorption processes using different adsorption theories;
- estimate and calculate the performance of porous materials in adsorption applications, including total adsorption capacity and selectivity;
- demonstrate an understanding of different properties of porous materials in adsorption and catalytic applications;
- understand a variety of industrial processes where porous materials can be employed, including carbon capture, hydrogen economy and drug delivery MOFs and how porous materials are evaluated.

Assumed Knowledge

Material	*Source*
Basic principles of chemical engineering	CET I Introductory chemical engineering
Absorption and distillation processes	CET I Separations
	CET IIA Separation processes 2
Basic principles of materials science	CET IIA Corrosion and materials
Equilibrium thermodynamics	CET IIA Equilibrium thermodynamics
Basic adsorption	CET IIA Heterogeneous Reactors

Connections To Other Units

This unit builds on the separation lectures and equilibrium thermodynamics from CET I Separations, CE processes 2 and CET IIA Equilibrium thermodynamics

Self Assessment

Three problem sheets will be issued based on isotherm fitting calculations for single component and mixtures.

Assessment

The material in this unit is assessed by coursework, including two assessment on the use of numerical modelling of gas adsorption isotherms using different adsorption theories and a literature review on specific topics.

Prepared	*Approved*	*Subject Grouping*
DFJ 9/21	AJS	

Unit	***Staff***
Adsorption and advanced nanoporous materials	Dr D. Fairen-Jimenez

Synopsis

Section 1: adsorption

The unit will start with a brief review of the adsorption phenomena and in particular adsorption in porous materials and will include a clarification of the main terminology and the principal definitions.

The differences between absorption and adsorption, physisorption, and chemisorption will be described, followed by an explanation of the main forces that cause adsorption. It will provide a description of the fundamentals of adsorption, with an introduction about the classification of adsorption isotherms based on their performance and characteristics including the classification of the porosity of materials based on size.

Section 2: porous materials

The unit will bring a description of nanoporous materials such as activated carbons, zeolites, metal-organic frameworks (MOFs) and porous coordination polymers (PCPs). It will go about their history and will bring a state-of-the-art description of their properties of interest. It will cover some of their advances in synthesis.

Section 3: adsorption theory

The unit will provide a detailed description of how gas adsorption is used for porous materials characterization, giving a detailed description of typical methods employed. It will go through the different adsorption theories, including Polanyi and Langmuir, and will move to the modelling of adsorption phenomena using BET, Horwath-Kawazoe, t-plot, BJH, and DFT models. This will include some examples of calculations in different adsorption isotherms.

Section 4: high-pressure gas adsorption

The importance of gas adsorption theory to evaluate the performance of porous materials will be evaluated. This includes questions about how to perform high-pressure adsorption in single component and mixtures and the main issues found in the process. This will be related to pressure swing and temperature swing adsorption processes generally applied in industry.

Section 5: novel porous materials

The importance of new properties found in porous materials will be explored, including high porosity materials, unsaturated metal centres, and flexibility.

Section 6: industrial applications of porous materials

Gas and liquid-phase adsorption applications will be discussed, including carbon capture, hydrogen adsorption and drug delivery processes.

Teaching Materials

- Rouquerol, Rouquerol and Sing, Adsorption by Powders and Porous Solids, Academic Press, 1999.

Unit

Fluid Mechanics and the Environment

Level	***Term***	***Duration***
CET IIB	MT 2021	16 lectures

Background

Fluid mechanics is central to chemical engineering. Chemical engineers are concerned with flows in industrial processes and also in the natural environment. Examples of the latter include the discharge of gaseous effluents from chimneys, the accidental release of chemicals into the ocean or atmosphere, the motion of pollutants in soil and the flow of stored carbon dioxide in porous rocks. As fluids flow in the environment, their physical properties are altered, they are mixed or separated, and they take part in chemical reactions. Both natural and human-induced flows have a large impact on the Earth. In this course, we introduce the fundamentals needed to describe and quantify such flows.

Aims

The aim is to cover the fundamental fluid mechanics principles to enable the solution of laminar and turbulent environmental flows.

