COURSE CONTENT

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>AY2018/19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>1</td>
</tr>
<tr>
<td>Course Coordinator</td>
<td>Teoh Swee Hin</td>
</tr>
<tr>
<td>Course Code</td>
<td>BG0491 / CH0491</td>
</tr>
<tr>
<td>Course Title</td>
<td>Engineers &amp; Society</td>
</tr>
<tr>
<td>Study Year (if applicable)</td>
<td>3</td>
</tr>
<tr>
<td>Pre-requisites</td>
<td>Nil</td>
</tr>
<tr>
<td>No of AUs</td>
<td>3</td>
</tr>
<tr>
<td>Contact Hours</td>
<td>Lecture: 26 hrs; Tutorial: 13 hr; Lab: 0 hr.</td>
</tr>
<tr>
<td>Proposal Date</td>
<td>16 Jan 2018</td>
</tr>
</tbody>
</table>

Course Aims

This course aims to provide a general understanding of the society we live in and the engineers’ roles and responsibilities towards society’s well-being. The course is part of broadening education objective in the engineering curriculum. The course covers a wide range of topics including history, political, social and economic development, foreign policy and defence of Singapore and the issues confronting it, the history of engineering, engineering ethics and practices, international politics and globalization and contributions by engineers towards society. The students will have a holistic understanding of Singapore’s past and present situation and on the impact of industry to the society.

Intended Learning Outcomes (ILO)

By the end of this course, you would be able to:

1. Identify how Singapore transited from being a 3rd World to 1st country and lessons to be learnt
2. Illustrate the role engineers play in the development of Singapore and future challenges
3. Interpret the significance of professional ethics,
4. Interpret the significance of engineering practice in safety and sustainability, and
5. Evaluate the significance of globalization and impact of industry to the society

Course Content

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hrs</th>
<th>Tutorial Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-independence history of Singapore</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Social and political development issues</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Economic and industrial development issues</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>National cohesion and total defence</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>History of engineering</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Engineering ethics</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Engineering practice in Singapore (WSH and sustainability)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Our neighbours and international relations</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Challenges of globalization and the new economy</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Contribution of engineers in the new economy 2 1
Impact of industry to the society (by external speakers) 2 1
Total: 26 13

Assessment (includes both continuous and summative assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested</th>
<th>Related Programme LO or Graduate Attributes</th>
<th>Weightage</th>
<th>Team/ Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Final Examination</td>
<td>1, 2, 3, 4, 5</td>
<td>EAB SLOs (f), (g), (h) and (l)</td>
<td>60%</td>
<td>Individual</td>
<td>Refer to Appendix 1</td>
</tr>
<tr>
<td>2 Continuous Assessment (CA): Presentation</td>
<td>1, 2, 3, 4, 5</td>
<td>EAB SLOs (f), (g), (h) and (l)</td>
<td>40%</td>
<td>Team</td>
<td>Refer to Appendix 1</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* EAB Student Learning Outcomes (12 points)


(f) The engineer and Society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

(g) Environment and Sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.

(h) Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

(l) Life-long Learning: Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Formative feedback

Upon finishing your presentation with Q&A, you will receive feedback on whether you have covered sufficiently with facts/contents, challenges faced/caused/overcome, and going forward with takeaways.

Learning and Teaching approach

Class meets once per week over 2 hours in lecture format and 1 hour in tutorial format for classroom presentation

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>outcomes?</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td></td>
</tr>
<tr>
<td>Formal lectures on the topics with in-class discussions</td>
<td></td>
</tr>
<tr>
<td>Team presentation</td>
<td></td>
</tr>
<tr>
<td>This helps you to achieve one or more of the outcomes, as you need to do self-study, research, and then make classroom presentation.</td>
<td></td>
</tr>
<tr>
<td>(The class is split into 6 presentation teams. Two groups will make presentation with Q&amp;A in each week. You will be grouped into 3-5 students per team.)</td>
<td></td>
</tr>
</tbody>
</table>

**Reading and References**

References:
5. Lee Kuan Yew: hard truths to keep Singapore going / Han Fook Kwang / et al. Singapore: Straits Times. (DS610.73.L46L478KY + 1 DVD)

**Course Policies and Student Responsibilities**

1. General
   Students are expected to make presentations on all assigned projects and attend all tutorial classes punctually. Students are expected to participate in the Q&A sessions of all the presentations.

2. Absenteeism
   The course requires you to attend all tutorial classes to participate in the Q&A sessions of all the presentations. Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU’s approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class presentation activities.

**Academic Integrity**

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are
at the core of NTU’s shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Lum Kit Meng</td>
<td>N1-01b-52</td>
<td>6790 5318</td>
<td><a href="mailto:ckmlum@ntu.edu.sg">ckmlum@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Dr Chew Ah Seng, David</td>
<td>N1-01b-48</td>
<td>6790 5300</td>
<td><a href="mailto:caschew@ntu.edu.sg">caschew@ntu.edu.sg</a></td>
</tr>
</tbody>
</table>

Planned Weekly Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture</th>
<th>Course LO</th>
<th>Tutorial</th>
<th>Course LO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>History of engineering</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Pre-independence history of Singapore</td>
<td>1</td>
<td>Briefing on presentation</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Social and political development issues</td>
<td>1</td>
<td>Consultation on presentation</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Engineering ethics</td>
<td>3</td>
<td>Presentation – Series 1</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>5</td>
<td>Engineering ethics (examples)</td>
<td>3</td>
<td>Presentation – Series 1</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>6</td>
<td>Engineering practice in Singapore (WSH)</td>
<td>4</td>
<td>Presentation – Series 1</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>7</td>
<td>Engineering practice in Singapore (sustainability)</td>
<td>4</td>
<td>Presentation – Series 2</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>8</td>
<td>Economic and industrial development issues</td>
<td>5</td>
<td>Presentation – Series 2</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>9</td>
<td>National cohesion and total defence</td>
<td>1</td>
<td>Presentation – Series 2</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>10</td>
<td>Our neighbours and international relations</td>
<td>1</td>
<td>Presentation – Series 3</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>11</td>
<td>Challenges of globalization and the new economy</td>
<td>5</td>
<td>Presentation – Series 3</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>12</td>
<td>Contribution of engineers in the new economy</td>
<td>2</td>
<td>Presentation – Series 3</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>13</td>
<td>Impact of industry to the society (by external speakers)</td>
<td>5</td>
<td>Presentation – if needed</td>
<td>1, 2, 3, 4, 5</td>
</tr>
</tbody>
</table>

Appendix 1: Assessment Rubric
<table>
<thead>
<tr>
<th>Performance Indicators/ Course LO Tested</th>
<th>Below expectations: 1</th>
<th>Average, meet expectation: 2</th>
<th>Good: 3</th>
<th>Outstanding: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply workplace safety measures for protection of people and property/ LO 4</td>
<td>Unable to apply concepts applicable for workplace safety measures</td>
<td>Able to apply concepts applicable for workplace safety measures for one or two situations</td>
<td>Able to apply concepts applicable for workplace safety measures for some situations</td>
<td>Able to apply concepts applicable for workplace safety measures for most situations</td>
</tr>
<tr>
<td>Recognise the needs and the importance of life-long learning/ LO 1, 2, 5</td>
<td>Unable to recognise the needs and importance of life-long learning</td>
<td>Able to recognise the needs and importance of life-long learning for one or two situations</td>
<td>Able to recognise the needs and importance of life-long learning for some situations</td>
<td>Able to recognise the needs and importance of life-long learning for most situations</td>
</tr>
<tr>
<td>Adopt systems thinking for sustainable development/LO 4</td>
<td>Unable to adopt systems thinking for sustainable development</td>
<td>Able to adopt systems thinking for sustainable development for one or two situations</td>
<td>Able to adopt systems thinking for sustainable development for some situations</td>
<td>Able to adopt systems thinking for sustainable development for most situations</td>
</tr>
<tr>
<td>Comprehend engineering codes of ethics/ LO 3</td>
<td>Unable to comprehend the engineering codes of ethics</td>
<td>Able to comprehend one or two aspects of engineering codes of ethics</td>
<td>Able to comprehend some aspects of engineering codes of ethics</td>
<td>Able to comprehend the complete spectrum of engineering codes of ethics</td>
</tr>
<tr>
<td>Apply engineering codes of ethics to avoid conflicts/ LO 3</td>
<td>Unable to apply engineering codes of ethics to working life of an engineer</td>
<td>Able to apply engineering codes of ethics to one or two situations in the working life of an engineer</td>
<td>Able to apply engineering codes of ethics to some situations in the working life of an engineer</td>
<td>Able to apply engineering codes of ethics to all situations in the working life of an engineer</td>
</tr>
</tbody>
</table>
CH1102 Introduction to Chemical Engineering in the New Era (added since AY13/14 intake)

[Lectures: 13 hours; Pre-requisites: NIL; Academic Unit: 1]

Objectives

This course provides an overview of the chemical engineering profession in the new era. First, it gives an overview of careers in the traditional chemical engineering sector as well as in other emerging industries. Topics on petroleum, petrochemical, specialty chemical, pharmaceutical, biotechnology, advanced materials, electronics, energy, environment, management consulting, nanotechnology, and graduate school in business, law, medicine, and engineering will be covered. It also discusses the rationale for the curriculum, career paths, resume writing, oral/written communication skills, and ethics.

Student Learning Outcomes

Upon completion of this course, students should be:
1) Able to understand the wide range of opportunities for chemical engineers.
2) Able to explain the roles of chemical engineers to layman.
3) More interested in chemical engineering.
4) Excited about new opportunities in the non-traditional sectors for chemical engineers.
5) Able to prepare themselves for their desired industries and roles.

Course Assessment

Students will be assessed by:
   Course assessment (100%) - 1 Quiz (100%)

Textbooks/References

Nil.

Topics

1) Modern tools of chemical engineering
2) Petroleum Refinery
3) Petrochemical Industry
4) Chemical Industry
5) Pharmaceutical Industry
6) Biotechnology
7) Polymer
8) Electronics
9) Energy
10) Environmental
11) Computational and Modelling
CH1104 Materials and Energy Balance
[Lectures: 33 hours; Tutorials: 12 hours; Pre-requisites: nil; Academic Unit: 4]

Objectives
This subject focuses on the material and energy balances in chemical processes and lays the foundation in other chemical engineering subjects such as thermodynamics, unit operations, reaction kinetics, etc. It introduces the engineering approach to problem solving: Breaking a process down into its components, establishing the relations between known and unknown process variables, assembling the information needed to solve for the unknowns, and finally obtaining the solution using appropriate computational methods.

Student Learning Outcomes
Upon successful completion of this course, students will be able to:
1) Check the units in an equation for consistency and convert values between different unit systems.
2) Calculate process flow rates in mass, molar, and volumetric units given the appropriate process data.
3) Construct a flow chart from a written description of a process.
4) Balance material flow sheets incorporating multiple process units with recycle, purge, and bypass streams for processes without chemical reactions.
5) Balance a material flow sheet incorporating multiple process units, and recycle, purge, and bypass streams for reactive processes given extents of reaction and/or yield and selectivity data for the reactions.
6) Use the ideal gas law to calculate properties of pure gases and gas mixtures.
7) Estimate the properties of real gases/liquids using a non-ideal equations and compressibility chart.
8) Perform mass balance calculations for processes involving gas-liquid phases. Understand colligative properties (vapor pressure, boiling point and melting point) of solid-liquid systems.
9) Apply the first law of Thermodynamics and use it to perform energy balances on closed/open systems to calculate the changes in Energy/Work/Other system parameters.
10) Use the Property Tables of steam/humid air and other important molecules/systems.
11) Design the hypothetical paths for the computation of energy balance for steady state and transient state energy balances, in a system with phase changes and chemical reactions.
12) Learn & practice the commercial software in Energy Balances application.

Topics
1) Unit Conversion And Process Variable
2) Material Balance
3) Material Balance For Single And Multi-Phase Systems
4) Energy Balance
5) Energy Balance On Reactive/Transient Processes
6) Computer Simulation For Energy Balance
Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hours</th>
<th>Tutorial Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unit conversion and process variable</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>Material balance for physical process</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>Material balance for chemical processes</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>Material balance for single and multi-phase systems</td>
<td>6</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>Energy and energy balance</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>Balances on nonreactive processes</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>Balances on reactive processes</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>Balance on transient processes</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>33</td>
<td>12</td>
</tr>
</tbody>
</table>

Course Assessment

Students will be assessed on:

a) CA (40%)
   a. Class quiz on Mass balance (20%)
   b. Class quiz on Energy balance (20%)

b) Exams (60%): closed-book. 2.5 hours

Textbook


References

CH1105 Materials Science

[Lectures: 26hrs; Tutorials: 13hrs; Prerequisites: Nil; Academic Units: 3]

Objectives

Materials Science is an interdisciplinary field where the properties of materials are related to their structures at the atomic, microscopic and macroscopic levels. Understanding this relationship helps students to achieve the required combination of properties in a given material for specific functionalities and therefore applications. This is an introductory course where basic scientific concepts are evolved from fundamental physics and chemistry to the roles of atomic and micro/macrosopic structures on the properties of different types of materials. Important topics on functional properties such as metallic, semiconducting, optical, magnetic, thermal and mechanical properties are covered in greater detail. This course also includes the use of materials in Chemical and Biomolecular Engineering.

Student Learning Outcomes

At the end of the course, the student should be able to:

1) Understand the structures of materials including atomic structure, crystal structure, defects, phase diagrams of alloys, etc.
2) Know different types of material properties and their general testing and characterizing procedures.
3) Know different type of materials and their general properties.
4) Understand the relationship among structure, processing and properties.
5) Have a basic idea how to choose a material with required properties for a specific application especially in Chemical and Biomolecular Engineering.

Course Assessment

Students will be assessed by:

1) Final examination (60%)
2) Continuous assessment (40%)

Textbooks/References


Topics

1) Introduction
2) Bonding Between Atom
3) Crystal Structure
4) Defects And Diffusion
   1) Mechanical Properties Of Materials Elastic, Plastic Behaviour, Phases And Microstructures
   2) Functional Properties Of Materials
   3) Materials In Nanotechnology
CH1106 Engineering Mathematics A (combined into CH1107/1117 from AY2012/13)

[Lectures: 26 hours; Tutorials: 13 hours; Pre-requisites: NIL; Academic Unit: 3.0]

Objectives
To learn advanced engineering analysis in modeling, solutions of differential equations and linear algebra. After completing this course, the student will be able to apply the analytical tools learnt in this course to various engineering disciplines in the following years of study.

Student Learning Outcomes
At the end of this course, the student will be able to:

1) Model a simple system to obtain a first order ODE.
2) Solve linear and nonlinear first order ODEs
3) Solve second order linear homogeneous and nonhomogeneous ODE
4) Understand concept of linear independence.
5) Evaluate Taylor series and use it to find the approximate values of general functions.
6) Utilize Heaviside and Delta functions to model abrupt phenomena.
7) Solve initial value problems using the Laplace transform.
8) Calculate determinant and matrix inverse of higher order matrices.
9) Solve a system of linear algebraic equations using Gauss elimination.
10) Calculate eigenvalues and eigenvectors
11) Use eigenvalues and eigenvectors to solve 1st order linear systems

Course Assessment
Students will be assessed by:
1) Final examination (50%)
2) Tutorial assessment (50%)

Textbooks/References

Topics
1) Modeling, linear and nonlinear 1st order ODE
2) 2nd order ODE: linear homogeneous
3) 2nd order ODE: linear nonhomogeneous
4) 2nd order ODE: applications
5) Higher order ODE and series solutions
6) Laplace transforms, Heaviside, Delta functions
7) Linear algebra and eigenvalues/eigenvectors
8) System of linear first order ODE
CH1107/CH1117 Mathematics 2 (Combined with CH1106 Mathematics 1 from AY12/13 intake)

[Lectures: 39hrs; Tutorials: 13hrs; Pre-requisite: Nil; Academic Units: 4.0]

Objectives

This course aims to teach advanced engineering analysis in modelling, solutions of multiple integrals, vector calculus and ordinary differential equations (ODE). After completing this course, the student will be able to apply the analytical tools learnt in this course to various engineering disciplines in the following years of study.

Student Learning Outcomes

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

1) Model a simple system to obtain a first order ODE.
2) Solve linear and nonlinear first order ODEs
3) Solve second order linear homogeneous and nonhomogeneous ODE
4) Understand concept of linear independence.
5) Evaluate Taylor series and use it to find the approximate values of general functions.
6) Utilize Heaviside and Delta functions to model abrupt phenomena.
7) Solve initial value problems using the Laplace transform.
8) Solve a system of linear algebraic equations using Gauss elimination.
9) Use eigenvalues and eigenvectors to solve 1st order linear systems
10) Apply partial derivatives to evaluate directional derivatives, gradient vectors, tangent planes, etc.
11) Determine the extrema of functions of multiple variables and apply it to different practical maximization/minimization problems.
12) Perform multiple integration.
13) Apply multiple integration to evaluate areas, volumes, etc.
14) Apply vector algebra to solve geometry problems.
15) Perform line integral over given curves.
16) Apply surface integral to evaluate area of various surfaces, flux across given surface.

Course Assessment

Students will be assessed by:
1) Final examination (60%)
2) Continuous assessment (40%)

Textbooks/References


Topics

1) Modelling, linear and nonlinear 1st order ODE
2) 2nd order ODE: linear homogeneous
3) 2nd order ODE: linear nonhomogeneous
4) 2nd order ODE: applications
5) Higher order ODE and series solutions
6) Laplace transforms, Heaviside, Delta functions
7) Linear algebra and eigenvalues/eigenvectors
8) System of linear first order ODE
9) Partial differentiation and extrema of functions with multiple variables
10) Multiple integrals
11) Vector algebra and differential calculus
Vector integral calculus (line and surface integral)
CH1131 Biomolecular Engineering 1 (combined with CH2105 Biomolecular Engineering II from AY12/13 intake)

[Lectures: 39 hours; Tutorials: 0 hours; Pre-requisites: nil; Academic Unit: 4]

Objectives

Basic cell biology from molecular structure, gene regulation to protein function is presented from a chemical engineer's perspectives. This course is designed for students with an engineering background to learn the biological fundamentals of biotechnology. The course emphasizes conceptual appreciation of the molecular interplays, which is the basis of "chemical processes" in living systems. The objective of the course is to provide students with a comprehensive and concise overview of biological science with emphases on quantitative perspectives. The fundamental processes of life are analysed quantitatively with engineering principles.