Learning Outcomes

On completing this course and the associated problem sheets, students should be able to:

- analyse and solve problems concerning inert and reactive flows arising from localized, instantaneous discharges in the ocean and atmosphere
- analyse and solve problems concerning the inert and reactive transport of chemicals in porous media

Assumed Knowledge

Material	*Source*
Basic fluid mechanics	CET I Fluid Mechanics
Navier-Stokes equation	CET IIA Fluid Mechanics
ODEs and PDEs	CET I Mathematics, CET IIA Mathematics

Connections To Other Units

This unit builds on previous fluid mechanics options. It may complement other CET IIB options.

Self Assessment

Two examples sheets will be issued during lectures.
The following examination papers indicate the level of achievement expected:
CET IIB: 2017-21 Paper B6; 2015 Paper B4 ; 2014 Paper B5; 2013 Paper B5; 2012 Paper B4.

Assessment

The material from this unit is assessed by written examination.

Prepared	***Approved***	***Subject Grouping***
SSSC 7/7/2021	AJS	Group B: Advanced Chemical Engineering Topics

Unit	*Staff*
Fluid Mechanics and the Environment	Professor S.S.S. Cardoso

Synopsis

This course is divided into two parts, covering turbulent flows in the atmosphere and oceans, and laminar flows in porous rocks.

1 Turbulent flows in the atmosphere and oceans

2.1 Inert and reactive plumes
Turbulent plumes; dimensional analysis.
Equations of motion; entrainment; Gaussian profiles. Density stratification.
Multiphase plumes. Effects of chemical reaction and dissolution. BP oil plume in the Gulf of Mexico 2010.

2.2 Jets
Forced plumes and buoyant jets.
Characteristic length-scales.
Entrainment and rate of spreading.

2.3 Plumes and jets in nature and industry
Various examples of real flows. Solved example problems.

2.4 Inert and reactive thermals
Turbulent thermals; dimensional analysis.
Equations of motion; entrainment.
Effects of chemical reaction.
The Fukushima nuclear cloud 2010.

2 Laminar flows in porous rocks

2.1 Inert and reactive flows in porous media
Darcy’s equation.
Conservation of mass, chemical species and energy.
Examples of inert flows in the Earth’s sub-surface in 1-D, 2-D and 3-D geometries; Bessel functions.

2.2 Buoyant convection in a layer of fluid
Linear Stability Analysis. Base state. Perturbations. The Rayleigh number.
Minimum critical Rayleigh number for the onset of convection.
Climate change. Carbon dioxide sequestration in saline aquifers. Effects of geochemical reactions.

2.3 Buoyant plumes in fluid-saturated porous media
Boundary-layer approximations of the governing equations.
Velocity and temperature distributions in 2-D and 3-D plumes. Radius of the plume.
Flow under the seafloor: continental margin- and seep-plumes driven by thermal and solutal density differences.

2.4 Osmotic and buoyant flow
Osmosis in a porous medium. Solute size-restriction and other mechanisms. Kedem-Katchalsky equations. Derivation from kinetic theory, fluid mechanics and thermodynamics.
Flow near submarine mud-volcanoes: implications for methane-hydrate melting and climate change.

Teaching Materials
Recommended books

- D.J. Tritton “Physical Fluid Dynamics”, Oxford University Press, 2nd Edition 1988.
- J.S. Turner, “Buoyancy Effects in Fluids”, Cambridge University Press, 1973.
- P.F. Linden, “Convection in the environment”. In *Perspectives in Fluid Dynamics* (ed. G.K. Batchelor, H.K. Moffat & M.G. Worster), Cambridge University Press, 2000.
- D.L. Turcotte and G. Schubert “Geodynamics”, Cambridge University Press, 2nd Edition 2002.

Unit		
Electrochemical Engineering		
Level CET IIB	***Term*** MT 2021	***Duration*** 16 lectures

Background

There are a range of applications in which knowledge of electrochemical engineering principles is important. These include electrochemical power sources such as fuel cells and solar cells. These have near-zero carbon dioxide emissions and so offer an important alternative to power sources derived from fossil fuels.

Aims

This course aims to provide a fundamental understanding of the issues which control electrolysis and electrochemical reactions. Particular emphasis is given to electrochemical methods of power generation (fuel cells and solar cells), but other applications will also be considered.