Student Learning Outcomes

Upon successful completion of the course, students should be able to:

1) Understand the background of cellular systems
2) Understand various components of cellular systems
3) Understand various functions of cellular systems
4) Understand the interplay between chemical engineering and biotechnology

Course Assessment

Students will be assessed by:
1) Continuous Assessment (%) - 30%
2) Final examination (%) - 70%

Textbooks/References


Topics

1) Molecular Basis of Living Systems
2) Gene Structure and Expression
3) Biophysics of Proteins
4) Cellular Systems and Dynamics
5) Cellular Signalling and Functions
6) Engineering of Cellular Systems
CH1801 Chemical and Biomolecular Engineering Laboratory 1A

[Lectures: 0 hours; Tutorials: 0 hours; Pre-requisites: Nil; Academic Unit: 1]

Objectives

This laboratory course aims to provide practical applications to reinforce theories and concepts taught in chemical engineering, physical and analytical chemistry, biomolecular engineering, materials science.

Student Learning Outcomes

After completing this course, the student will be able to apply the concepts learnt in chemical engineering, physical and analytical chemistry, biomolecular engineering, and materials science in a more practical setting.

Course Assessment

Students will be assessed by:
- Continuous assessment (100%)

Textbooks/References

NIL

Topics

Experiments related to chemical engineering, physical and analytical chemistry, biomolecular engineering, materials science
CH1802 Chemical and Biomolecular Engineering Laboratory 1B

[Lectures: 0 hours; Tutorials: 0 hours; Pre-requisites: Nil; Academic Unit: 1]

Objectives

This laboratory course aims to provide practical applications to reinforce theories and concepts taught in chemical engineering, physical and analytical chemistry, biomolecular engineering, materials science.

Student Learning Outcomes

After completing this course, the student will be able to apply the concepts learnt in chemical engineering, physical and analytical chemistry, biomolecular engineering, and materials science in a more practical setting.

Student Assessment

Students will be assessed by:
- Continuous assessment (100%)

Textbooks/References

NIL

Topics

Experiments related to chemical engineering, physical and analytical chemistry, biomolecular engineering, materials science
COURSE CONTENT

Academic Year: 2018/19
Semester: 1
Course Coordinator: Paul Liu Wen
Course Code: CH2010
Course Title: Engineering Statistics
Pre-requisites: MH1810
No of AUs: 3
Contact Hours: 26 Lecture hours and 13 tutorial hours
Proposal Date: 23 Jan 2017

Course Aims
The objective of this course is to introduce the concept of statistics and probability in engineering. It helps students to obtain correct interpretation from data collected and construct models for performance prediction.

Intended Learning Outcomes (ILO)

Student will be able to:
1. Apply concepts of probability and probability distributions.
2. Identify the different type of statistical distributions (e.g., normal, and log-normal) and describe the typical phenomena of these distributions.
3. Apply the concepts of point and interval estimation.
4. Apply the concepts of hypothesis testing.
5. Apply least squares method to estimate the parameters in a regression model.
6. Use standard software (e.g., Excel) to facilitate statistical analysis.

Course Content

Key topics taught:
1. Probability and probability distributions
2. Sampling distributions
3. Point estimation
4. Confidence intervals
5. Hypothesis testing
6. Regression

Assessment (includes both continuous and summative assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested</th>
<th>Related Programme LO or Graduate Attributes</th>
<th>Weighting</th>
<th>Team/Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Examination</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>EAB SLO* a, b, c, d</td>
<td>60%</td>
<td>Individual</td>
<td></td>
</tr>
</tbody>
</table>
2. Continuous Assessment 1 (CA1): Quiz

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>EAB SLO* a, b, c, d</th>
<th>15%</th>
<th>Individual</th>
</tr>
</thead>
</table>

3. CA2: Quiz

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>EAB SLO* a, b, c, d</th>
<th>15%</th>
<th>Individual</th>
</tr>
</thead>
</table>

4. CA3: Project

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>EAB SLO* a, b, c, d, e, j, i</th>
<th>10%</th>
<th>Team</th>
<th>See Appendix 1</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>EAB SLO* a, b, c, d, e, j, i</th>
<th>10%</th>
<th>Team</th>
<th>See Appendix 1</th>
</tr>
</thead>
</table>

Formative feedback

During tutorials, the instructor will communicate expected learning outcomes in detail.

After each CA, the instructor will go through the problems during tutorials. Common mistakes and misunderstanding in concepts will also be addressed.

Specific feedback to project work will be returned to students in writing. General feedback to project work will be published online.

Learning and Teaching approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>LECTURE</td>
<td>Course materials covering all topics</td>
</tr>
<tr>
<td>TUTORIAL</td>
<td>12 classroom discussion sessions on tutorial questions and related topics</td>
</tr>
</tbody>
</table>

Reading and References


Course Policies and Student Responsibilities

You are responsible for meeting all course requirements, observing all deadlines, examination times, and other course procedures.

You will be awarded ZERO mark for being absence from quizzes unless it is due to the following reasons:

- Illness (valid medical certificate is required, not from Chinese doctor)
- Passing away of immediate family member (parents, siblings or grandparents)
- Participate in an activity representing NTU (support letter from participating organization)
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Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU’s shared values.

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Course Instructors

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lau Wai Man</td>
<td>N1.2-B2-32</td>
<td>63168830</td>
<td><a href="mailto:wmlau@ntu.edu.sg">wmlau@ntu.edu.sg</a></td>
</tr>
</tbody>
</table>

Planned Weekly Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Statistics and Data Analysis</td>
<td>1, 4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Probability</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Random Variables and Probability Distributions</td>
<td>1, 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>4 &amp; 5</td>
<td>Discrete and Continuous Probability Distributions</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sampling Distributions and CA1</td>
<td>1, 2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>One and Two Sample Estimation Problems</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>One and Two Sample Tests of Hypothesis</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Simple Linear Regression</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Multiple Linear Regression and Nonlinear Regression Models</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>CA2</td>
<td>3, 4, 5</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>CA3</td>
<td>1, 2, 3, 4, 5, 6</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Applications in Engineering Problems</td>
<td>1, 2, 4, 5, 6</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix 1: Project

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Exceed Expectations</th>
<th>Meet Expectations</th>
<th>Meet Baseline Expectations</th>
<th>Below Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO 1, 2 and 6</td>
<td>Applied an appropriate concept of probability and probability distribution model for the project.</td>
<td>Applied an appropriate concept of probability and probability distribution model for the project.</td>
<td>Applied an appropriate concept of probability and probability distribution model for the project.</td>
<td>Unable to apply an appropriate probability and probability distribution model for the project</td>
</tr>
<tr>
<td></td>
<td>Appropriate regression methodology was applied to model the data.</td>
<td>Appropriate regression methodology was applied to model the data.</td>
<td>Appropriate regression methodology was applied to model the data.</td>
<td>No result and/or interpretation to showcase</td>
</tr>
<tr>
<td></td>
<td>The results were interpreted clearly and conclusion was drawn in highly articulate statistical and English language.</td>
<td>The results were interpreted correctly but the conclusion can be drawn in a more technical language supported with statistical findings.</td>
<td>The result interpretation was acceptable but the conclusion was not supported by appropriate statistical findings.</td>
<td></td>
</tr>
</tbody>
</table>
CH2102 Organic Chemistry and Spectrophotometry
[Lectures: 39 hours; Tutorials: 13 hours; Pre-requisites: Nil; Academic Unit: 4.0]

Objectives
This course aims to teach students organic chemistry at the intermediate level. The course focuses primarily on all the basic reactions of organic functional groups, and teaches students stereochemistry and spectroscopy of organic structures.

Student Learning Outcomes
Upon completion of the course, students will grasp the knowledge of organic reactions, stereochemistry, reaction mechanism and spectroscopy of organic compounds.

Course Assessment
a) Two quizzes: CA1 - 20% and CA2 - 20%.
   CA1 (20%) will test the knowledge on the basics of organic chemistry, the stereochemistry, the reactions of ally halides, alkene alcohol and ethers.
   CA2 (20%) will test on aromaticity, electrophilic aromatic substitution, aldehydes and ketones and carboxylic acid reactions.

b) Final exam: 60% (Closed book, 2.5 hours).