Learning Outcomes

On completing this course and the associated problem sheets, students should be able to:

- describe and apply the physical and chemical mechanisms which control the efficiency of electrolysis electrochemical reactions
- derive the Butler-Volmer equation relating the current/voltage relationship for classical electrolysis reactions
- use Tafel analysis for the calculation of electrolysis reaction parameters such as charge transfer kinetics
- explain and predict the voltammetric characteristics of a range of electron transfer and coupled electron transfer/chemical reactions
- predict the electrochemical impedance response of electrolytic cells under a range of operating conditions
- describe and evaluate the current status of fuel and solar cell developments

Assumed Knowledge

Material	*Source*
Mass transport and reaction kinetics	CET I and CET IIA

Connections To Other Units

The course builds on the concepts introduced throughout the chemical engineering course. A typical electrolysis reaction requires an understanding of transport via diffusion, electrical migration etc., the chemical reactivity of species in solution, along with the thermodynamics and kinetics associated with electrically driven reactions.

Self Assessment

A set of example questions will be issued during the course.
The following examination papers indicate the level of achievement expected:
CET IIB: 2015 Paper B3; 2013-14 Paper B4; 2011-2012 Paper B3 ; 2010 Paper B4 ; 2009 Paper 5 ; 2008 Paper 6

Assessment

The material from this unit is assessed by written examination.

Prepared	***Approved***	***Subject Grouping***
HCSS 9/2021	AJS	Group B: Advanced Chemical Engineering Topics

Unit	***Staff***
Electrochem Eng	Dr A.C. Fisher

Synopsis

Fundamentals

- Introduction and overview of electrolysis
- Potential and thermodynamics of electrochemical cells
- Kinetics of electrode reactions
- Mass transfer in electrode processes
- Voltammetric methods
  - Potential step
  - Linear sweep
  - Cyclic voltammetry
- Electrical double layer
- Hydrodynamic devices
  - Rotating disc electrode
  - Dropping mercury electrode
  - Microfluidic devices
- Electrochemical impedance spectroscopy
- Digital simulation

Applications

- Power sources
  - Fuel cells
  - Solar cells
  - Batteries
- Electrochemical sensors
  - Gas sensors
  - Biosensors (glucose electrode etc.)
  - Ion selective electrodes
- Scanning probe techniques
  - High resolution imaging (STM etc.)
  - Scanning electrochemical microscopy
  - Nanoengineering of metallic surfaces

Teaching Materials

A suitable reference text is:
A.J. Bard and L.R. Faulkner, "Electrochemical Methods: Fundamentals and Applications", Wiley, 2nd ed. 2001.

Unit

Optical Microscopy

Level	*Term*	*Duration*
CET IIB	MT 2021	16 lectures

Background

The observation of microscopic processes is key to a huge number of scientific and industrial applications. Optical microscopy is one of the most widely used analytical techniques, used for material characterisation, quality control, chemical composition analysis, process analytics, DNA sequencing, observation of biomedical processes, etc.

Aims

The aim of this unit is to develop an understanding of the principles underlying state-of-the-art optical measurement techniques used for microscopy and to describe several key technologies and applications that are used in industry and research.

Learning Outcomes

On completing this course and the associated problem sheets, students should be able to:

- understand fundamental principles of image formation in different modes of light microscopy.
- understand the physical concepts that affect image resolution and contrast.
- design conceptually advanced microscopy instrumentation that achieves the required sensitivityand resolution for a given application.
- analyse image data correctly and quantitatively in the presence of noise.
- understand the underlying technology of advanced microscope instrumentation.
- provide real world examples of modern microscopy technologies used in research and industry.

Assumed Knowledge

Material	*Source*
Basic mathematics	Part IA, CET I
Basic spectroscopy	Part IA Chemistry or CET I Analytical Chemistry

Connections To Other Units

Self Assessment

Two problem sheets will be issued during the course.
This course was first introduced in 2014-15.
Past examination papers: CET IIB 2016-20 Paper C1 ; 2015 Paper B5.
Some examination questions on a related former course are useful: CET IIB: 2013 Paper B6 Q2(a) and (b); 2008 Paper B7 Q1(a); 2006 Paper B6 Q3
Note that course content changes from year to year, and parts taught previously, may not be covered in the current course.