Course Content

<table>
<thead>
<tr>
<th>Topics</th>
<th>Lecture hrs</th>
<th>Tutorial hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Organic Chemistry</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>Revision of basics: Electronic structures,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>molecular structures &amp; bonding, resonance,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>polarity. Acidity/Basicity concepts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkanes/ Cycloalkanes</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Definitions, nomenclature, properties,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>syntheses/reactions and reactivity concepts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in halogenation; conformations &amp;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cycloalkanes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereochemistry</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Nomenclature. Enantiomers. Diastereomers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkyl Halides and Reactions</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Naming and structures of alkyl halides.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation of alkyl halides. Radical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>halogenation of alkanes. Allylic bromination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of alkenes. Stability of allyl radical.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation of alkyl halides from</td>
<td></td>
<td></td>
</tr>
<tr>
<td>alcohols. Grignard reagents. Organometallic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coupling reactions. Stereochistry of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nucleophilic substitution. SN2 and SN1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reactions. Elimination reactions of alkyl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>halides. E1 and E2 reactions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkenes and their Reactions</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>Nomenclature. Alkene synthesis. Electrophilic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>addition, catalytic reduction, cyclopropanation,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>oxidative addition and oxidative cleavage of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>alkenes. Acetylide Chemistry. Addition to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the triple bond. Oxidation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohols and Reactions</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>Synthesis from alkenes, alkyl halides and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>carbonyl compounds. Oxidation-reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reactions. Cleavage of hydroxyl group and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hydroxyl proton.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethers, Epoxides and Sulfides</td>
<td>1.5</td>
<td>1</td>
</tr>
</tbody>
</table>
### Nomenclature. Structure & properties of ethers.

#### Conjugated Systems

| 2 | 1 |

#### Benzene and Aromaticity

| 2 | 1 |

#### Aromatic Compounds and Reactions
Bromination of aromatic rings. Friedel-Crafts reaction. Acylation of aromatic rings. Substituent effects in substituted aromatic rings. Trisubstituted benzenes:

| 3 | 1 |

#### Carbonyl Compounds
Ketones and Aldehydes: Preparation of aldehydes and ketones, oxidation, hydration, cyanohydrins, alcohol formation, reduction, imine and enamine

| 4 | 1 |

#### Amines and Phenols

| 3 | 1 |

#### Carboxylic Acids and Derivatives

| 4 | 1 |

#### Spectroscopy
Structure determination: IR, NMR

| 4 | 1 |

**Total:**

| 39 | 13 |

### Textbooks/References
### Course Content

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>2017-18</th>
<th>Semester</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Coordinator</td>
<td>Lau Wai Man/Dang Thuy Tram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course Code</td>
<td>CH2103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course Title</td>
<td>Fluids Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-requisites</td>
<td>Fundamental Mathematics, Engineering Mathematics, Materials and Energy Balance, Introduction to Thermodynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of AUs</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact Hours</td>
<td>39 hours of lectures, 12 hours of tutorials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposal Date</td>
<td>4 Aug 2017</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Course Aims

At the end of the course, you will be able to apply fluid flow principles in specific applications involved in chemical reactors, heat exchangers, and separation equipment such as distillation column, fluidized bed and filter bed.

### Intended Learning Outcomes (ILO)

Students will be able to:
1. Identify the properties of fluids and the state of fluids at rest and during motion.
2. Determine unknown fluid flow information in a system by applying mass, energy and momentum balances with the use of appropriate mathematical tools.
3. Interpret fluid flow properties based on specific location and time in a system.

### Course Content

Key topics taught
1) Introduction, fluid properties and forces
2) Mass and Energy Balances
3) Momentum Balances
4) Fluid flow in pipes
5) Flow in non-circular duct and compressible flow
6) Pipe and fittings
7) Dimensional analysis
8) Pumps and compressors
9) Fluid drag
10) Microscopic balances. Exact solutions to Navier-Stokes equations.
12) Advanced topics. Boundary layer approximation.

### Assessment (includes both continuous and summative assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested</th>
<th>Related Programme LO or Graduate Attributes</th>
<th>Weighting</th>
<th>Team/Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Final Examination</td>
<td>1, 2, 3</td>
<td>EAB SLO* a, b, c</td>
<td>60%</td>
<td>Individual</td>
<td>Appendix 1i, ii, iii, iv</td>
</tr>
<tr>
<td>2. Continuous Assessment 1 (CA1): Quiz</td>
<td>1, 2</td>
<td>EAB SLO* a, b, c</td>
<td>20%</td>
<td>Individual</td>
<td>Appendix 1i</td>
</tr>
<tr>
<td>3. CA2: Continuous Assessment 2 (CA2): Quiz</td>
<td>1, 2, 3</td>
<td>EAB SLO* a, b, c</td>
<td>20%</td>
<td>Individual</td>
<td>Appendix 1ii, iii, iv</td>
</tr>
</tbody>
</table>
Formative feedback
After each CA, the problems will be discussed during tutorials. Common mistakes and misunderstanding in concepts will also be addressed.

Learning and Teaching approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>Lectures are mainly focusing on the principles and concepts of fluid mechanics in chemical engineering.</td>
</tr>
<tr>
<td>Tutorial</td>
<td>Tutorial problems are direct applications of the principles and concepts introduced in lectures. Industrial based applications are also introduced as in-class exercises where students are encouraged to discuss with each other in a collaborative manner.</td>
</tr>
</tbody>
</table>

Reading and References

List of readings and references used in the course

Course Policies and Student Responsibilities
You are responsible for meeting all course requirements, observing all deadlines, examination times, and other course procedures.

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*Note: This is a standard recommended text for academic integrity in the course. If you wish to amend, please make sure that it is in accordance with the official policy by visiting the link provided above.*

**Course Instructors**

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lau Wai Man</td>
<td>N1.2-B2-32</td>
<td>6316 8830</td>
<td><a href="mailto:wmlau@ntu.edu.sg">wmlau@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Dang Thuy Tram</td>
<td>N1.3-B3-09</td>
<td>6790 4257</td>
<td><a href="mailto:ttdang@ntu.edu.sg">ttdang@ntu.edu.sg</a></td>
</tr>
</tbody>
</table>

**Planned Weekly Schedule**

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction, fluid properties and forces</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mass and energy balances</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Momentum balance</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Applications of mass, energy and momentum balances in chemical</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fluid flow in pipes</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Flow in non-circular duct and compressible flow</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Fluid Drag</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pipe, fittings, pumps and compressors</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Intro to microscopic fluids, velocity field, forces, generalized continuity and momentum equations,</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Exact solution for viscous flows</td>
<td>2,3</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Non-dimensionalization, approximate solution of N-S equations.</td>
<td>2,3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Inviscid flows, stream function, velocity potential, elementary plane flows</td>
<td>2,3</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Boundary layer, Non-newtonian fluids</td>
<td>1,2,3</td>
<td></td>
</tr>
</tbody>
</table>
### EVALUATION RUBRIC: CH2103 Fluids Systems
#### ASSESSMENT FORM (Course Coordinator: Lau Wai Man)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Unsatisfactory (1)</th>
<th>Borderline (2)</th>
<th>Satisfactory (3)</th>
<th>Very good (4)</th>
<th>Exemplary (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Solving fluid flow problems with the applications of mass, energy and momentum balances</td>
<td>Unable to visualize a problem and do not know how to apply the correct balances to solve the problem</td>
<td>Able to visualize the problem and know what balances to use but cannot write the governing equations correctly or solve mathematically</td>
<td>Able to visualize the problem, setup an individual balance correctly and solve the equation mathematically</td>
<td>Good understanding of the problem, able to setup a combination of two balances and solve mathematically</td>
<td>Excellent understanding of the problem, able to setup a combination of at least 3 or more balances and solve mathematically</td>
</tr>
<tr>
<td>ii. Solving pipe flow related problems</td>
<td>Unable to differentiate between laminar and turbulent fluid regimes in a pipe</td>
<td>Able to differentiate between laminar and turbulent fluid regimes in a pipe but only can solve laminar flow related problems</td>
<td>Able to differentiate between laminar and turbulent fluid regimes in a pipe but only can solve laminar flow or turbulent flow problems with a given friction factor</td>
<td>Good understanding of both laminar and turbulent pipe flow problems and able to solve both laminar and turbulent problems by the help of friction factor and energy equation</td>
<td>Excellent understanding of both laminar and turbulent pipe flow problems, and able to solve complex design problems involving pumps and turbines</td>
</tr>
<tr>
<td>iii. Interpret and analyze drag force around an object</td>
<td>Unable to comprehend the drag forces across different object geometries</td>
<td>Able to perform analysis and calculations on drag forces on spherical objects under Stokes regime</td>
<td>Able to perform analysis and calculations on drag forces on spherical objects under all flow regimes</td>
<td>Good understanding of drag forces on most object geometries under all flow conditions</td>
<td>Excellent understanding of drag forces on most object geometries under all flow conditions and able to make design recommendations</td>
</tr>
<tr>
<td>iv. Analyze fluid flow problems based on microscopic fluid dynamics</td>
<td>Unable to identify the correct Navier Stokes equation relating to a flow problem</td>
<td>Able to identify the correct Navier Stokes equation and but not able to reduce the equation based on the flow conditions and boundary conditions</td>
<td>Able to identify the correct Navier Stokes equation, reduce the equation correctly based on the flow conditions but unable to identify the correct boundary conditions</td>
<td>Able to identify the correct Navier Stokes equation, reduce the equation correctly based on the flow conditions and able to solve the problem by identifying the correct boundary conditions</td>
<td>Excellent understanding of the Navier Stokes equation and solve complex fluid problems using simultaneously equations and multiple boundary conditions correctly</td>
</tr>
</tbody>
</table>
CH2104 Heat and Mass Transfer in Chemical and Biological Systems
(Core)
[Lectures: 39 hours; Tutorials: 13 hours; Pre-requisites: CH1104 & CH1108 & CH1117 & CH2103 & MH1810; Academic Unit: 4]

Objectives
The course aims to enable students to understand the meaning of the terminology and physical principles of heat and mass transfer. Students are taught to compute heat transfer rate and/or temperature distribution for processes involving heat and mass transfer, when requisite conditions are given. They are taught to develop representative models of real processes and system (e.g. heat exchanger, cooling tower) and to draw conclusion from analysis.