Assessment

The material from this module will be assessed by written examination.

Prepared	*Approved*	*Subject Grouping*
HCSS 9/2021	AJS	Group C: Broadening Topics

Unit	**Staff**
Optical Microscopy	Prof. C.F. Kaminski

Synopsis

Fundamental Background

- A brief history of the microscope
- Concepts of image formation
- Mathematical background: the Fourier transform (and its importance for image formation and resolution)
- The problem of optical diffraction and its effect on image resolution: Point spread andoptical transfer functions
- Microscope resolution, contrast and sensitivity
- Interrogating molecules: light absorption, emission, and scattering
- The technology: lasers, lenses, cameras, and all that

Basic Microscopy techniques

- Brightfield microscopy
- Fluorescence microscopy: Obtaining chemical specificity
- Coherent and incoherent imaging
- Improving image contrast: Confocal microscopy

Sample preparation techniques

- Synthetic fluorophores
- Fluorescent proteins, antibodies, and labelling of biological samples.

Advanced Techniques

- Imaging the molecular environment: Fluorescence lifetime microscopy and polarisationresolved imaging.
- Detecting single molecules
- Optical super-resolution techniques: resolving objects smaller than the wavelength of light

Image processing techniques

- Deconvolution of image noise
- Contrast enhancement techniques
- Object identification and tracking

Applications

- Microscopy for chemical detection and process control
- Gene sequencing
- Imaging in living systems and uncovering molecular mechanisms of disease
- Imaging whole organisms

Teaching Materials

No book covers the course material exactly; most books are either too basic or too advanced for the purpose of this course. However the following are outstanding web resources that illustrate aspects of thecourse. They contain interactive Java tutorials which allow you to see different modes of imaging and to explore physical concepts:

- The *optical microscopy primer* website: http://micro.magnet.fsu.edu/primer/index.html
- The *microscopyu* website: http://www.microscopyu.com/

Unit

Healthcare Biotechnology

Level	*Term*	*Duration*
CET IIB	LT 2022	16 hours lectures + workshops

Background

Healthcare is the diagnosis, treatment, and prevention of disease, illness, injury, and other physical and mental impairments in humans. It is regarded as an important determinant in promoting the general health and well-being of the world's population and can form a significant part of a country's economy, with costs in the range 10-16% of GDP in OECD countries. Healthcare accounts for ~65% of current R&D spending in biotechnology.

Aims

This course aims to lay a foundation in the prevalence, pathologies, diagnosis and treatment of the major diseases afflicting humans in the 21st century. The course will cover the challenges encountered in drug discovery and development, drug delivery, regulation and the newer approaches involving gene, protein, cell-based and bionic therapies. Key developments for the future, including stratified and personalised medicine and digital health applications will also be discussed.

Learning Outcomes

On completion of this course and associated problem sheets, students should be able to:

- Demonstrate an understanding of the major healthcare challenges in the 21st century and their impact on society.
- Understand the threat of newly emerging and re-emerging infectious diseases on established and emerging economies.
- Show an ability to evaluate healthcare drivers, threads and applications. Students should be able to calculate disease incidence and prevalence and acquire knowledge on fundamental health economics.
- Appreciate the value of biomarker discovery in diagnostic, prognostic and personalized medicine. Students should be able to suggest appropriate biomarker strategies for healthcare applications such as diagnosis and drug discovery; students should be able to calculate sensitivity and specificity of a test or intervention.
- Demonstrate an understanding of the drug discovery stages and clinical trial phases within the pharmaceutical industry; students should be able to evaluate clinical trial designs and comment on the advantages and limitations of a given design.
- Define the potential and current limitations in regenerative and bionic medicines
- Appreciate digital health applications and their potential impact on society in terms of Big Data applications for healthcare provision.

Assumed Knowledge

This course will assume some basic biology gained in CET I Biotechnology and CET IIA Bioprocessing.

Connections To Other Units

This course is independent of other units.