Student Learning Outcomes
Upon completion of the course, students should be able to understand fundamental theories and applications of heat and mass transport phenomena, emphasizing their analogies and contrasts. They will understand Fourier’s law, steady and unsteady thermal conduction, heat transfer coefficients, heat exchangers, condensation and boiling, radiation, Kirchoff’s law and view factors, Fick’s law, steady and unsteady diffusion, mass transfer coefficients, absorbers, simultaneous heat and mass transfer. They will be able to develop representative models of real processes and system (e.g. heat exchanger, cooling tower) and to draw conclusion from analysis.

Course Assessment:

With effect from AY16S2, students will be assessed by:

1) Final written examination (60%): 2.5hr. Restricted open-book examination. Candidates are allowed to bring in ONE A4 size paper inscribed with any information.

2) Continuous assessment (40%)
   i. Quiz 1: heat transfer 1 (15%) – short questions
   ii. Quiz 2: heat transfer 2 (15%) – short questions
   iii. Quiz 3: mass transfer (10%) – short questions

Course Outline:

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topics</th>
<th>Lecture hrs</th>
<th>Tutorial hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Heat Eq.</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>Solution Methods for heat Equations and boundary conditions</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>Heat Conduction</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Heat Convection</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Transient heat problems</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Radiation</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Fundamentals of mass transfer</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>Mass transfer equations</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>9</td>
<td>Molecular diffusion</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>10</td>
<td>Convective mass transfer</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>39</td>
<td>13</td>
</tr>
</tbody>
</table>
Textbook/References

4) Dean, Analysis of Transport Phenomenon
5) Farlow, Partial differential equations for scientists and engineers
CH2106 Introduction to Multidisciplinary Engineering (introduced from AY12/13 intake)

[Lectures: 26 hours; Pre-requisites: NIL; Academic Unit: 2]

Objectives

Modern chemical industry is multidisciplinary involving different engineering disciplines. The course is designed to introduce chemical engineering students to the practical principles and techniques of mechanical engineering, electric and electronics needed in chemical industry.

Student Learning Outcomes

Upon completion of the course, students would be able to read basic engineering drawing and communicate efficiently with other engineers on practical principles and techniques of mechanical engineering, electric and electronics engineering in chemical industry.

Course Assessment

Students will be assessed by:
1) A 2.5-hour final written examination (60%)
2) Continuous assessment including individual assignment, group projects and Quizzes (40%)
   - 2 Quizzes (10% each, total 20%)
   - Group project (10%)
   - Individual assignment (10%)

Textbooks/References


Topics

1) Metallurgy, metal working, and machine components
2) How to read engineering drawing
3) Introduction to computer aided drafting
4) Circuit elements, and how amplifiers, D/A and A/D conversion work
5) Capacitors and inductors
6) Signals and oscilloscope
7) AC circuits and impedance
8) Introduction to electronics
9) Logic system (power supply)
10) Digital system (I/O for PC)
## Course Content

<table>
<thead>
<tr>
<th>Course Overview and Concepts of Computational Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solving complex problem using computer - enables the student to work out exactly what to tell the computer to do.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overview of Programming Languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic programming, high level programming languages (Matlab)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basic internal operation of computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic computer organization and how a computer execute a program (Machine instructions)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basic program structure: control constructs and data types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts of data types, variables;</td>
</tr>
<tr>
<td>Pseudocode and flowcharts;</td>
</tr>
<tr>
<td>Sequences, Selection (if/else), iteration (for/while loop);</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CT concept – Abstraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem formulation - reducing something to a set of sub problems which have existing numerical algorithms/methods such as linear/nonlinear equations, optimization, curve fitting, numerical integration/differentiation, numerical differential equations</td>
</tr>
</tbody>
</table>

### Course Aims

Computational thinking (CT) is a problem solving process with the aid of computer; i.e. formulating a problem and expressing its solution in such a way that a computer can effectively carry it out. It includes a number of characteristics, such as breaking a problem into small and repetitive ordered steps, logically ordering and analyzing data and creating solutions that can be effectively implemented as algorithms running on computer. As such, computational thinking is essential not only to the Computer Science discipline, it can also be used to support problem solving across all disciplines, including math, science, engineering, business, finance and humanities.

The aim of this course is hence to take students with no prior experience of thinking in a computational manner to a point where you can derive simple algorithms and code the programs to solve some basic problems in chemical engineering domain.

### Intended Learning Outcomes (ILO)

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

1. Code basic programs based on the programming language such as MATLAB.
2. Formulate a problem and express its solution in such a way that a computer can effectively carry it out. (i.e. equip you with CT skills)
3. Identify appropriate numerical methods in solving realistic problems in chemical engineering using computing language (such as MATLAB).
CT concept - Decomposition
Break a complex problem into smaller and more manageable parts/steps and find the appropriate algorithms/methods for them including the methods for linear/nonlinear equations, optimization, curve fitting, numerical integration/differentiation, numerical differential equations.

CT concept – Pattern recognition
Looking for similarities among and within problems, which also enable re-use knowledge of previous similar problems.

CT concept – Algorithm
Reformulating the problem into series of ordered steps through Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.

Limit of computing
Analysis of Algorithm Complexity to determine how much resources (space and time) are needed to execute an Algorithm in order to achieve code optimization.

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested</th>
<th>Related Programme LO or Graduate Attributes</th>
<th>Weighting</th>
<th>Team/Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Continuous Assessment 1 (CA1 and CA2): Quizzes</td>
<td>1, 2, 3</td>
<td>EAB SLO* a, b, f</td>
<td>80%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>2. CA3: Assignments</td>
<td>1, 2, 3</td>
<td>EAB SLO* a, b, c, f</td>
<td>20%</td>
<td>Individual</td>
<td>Appendix 1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Formative feedback
You will get back your quizzes scores and the answers;
You will receive feedback during tutorials based on your performance;
You will also receive feedback on your assignment performance.

Learning and Teaching approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>LECTURE</td>
<td>Course materials covering all topics</td>
</tr>
<tr>
<td>LAMS Online Lecture</td>
<td>MATLAB Implementation</td>
</tr>
<tr>
<td>TUTORIAL</td>
<td>12 classroom discussion sessions on tutorial questions and related topics</td>
</tr>
</tbody>
</table>
## Reading and References

**TextBook**


**References**


## Course Policies and Student Responsibilities

- Completed assignments should be submitted through box labeled CH2107. No late assignments will be accepted.
- There will be no make-up quizzes. Zero points for no show up. Exceptions will be made for leave of absence due to medical reasons (with valid proof). In this case, points will be awarded based on your performance in the final examination.
- Active note taking in the class is encouraged.

## Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU’s shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the [academic integrity website](#) for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

## Course Instructors

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mukta Bansal</td>
<td>N1.2-B2-28</td>
<td>63168775</td>
<td><a href="mailto:mbansal@ntu.edu.sg">mbansal@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Ni Ran</td>
<td>N1.2-B1-12</td>
<td>6790 6737</td>
<td><a href="mailto:r.ni@ntu.edu.sg">r.ni@ntu.edu.sg</a></td>
</tr>
</tbody>
</table>

## Planned Weekly Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/ Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Course Overview and Concepts of Computational Thinking</strong>&lt;br&gt;Simple Mathematical Model, Programming and Software &amp; Approximation &amp; Round-Off Errors</td>
<td>1, 3</td>
<td>1, 3, 4</td>
</tr>
<tr>
<td>2</td>
<td><strong>Overview of</strong></td>
<td>1, 3, 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MATLAB</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Taylor Series</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td><strong>Computational Algorithms:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bracketing Methods &amp; Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Decomposition &amp; Algorithm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open Methods &amp; Quiz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Decomposition &amp; Algorithm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Algorithm</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>LU Decomposition and Matrix</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inversion &amp; Review</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 &amp; 9</td>
<td>Abstraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Optimization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td><strong>Pattern recognition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Curve Fitting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Algorithm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Numerical Integration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Algorithm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Differential Equation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Review &amp; Quiz</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>
## Appendix 1: Assessment criteria for the assignment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Unsatisfactory: 1</th>
<th>Borderline: 2</th>
<th>Satisfactory: 3</th>
<th>Very good: 4</th>
<th>Exemplary: 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation (LO 2 and 3)</td>
<td>Interpretation of the problem is not clear</td>
<td>Interpretation of the problem and explanation of the algorithm suggests minimal understanding of the basics</td>
<td>Interpretation of the problem and explanation of the algorithm suggests that there is basic understanding</td>
<td>Interpretation of the problem and explanation of the algorithm suggests that there is clear understanding of the numerical methods.</td>
<td>Interpretation of the problem and explanation of the algorithm suggests a very clear understanding of the numerical methods that is needed for the assignment and provide recommendations</td>
</tr>
<tr>
<td>MATLAB implementation (LO 1, 2, 3)</td>
<td>Not able to implement it in MATLAB</td>
<td>Able to do it without having much idea.</td>
<td>Able to understand and implement it in MATLAB</td>
<td>Able to implement it in MATLAB and able to interpret the results.</td>
<td>The MATLAB simulation meets all the requirements and presents the results in a very user friendly/useful way.</td>
</tr>
</tbody>
</table>
CH2107 Computational Methods in Chemical Engineering
Lectures: 26hrs; Tutorials/Labs: 12hrs; Pre-requisites: MH1810; Academic Unit: 3.0

Objectives
The course enables students to learn analytical and numerical methods to solve mathematical problems, which are closely related to the chemical engineering principles, via computer-aide mathematical package, Matlab.