Self Assessment

Students will be able to assess their progress through interaction with staff giving the course and through feedback gained from presenting their analyses to the class and through workshops.

Assessment

This course is assessed entirely by coursework (group oral presentations and individual written essays). The essay will be an extended piece of work on some relevant aspect of healthcare biotechnology. Students will be expected to synthesise knowledge from across the course.

Prepared	*Approved*	*Subject Grouping*
SB 7/2021	AJS	Group C: Broadening Topics

Unit	*Staff*
Healthcare Biotech	Prof. S. Bahn

Synopsis

1. Healthcare challenges in the 21st century
2. Introduction to healthcarebiotechnology
3. Introduction to healthcare biotechnology (continued)
4. Newly emerging and re-emerging infectious diseases
5. Neurodegenerative and neuropsychiatric disorders
6. Neurodegenerative and neuropsychiatric disorders (continued)
7. Cancer pathology and diagnosis
8. Biomarker technologies for increasing our understanding of major diseases and their clinical application
9. Biomarker technologies for increasing our understanding of major diseases and their clinical application (continued)
10. Drug discovery and pharma industry
11. Drug discovery (continued)
12. Digital Health
13. Digital Health (continued)
14. Workshop: Group work; Biomarker applications for personalized medicine approaches; ~3 hours presentations

Some lectures/topics may change.

Teaching Materials

Lecture notes lists will be provided and posted on Moodle.

Unit

Biophysics

Level	*Term*	*Duration*
CET IIB	MT 2021	16 lectures

Background

Modelling biological systems is essential for applications of engineering and bioscience to develop products from biological cells and systems. The future Healthcare, Food and Energy sectors will rely heavily on these skills, and thus the course will be invaluable for future Chemical Engineers.

Aims

To understand how to model biological systems and make them amenable for quantitative exploitation.

Learning Outcomes

On completing this course and the associated problem sheets, students should be able to:

- appreciate various biological processes at a molecular, cellular and tissue level
- have an overview of quantitative biology
- apply various modelling approaches, including the basics of numerical methods in biological physics
- apply basic concepts involving thermal and statistical physics in living systems
- understand the basic concepts of biomolecules as two state systems, e.g. on/off states
- understand the principle behind various biophysical techniques such as atomic force microscopy, NMR, optical tweezers etc.
- understand the basic principles behind various optical techniques, such as super-resolution, Foerster resonance transfer-based microscopy techniques
- understand the principles behind DNA origami and nanofabrication

Assumed Knowledge

Material	*Source*
Biological concepts	CET I Biotechnology

Connections To Other Units

The material in this unit may complement other CET IIB options.

Self Assessment

Three examples sheets will be issued during lectures.
Past examination paper:
CET IIB 2017 Paper
C8. CET IIB 2018
Paper C8
CET IIB 2019 Paper C8

Assessment

The material from this unit is assessed by written examination;

Prepared	*Approved*	*Subject Grouping*
GSK 9/2021	AJS	Group C: Broadening Topics

Unit	Staff
Biophysics	Dr G.S. Kaminski Schierle

Synopsis

1. Introduction
2. Quantitative Biology
   - Demonstration on how diverse aspects of living systems are underpinned by the physics of complex systems.
   - Modelling based on physical principles to complement experimental investigations.
   - Overview of quantitative cell biology including primer lectures on cell biology for chemical engineers.
3. Energy balance of Living Systems
   - Examination of life from a biophysicist's perspective and application of some thermal andstatistical models for living systems with examples ranging from motor proteins to cooperative binding.
   - Impact of energy balance on protein folding/misfolding, on determining the structure function relationship of proteins, on molecular motors, etc.
4. Biophysical Techniques
   - Introduction to various biophysical techniques such as atomic force microscopy, NMR, transmission electron microscopy, mass spectrometry, etc.
   - Specific applications of the various techniques in living systems will be discussed.
5. Optical Techniques
   - A brief introduction to various optical techniques (super-resolution microscopy, optical tweezer, Foerster resonance energy transfer etc.) will be given and their application in living systems willbe discussed
6. DNA origami and nanofabrication
   - How biological systems can be exploited to produce nanostructures, such as DNA origami and how nanofabrication, such as lab-on-chips can be exploited to study living organisms in a fully controlled environment.

Teaching Materials

The recommended textbook is:
- R. Phillips, J. Kondev, J. Theriot and H.G. Garcia, "Physical Biology of the Cell", Garland Science, 2nd ed. 2013.

A suitable reference textbook on cell biology is
- B. Alberts *et al.*, "Molecular Biology of the Cell", Garland Science, 6th ed. 2014.

Unit

Biosensors and Bioelectronics

Level	*Term*	*Duration*
CET IIB	LT 2022	16 lectures + lab

Background

The teaching of this unit is shared between the Department of Chemical Engineering and Biotechnology (CEB) and the Department of Engineering (CUED. The course covers the principles, technologies, methods and applications of biosensors and bioelectronics.

Aims

The objective of this course is to link engineering principles to understand biosystems in sensors and bioelectronics. It will provide details of methods and procedures used in the design, fabrication and application of biosensors and bioelectronic devices.

Learning Outcomes

On completing this course students should be able to:

- extend principles of engineering to the development of biosensors and bioelectronic devices.
- understand the principles of signal transduction between biology and electronics.
- appreciate the basic configuration and distinction among biosensors and bioelectronic systems.
- demonstrate appreciation for the technical limits of performance.
- make design and selection decisions in response to measurement and actuation problems amenable to the use of biosensors and bioelectronic devices.
- be able to evaluate novel trends in the field.

Assumed Knowledge

Material	*Source*

No previous knowledge of biosensors is required.

Connections To Other Units

Self Assessment

Assessment

The material from this unit is assessed by coursework.

There will be two marked assignments. The first will involve a laboratory session illustrating the functional demonstration of glucose sensor technology. The second assignment will involve a laboratory session illustrating the principles of electrophysiology applied to bioelectronic devices.

Prepared	*Approved*	*Subject Grouping*
EAHH/GGM 9/2021	AJS	Group C: Broadening Topics

Unit	***Staff***
Biosensors and Bioelectronics	Profs G.G. Malliaras (Engineering) and E.A.H. Hall (CEB)

Synopsis

Introduction to Biosensors

- Overview of Biosensors
- Fundamental elements of biosensor devices
- Engineering sensor proteins

Electrochemical Biosensors

- Electrochemical principles
- Amperometric biosensors and charge transfer pathways in enzymes
- Glucose biosensors
- Engineering electrochemical biosensors

Optical Biosensors

- Optics for biosensors
- Attenuated total reflection systems

Diagnostics for the real world

- Communication and tracking in health monitoring
- Detection in resource limited settings

Introduction to bioelectronics

- Overview of technology (implantable, cutaneous, ex vivo)
- Anatomy, function of nervous system, other electrically active tissues
- Principles of electrophysiology
- Recording and stimulation (intracellular, extracellular, epidural, EEG)
- Transducers (pipette electrodes, Ag/AgCl, metal electrodes, Michigan and Utah probes, transistors)

Implantable devices

- Cardiac pacemaker
- Cochlear implant, retinal implant
- DBS (Parkinson’s, dystonia, epilepsy), spinal cord stimulators
- Brain-Computer Interfaces
- PNS stimulators, electroceuticals
- Implantable drug delivery systems
- Foreign body reaction

Wearable devices

- Cutaneous electrophysiology (brain, heart, muscle)
- Electronic skins (pressure, temperature)
- Sweat biosensing (glucose, lactate, …)
- Transdermal drug delivery

Ex vivo devices

- Electrochemical biosensors
- Impedance biosensors
- MEAs and patch clamp
- Organ-on-a-chip
- In vitro systems

Regulatory & Ethical issues

Teaching Materials

References will be supplied in lectures.

Unit		
Foreign Language		
Level CET IIB	***Term*** MT 2021 / LT 2022	***Duration*** 15 × 2 hour sessions

Background

Knowledge of a foreign language can be very useful for chemical engineers. The Centre for Languages and Inter-Communication (CLIC) within the Engineering Department offers courses in French, German, Spanish, Chinese and Japanese at beginner level, intermediate level and advanced level.