Student Learning Outcomes
At the end of the course, students will be able to solve complex problems faced in the chemical engineering field and develop programming skills to change any mathematical expressions to computational codes via asymptotic algorithm construction, and to solve the sophisticated problems in chemical engineering principles.

Course Assessment
1) Final examination (50%)
2) Continuous assessment (50%)

Textbooks/References

Topics
3) Linear algebraic equation: Solutions of systems of algebraic equations, existence and uniqueness of solutions.
5) Non-linear polynomial equation: Numerical solutions using fixed point iteration method, Newton-Raphson, and regula falsi. approximation and determination of complex roots with the methods of Bairstow
7) Ordinary differential equation: Initial value and Boundary value problems.
8) Partial differential equation: Solutions of parabolic, hyperbolic and elliptic equations.
CH2109 Decision Tools for Engineering Business
[Lectures: 34 hours; Tutorials: 5 hours; Pre-requisites: NIL; Academic Unit: 3]

Learning Objective
Making difficult choices in business, manufacturing, finance and engineering domains require mathematical knowledge like statistics, optimization, probability, control and modeling. The course emphasizes applying these mathematical tools to solve engineering/business problems though case study.

Course Content
1. Finance math basics
2. Statistics, probability and their application in business/engineering decision
3. Data exploration and data mining
4. Optimization methods for decision making
5. Case study for decision making in engineering business

Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hours</th>
<th>Tutorial Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Finance math basics</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Statistics, probability and their application in business/engineering decision</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Data exploration and data mining</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Optimization methods for decision making</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Case study for decision making in business</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>34</strong></td>
<td><strong>5</strong></td>
</tr>
</tbody>
</table>

Learning Outcome
Upon completion of this course, students should be able to:

- Use the results of mathematical calculations via statistic and probability models to help evaluate various options in reaching financial decisions, whether personal or business-related.
- Understand the meaning, relationship and usage of various financial statements
- Understand the operation decisions for different circumstances
- Use of optimization and data mining methods for engineering business decision making
- Evaluate and select financial arrangements, which are best for you as a consumer.

Student Assessment
Students will be assessed by:

a. Final 2.5-hour written closed book examination (60%)
b. Project assessment (40%)
   - 2 Quizzes (30%)
   - Tutorial Participation (10%). Students will be assessed on their participation in class discussions and showing of initiative in class activities.
Textbooks/References


Data Mining Techniques: For Marketing, Sales and Customer Relationship Management, by Gordon S. Linoff, Michael J. A. Berry, 2011, Wiley

**CH2113 Fluids Systems** [Lectures: 27 hours; Tutorials: 12 hours; Pre-requisites: NIL; Academic Unit: 3.0]

**Learning Objective**
To learn the application and governing equations of fluid flow in various systems. To build analytical and mathematical skills to solve the fluid related problems. To link theory and practice of the course concepts.

**Content**

**Course Outline**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hours</th>
<th>Tutorial Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction, fluid properties and forces</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Mass and Energy Balances</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Momentum Balances</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Fluid flow in pipes</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Fluid drag</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Dimensional analysis</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Pipings, Fittings, Pumps and compressors</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Microscopic balances: Conservation of mass and momentum</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Microscopic balances: Exact and approximate solutions to Navier-Stoke equations.</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Microscopic balances: Non-newtonian fluids, Boundary Layer</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total:</strong></td>
<td><strong>27</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>
Learning outcomes:
Students will learn the fundamentals of fluid mechanics at a theoretical level. Upon the end of the course, students are expected to be able to apply various balances on flow systems and determine the flow properties. Students will also have basic knowledge on dimensional analysis and its application in real-life situations, such as scale-up, selection of pumps, etc. Students should be able to solve simple one-dimensional problems using Navier-Stokes equations.

Student Assessment
a. Final written examination (60%)
b. Continuous assessment (40%)

Students will be assessed on:

a) CA (40%)
   (1) Quiz 1 (20%): open-book, comprises of MCQs, short and long questions from first half of topics
   (2) Quiz 2 (20%): open book, comprises of MCQs, short and long questions from second half of topics

b) Final Exam (60%): open-book. 2.5 hours

Textbooks/References


CH2140 Unit Operations  
[Lectures: 39 hours; Tutorials: 13 hours; Pre-requisite: CH1104, CH1108, CH3103; Academic Units: 4]

Objectives
1) To introduce different separation processes available to the process engineer.
2) To demonstrate how mass balance and thermodynamics can be combined to design single staged separations.
3) To develop, from first principles, graphical methods for design of multi-staged separation cascades.
4) To apply these principles to the design of distillation, absorption and stripping, and liquid-liquid separations.
5) To design and understand the operation of such systems.

Student Learning Outcomes
At the end of the course, the student should be able:
1) To have an idea of various separation processes available to the process engineer.
2) To read thermodynamic representations such as T-xy, P-xy, ternary diagrams etc.
3) To use basic equilibrium and kinetic data to decide of type of separation process to be employed.
4) To design single staged separation processes and to combine them to form separation cascades.
5) To use graphical and computational methods to design counter-current separations involving distillation, absorption, liquid-liquid extraction for binary separations
6) To use process simulation tools for the simulation of simple separation processes.
7) To describe variations in compositions in such unit operations
8) To describe mass transfer across phases
9) To represent these mass transfer phenomena in those operations
10) To predict outcomes in other similar operations.
11) To solve problems relating to design and optimization

Course Assessment
Students will be assessed by:
CA (40%):

(a) Quiz 1 on topics 1-6 (18%). This quiz is subjective/descriptive type where students are given 5-6 problems to solve in 1.5 hours. NO multiple choice type questions.

(b) Assignment on topics 1-6 (2%). The assignments are done in groups of 4. The assignments are to be solved using computational tools and these problems are complex enough that they can’t be solved analytically.

(c) Quiz 2 on topics 7-10 (20%). This quiz is MCQ where students are given 20 questions to solve in 1.5 hours and though it is MCQ, they need to perform calculations to come to an answer. Negative marking is used

Exams (60%): 2.5 hrs, Open booked exam
### Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topics</th>
<th>Lecture hrs</th>
<th>Tutorial hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Course policy; Introduction to separation processes</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Phase equilibria</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Design of single staged separations</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Design of separation cascades</td>
<td>2</td>
<td>1</td>
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<tr>
<td>5</td>
<td>Design of binary distillation</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Design of complex distillation configurations, open-steam, multiple feed/product streams</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Design of absorbers and strippers</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Design of liquid-liquid separation cascades</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Mass transfer analysis</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Design of separation equipment</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>39</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

### Textbooks/References

Objectives

This laboratory course aims to provide practical applications to reinforce theories and concepts taught in chemical and biomolecular engineering.

Student Learning Outcomes

After completing this course, the student will be able to apply the concepts learnt in chemical and biomolecular engineering in a more practical setting.

Course Assessment

Continuous assessment (100%)

Textbooks/References

NIL

Topics

Experiments related to chemical and biomolecular engineering.
CH2702 Chemical and Biomolecular Engineering Laboratory 2B

[Lectures: 0 hours; Tutorials: 0 hours; Academic Unit: 2]

Objectives

This laboratory course aims to provide practical applications to reinforce theories and concepts taught in chemical and biomolecular engineering.

Student Learning Outcomes

After completing this course, the student will be able to apply the concepts learnt in chemical and biomolecular engineering in a more practical setting.

Course Assessment

Continuous assessment (100%)

Textbooks/References

NIL

Topics

Experiments related to chemical and biomolecular engineering.
COURSE CONTENT

**Academic Year**: 2017/18  
**Semester**: 1  
**Course Coordinator**: Mukta Bansal  
**Course Code**: CH3101  
**Course Title**: Process Control & Dynamics  
**Pre-requisites**: CH1104, CH2106, CH1108, CH2104, CH3102  
**No of AUs**: 4  
**Contact Hours**: 39 Lecture hours and 12 tutorial hours  
**Proposal Date**: 7 August 2017

**Course Aims**
The objective of this course is to develop an understanding of process modelling and controller design. The theoretical details for these concepts as well as their application to process systems encountered in chemical and petrochemical industries are covered.