Aims

- To develop the main language skills (listening, speaking, reading and writing)
- To develop an understanding of grammar and lexis of the target language
- To develop a positive and confident attitude towards language learning
- To develop cultural understanding

The courses are aimed specifically at engineering students and may include some technical content.

Learning Outcomes

The specific outcomes vary according to the level.

Assumed Knowledge

- Beginner level: none.
- Intermediate level: roughly the equivalent of GCSE. There are three stages within this level according to proficiency.
- Advanced level: roughly the equivalent of AS and A level. There are two stages within this level according to proficiency.

Connections To Other Units

None.

Self Assessment

Students will be able to assess their progress by submitting homework as part of their portfolio. They will also be able to practise and improve their language skills by using CLIC's teaching resources, including those on Moodle.

Assessment

Listening, speaking, reading and writing skills are assessed, either continuously or in an exam at the end of Lent Term. Further details are on the CLIC's website.

Prepared	*Approved*	*Subject Grouping*
DT 7/9/2021	AJS	

Unit	***Staff***
Languages	D. Tual (Dept of Engineering Centre for Languages and Inter-Communication)

Synopsis

The following languages are available at Beginner, Intermediate and Advanced levels of study:

- French
- German
- Spanish
- Chinese
- Japanese

Further information can be found on CLIC's website at: https://www.clic.eng.cam.ac.uk/

Chemical engineers are only permitted to choose one language (at one level).

Teaching Materials

A list of useful resources will be provided.

Unit		
Research Project		
Level CET IIB	***Term*** MT 2021; LT start of ET 2022	***Duration*** MT to week 3 of ET

Background

Chemical engineers are often involved with research. Fundamental research includes understanding scientific principles, developing new experimental methods, and developing new computational methods. Applied research includes developing an innovative process, measuring parameters or modelling an existing process with a view to improving it, and developing a new product.

Aims

The aim is for students to develop research skills and experience the trials, tribulations and satisfactions of original research. This helps qualify students, in part, to undertake, commission or supervise such work.

Learning Outcomes

The learning outcomes will vary from project to project.

For most projects, students should be able to:

- assess the risks associated with the research
- perform work safely and complete relevant safety documentation
- extract relevant information from the scientific literature
- design experiments and/or write computer programs
- perform experimental work and/or perform computational simulations
- analyse experimental data and/or modelling results
- work as part of a team
- present work by oral presentation and poster
- write a dissertation on the project

Assumed Knowledge

Material	*Source*

This will vary from project to project.

Connections To Other Units

Students are recommended to attend any CET IIB modules that are directly related to their research project. Some research projects will have no direct connection to units within the Chemical Engineering Tripos.

Self Assessment

Students have weekly meetings with their supervisor to discuss progress.

Assessment

The material from this unit is assessed principally by written dissertation, with a small mark contribution from oral presentation and poster.

Prepared	***Approved***	***Subject Grouping***
JS 09/2021	AJS	Group D: Research Project

Unit	***Staff***
Research Project	Dr Joanna Stasiak (coordinator)

Synopsis

Each student undertakes a major project, usually in collaboration with another student, supervised by a member of academic staff. Students should meet with their academic supervisor weekly to discuss progress and future work. The supervisor may allocate one or more mentors, such as PhD students or post-doctoral workers, to assist with the day-to-day running of the project.

All students undertake a safety training course at the start of Michaelmas Term.

Students are expected to spend 10 hours per week in Michaelmas Term and Lent Term on the research project. Students may choose to work more hours on the project than this minimum, but should be aware that they need to strike a balance between work on the research project and on other elements of the course. Members of academic staff have been informed of this fact.

Students are expected to perform additional work over the vacations (e.g. data analysis, report writing), but are not normally expected to perform laboratory work during the vacation.

Students give a 6-minute oral presentation and a poster presentation on their project towards the end of Lent term.

Students submit a dissertation (maximum length of 40 pages) on their project in Easter term. The dissertations are marked independently by two Examiners.

Teaching Materials

This will vary from project to project.

Companies in the Teaching Consortium supporting undergraduate teaching in Chemical Engineering and Biotechnology 2021-22