**Intended Learning Outcomes (ILO)**
At the end of this course, you should be able to:
1. Interpret the need for stable control systems in process industries
2. Conceptually design and tune control systems and different types of controllers
3. Describe the common elements involved in control systems
4. Formulate models for process control
5. Use Matlab and Simulink for controller design and simulation

**Course Content**
1) Introduction to process control  
2) Introduction to modelling  
3) Models from fundamental laws  
4) Transfer functions  
5) Dynamic response  
6) Empirical modelling  
7) Introduction to feedback control  
8) PID controller  
9) Closed-loop stability  
10) Controller tuning  
11) Frequency Response  
12) Matlab/Simulink

**Assessment (includes both continuous and summative assessment)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested</th>
<th>Related Programme LO or Graduate Attributes</th>
<th>Weighting</th>
<th>Team/Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Final Examina</td>
<td>1, 2, 3, 4</td>
<td>EAB SLO* a, b, c, f</td>
<td>60%</td>
<td>Individual</td>
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</tr>
<tr>
<td>2. Continuous</td>
<td>3, 4</td>
<td>EAB SLO*</td>
<td>20%</td>
<td>Individual</td>
<td></td>
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</tbody>
</table>

Teaching, Learning and Pedagogy Division  
LT19A-B4-01, 50 Nanyang Avenue, Singapore 639798  
65923739  
TLPD-OBTL@ntu.edu.sg  
http://www.ntu.edu.sg/tpd
### Assessment

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Component</th>
<th>SLO</th>
<th>Weight</th>
<th>Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA1 (Quiz)</td>
<td>1, 2, 3, 4, 5</td>
<td>EAB SLO*</td>
<td>20%</td>
<td>Individual</td>
<td>Appendix 1</td>
</tr>
<tr>
<td>CA2 (Assignment)</td>
<td>a, b, c, f</td>
<td>20%</td>
<td>Individual</td>
<td>Appendix 1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Formative feedback

Describe how you would be giving feedback to students on how they are learning in this course.

Markers’ report on overall examination performance will be available to students;
Quizzes scores and answers;
During Tutorials based on their performance;
Assignment assessment.

### Learning and Teaching approach

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<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
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</thead>
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</tr>
<tr>
<td>TUTORIAL</td>
<td>12 classroom discussion sessions on tutorial questions and related topics</td>
</tr>
</tbody>
</table>

### Reading and References


### Course Policies and Student Responsibilities

- Completed assignments should be submitted through box labeled CH3101. No late assignments will be accepted.
- There will be no make-up quizzes. Zero points for no show up. Exceptions will be made for leave of absence due to medical reasons (with valid proof). In this case, points will be awarded based on your performance in the final examination.
- Active note taking in the class is encouraged.
### Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU’s shared values.

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### Course Instructors

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mukta Bansal</td>
<td>N1.2-B2-28</td>
<td>63168775</td>
<td><a href="mailto:mbansal@ntu.edu.sg">mbansal@ntu.edu.sg</a></td>
</tr>
</tbody>
</table>

### Planned Weekly Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Process Control</td>
<td>1, 3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Theoretical Models of Chemical Processes</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Transfer Function Models, Laplace Transform</td>
<td>3, 4, 5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dynamic Behaviour of First-Order and Second-Order Processes</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Dynamic Behaviour of Higher Order Processes</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Quiz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Development of Empirical Models from Process Data</td>
<td>2, 4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Feedback Controllers</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Closed-Loop Dynamics</td>
<td>2, 4, 5</td>
<td></td>
</tr>
<tr>
<td>10 &amp; 11</td>
<td>Stability of Closed-Loop Control Systems</td>
<td>1, 2, 4</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>PID Controller Design and Tuning</td>
<td>1, 2, 4</td>
<td></td>
</tr>
<tr>
<td>Frequency Response</td>
<td>1, 2, 4</td>
<td></td>
<td></td>
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## Appendix 1

<table>
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<tr>
<th>Criteria</th>
<th>Unsatisfactory: 1</th>
<th>Borderline: 2</th>
<th>Satisfactory: 3</th>
<th>Very good: 4</th>
<th>Exemplary: 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation (LO 1 – 4)</td>
<td>Interpretation of the problem is not clear</td>
<td>Interpretation of the problem and explanation of the proposed model suggests minimal understanding of the basics</td>
<td>Interpretation of the problem and explanation of the proposed model suggests that there is basic understanding</td>
<td>Interpretation of the problem and explanation of the proposed model suggests that there is clear understanding of the control system.</td>
<td>Interpretation of the problem and explanation of the proposed model suggests a very clear understanding of the control system that is needed for the assignment and provide recommendations</td>
</tr>
<tr>
<td>Matlab implementation (LO 5)</td>
<td>Not able to implement it in MATLAB</td>
<td>Able to do it without having much idea.</td>
<td>Able to understand and implement it in MATLAB</td>
<td>Able to implement it in MATLAB and able to interpret the results.</td>
<td>The Matlab simulation meets all the requirements and present the results in a very user friendly/useful way.</td>
</tr>
</tbody>
</table>
CH3102: Chemical Reaction Engineering

[Lectures: 39 hours; Tutorials: 13 hours; Pre-requisites: CH1104, CH2106; Academic Unit: 4]

Objectives

This course is designed to help students understand fundamental concepts and theories in chemical reaction engineering, particularly: Ideal reactors, heterogeneous reactions and non-ideal reactors. On completion of this course, the student should be able to analyze/design a variety of reaction systems in the areas of chemical engineering. In addition, this course is tailored to help the student link theory and practice of the course concepts.

Student Learning Outcomes

On completion of the course, the student is expected to qualitatively reason by applying fundamental principles of chemical reaction; to identify, analyze and solve problems by using chemical reaction engineering methods; to interpret chemical reaction engineering problems by formulating mathematical models.

Student Assessment

1) Final examination (50%)
2) Continuous assessment (50%)

Textbooks/References


Topics

1) Reaction rates and batch reactors
2) Continuous isothermal reactors - Single reaction
3) Continuous isothermal reactors - Multiple reactions
4) Nonisothermal reactors
5) Multiple steady states and transients
6) Mass transfer and catalytic reactor. Examples in chemical and biological processing
7) Non-ideal reactors, bioreactors, environmental modeling
CH3103 Chemical Thermodynamics

[Lectures: 33hrs; Tutorials: 6hrs; Pre-requisite: CH1108; Academic Units: 3]

Objectives

This course aims to teach students thermodynamics at a more advanced level; to develop thermodynamic relations for systems involving sophisticated situations; to apply laws and relations of thermodynamics for the analysis of physical and chemical reaction processes.

Student Learning Outcomes

Upon completion of the course students will have learnt to develop thermodynamic relations at a theoretically more advanced level. They will have gained knowledge on how laws of nature can be combined with basic thermodynamic properties and mathematical tools to develop useful thermodynamic relations that can be applied to solving many practical problems encountered in chemical engineering and other disciplines.

Course Assessment

Students will be assessed by:
1) Final examination (60%)
2) Continuous assessment (40%)

Textbooks/References


Topics

1) Review of basic laws and concepts of thermodynamics
2) Thermodynamic analysis of refrigeration and liquefaction
3) Residual properties and residual Gibbs energy function and their evaluation
4) Chemical potential and phase equilibria; fugacity and fugacity coefficient; methods for the evaluation of fugacity coefficient for gases, liquids and solids.
5) Fundamental property relations for systems of variable composition; Gibbs-Duhem equations; partial molar properties and their evaluation
6) Partial fugacity and phase equilibria involving mixtures; fugacity and fugacity coefficient of a component in a gaseous mixture; partial fugacity of a component in liquid mixtures; Lewis-Randall rule; Raoult’s and Henry’s laws
7) Concepts of excess properties; excess Gibbs energy function and activity coefficient; models for activity coefficient: Redlich/Kister, Margules, van Laar and Wilson equations; advanced models of NRTL, UNIQUAC and UNIFAC
8) Criteria of phase equilibrium in terms of chemical potential and fugacity; concept of K-factor and its application; VLE calculations: bubble point and dew point, partial condenser and flash drum, plate to plate; other topics of phase equilibrium: VLLE, LLE, VSE etc.

9) Criteria of chemical reaction equilibrium and concept of equilibrium constant; equilibria in homogeneous and heterogeneous reaction systems; multireaction equilibria
Objectives
Engineers working in the process industries are making increased use of biological systems for production and environmental management. To optimise these processes, chemical engineers need to understand the fundamentals of biological processes and their applications. This course is designed to teach chemical engineers key aspects associated with biochemical processes and key principles of microbiology such as the basic structure and function of cells, enzyme structure and function and basic molecular biology.

Student Learning Outcomes
At the end of this course, the student should have the ability to:
1) Describe the basic structure and function of cells as well as their growth behaviour. Explain the basic features of bioreactors and their operation. Apply chemical engineering principles to design basic biological products and processes.
2) Use different mathematical modelling tools to find out KM, Vmax of the native enzyme and immobilized enzyme.
3) Understand basic recombinant DNA technique that has been used widely in industry and academic
4) Obtain basic knowledge on protein engineering, including random mutagenesis (error-prone PCR and DNA shuffling) and rational design.

Course Assessment
Students will be assessed by:

CA (40%):

(a) Quiz 1 (topics from first half of course), there will be MCQs and short-answer questions (20%).

(b) Quiz 2 (topics from second half of course), will comprise of MCQs/ short questions and long questions (20%).

Exams (60%): 2.5 hrs, Closed-book exam
### Course Outline

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Lecture hrs</th>
<th>Tutorial hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to biochemical engineering, including industry examples</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Basics of molecular and cell biology</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Metabolism: common reaction motifs, glycolysis, TCA cycle, oxidative</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>phosphorylation</td>
<td></td>
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<tr>
<td>4</td>
<td>Metabolism: gluconeogenesis, photosynthesis, pentose phosphate pathway,</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>regulation</td>
<td></td>
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<tr>
<td>5</td>
<td>Alteration of cellular information and DNA recombinant technology</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Genetically engineered organisms</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Revision and Quiz 1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Introduction to Enzymes and Enzymes Kinetics</td>
<td>2</td>
<td>1</td>
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<tr>
<td>9</td>
<td>Significance &amp; Determination of Rate Parameters, Enzymes Inhibition</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Cell Growth in Batch Culture, Growth Kinetics</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Revision and Quiz 2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Cell Growth in Continuous Culture, Chemostat</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Multistage Chemostat Systems &amp; Stoichiometry of Microbial Growth &amp;</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Product Formation</td>
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<td><strong>Total:</strong></td>
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<td><strong>26</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

### Textbooks/References


COURSE CONTENT

Academic Year: 2018/19
Semester: 1

Course Coordinator: Mukta Bansal

Course Code: CH3111
Course Title: Process Control & Dynamics
Pre-requisites: CH1104, BG2142, MS1016, CH2114, CH2112, MH1810

No of AUs: 3
Contact Hours: 26 Lecture hours and 13 tutorial hours
Proposal Date: 26 Dec 2017

Course Aims

The objective of this course is to help you understand process modelling and controller design. The theoretical details for these concepts as well as their application to process systems encountered in chemical and petrochemical industries are covered.

Intended Learning Outcomes (ILO)

At the end of this course, you should be able to:
1. Interpret the need for stable control systems in process industries
2. Conceptually design and tune control systems and different types of controllers
3. Describe the common elements involved in control systems
4. Formulate models for process control
5. Use Matlab and Simulink for controller design and simulation

Course Content

1. Introduction to process control
2. Introduction to modelling
3. Models from fundamental laws
4. Transfer functions
5. Dynamic response
6. Introduction to feedback control
7. PID controller
8. Closed-loop stability
9. Controller tuning
10. Matlab/Simulink

Assessment (includes both continuous and summative assessment)
<table>
<thead>
<tr>
<th>Component</th>
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</thead>
<tbody>
<tr>
<td>1. Final Examination</td>
<td>1, 2, 3, 4</td>
<td>EAB SLO* a, b, c, f</td>
<td>60%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>2. Continuous Assessment 1 (CA1): Quiz</td>
<td>3, 4</td>
<td>EAB SLO* a, b, f</td>
<td>20%</td>
<td>Individual</td>
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<tr>
<td>3. CA2: Assignment</td>
<td>1, 2, 3, 4, 5</td>
<td>EAB SLO* a, b, c, e, f</td>
<td>20%</td>
<td>Individual</td>
<td>Appendix 1</td>
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<tr>
<td>Total</td>
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<td>100%</td>
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</tr>
</tbody>
</table>

**Formative feedback**
Describe how you would be giving feedback to students on how they are learning in this course.

The instructor will discuss the quiz scores and answers with you. You will also receive feedback on your performance during the tutorial and the assignment assessment. Finally, you will get the marker’s report on the overall examination performance of your cohort.

**Learning and Teaching approach**

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
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<tr>
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<td>12 classroom discussion sessions on tutorial questions and related topics</td>
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**Reading and References**


Course Policies and Student Responsibilities
- Completed assignments should be submitted through box labeled CH3111. No late assignments will be accepted.
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<td>Mukta Bansal</td>
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<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Activities</td>
<td>Activities</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Introduction to Process Control</td>
<td>1, 3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Theoretical Models of Chemical Processes</td>
<td>3, 4</td>
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<tr>
<td>3</td>
<td>Transfer Function Models, Laplace Transform</td>
<td>3, 4, 5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dynamic Behaviour of First-Order and Second-Order Processes</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dynamic Behaviour of Higher Order Processes</td>
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<td>7</td>
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<td>8</td>
<td>Feedback Controllers</td>
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<tr>
<td>9</td>
<td>Closed-Loop Dynamics</td>
<td>2, 4, 5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Stability of Closed-Loop Control Systems</td>
<td>1, 2, 4</td>
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<td>13</td>
<td>PID Controller Design and Tuning</td>
<td>1, 2, 4</td>
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**Recommended Appendices**

**Appendix 1**

<table>
<thead>
<tr>
<th>Criteria (LO 1)</th>
<th>Unsatisfactory: 1</th>
<th>Borderline: 2</th>
<th>Satisfactory: 3</th>
<th>Very good: 4</th>
<th>Exemplary: 5</th>
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<td>Interpretation</td>
<td>Interpretation of the problem is not clear</td>
<td>Interpretation of the problem and explanation of the proposed model suggests minimal understanding of the basics</td>
<td>Interpretation of the problem and explanation of the proposed model suggests that there is basic understanding</td>
<td>Interpretation of the problem and explanation of the proposed model suggests that there is clear understanding of the control system.</td>
<td>Interpretation of the problem and explanation of the proposed model suggests a very clear understanding of the control system that is needed for the assignment and provide recommendations</td>
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</table>

| Matlab implementation (LO 2, 3, 4 and 5) | Not able to implement it in MATLAB | Able to do it without having much idea. | Able to understand and implement it in MATLAB | Able to implement it in MATLAB and able to interpret the results. | The Matlab simulation meets all the requirements and presents the results in a very user friendly/useful way. |
CH3141  Advanced Unit Operations

[Lectures: 26hrs; Tutorials: 12hrs; Pre-requisite: Nil; Academic Units: 3.0]

Objectives

This course is designed for students with an engineering background to learn particle processing and the separation techniques used for pharmaceutical and biological industries. The course emphasizes the fundamental chemical engineering principles encountered in gas-solid/liquid-solid systems. The objective of the course is to provide students with a comprehensive and concise overview of different separation processes available for systems involving solids and to develop independent problem solving abilities.

Student Learning Outcomes

After the course, students will be able to apply fundamental chemical engineering principles such as heat/mass transfer behaviors and flow flows in unit operations involving fluid-solid and solid-solid separations. More importantly, students will be able to identify, formulate and solve engineering problems.

Course Assessment

2 quizzes (15% each, total 30%); 1 Final exam (70%)

Textbooks/References


Topics

1) Particle size analysis
2) Packed bed
3) Introduction to fluidized bed
4) Dense phase fluidization
5) Dilute phase fluidization
6) Gas-liquid-solid fluidized bed
7) Particle separations in fluidized bed
8) Introduction to crystallization process
9) Crystal science
10) Crystallization kinetics
11) Crystal growth and size distribution
12) Introduction to filtration process
13) Constant flow and constant pressure filtration
14) Ultrafiltration/reverse osmosis
15) Introduction to centrifugation
16) Centrifugation principles and mechanisms
CH3702 Chemical and Biomolecular Engineering Laboratory 3

[Lectures: 0 hours; Tutorials: 0 hours; Pre-requisites: Nil; Academic Unit: 3]

Objectives

This laboratory course aims to provide practical applications to reinforce theories and concepts taught in chemical and biomolecular engineering.

Student Learning Outcomes

After completing this course, the student will be able to apply the concepts learnt in chemical and biomolecular engineering in a more practical setting.

Course Assessment

Continuous assessment (100%)

Textbooks/References

NIL

Topics

Experiments related to chemical and biomolecular engineering.
CH4101 Chemical, biological & Plant Safety

[Lectures: 21hrs; Tutorials: 6hrs; Pre-requisite: CH3820, Year 4 standing; Academic Units: 2]

Objectives

This course aims to teach students about chemical, biological and plant safety at advanced level; and to understand and application of fundamental tools used to design, manage, operate safety and quantify risks in chemical and biological plants.

Student Learning Outcomes

At the end of the course, students will have learnt skills on how to design, manage, operate and quantify risks in chemical and biological plants. With that students would be able to establish the scheme to identify risks and recommend safety measures in chemical and biological plants.

Course Assessment

Students will be assessed by:
1) Final written examination (50%)
2) Continuous assessments (50%)

Textbooks/References

2) Living in the Environment by G. T. Miller, S. E. Spoolman

Topics

1) Introduction to Engineering ethnics, accident and loss statistics, acceptable risks, public perception, nature of accident processes.
2) Toxicology: How toxicant enters in or removed from biological organisms. effects on biological organisms, toxicological studies, does versus response, response curves, threshold limit, toxic release and dispersion model, release mitigation, etc.
3) Industrial hygiene & Hazards identification: Government regulations, identification, evaluation, control, Hazards Survey & checklist, safety review.
4) Fire, explosion, and prevention: The fire triangle, flammability characteristics of liquids and vapors, minimum oxygen concentration and inerting, autoignition, spray & mists, explosions, static electricity and controlling, explosion proof equipment and instrument, ventilation, sprinkle system
5) Reliefs: Concepts, locations, scenarios, install practice, relief sizing for liquid, vapor or gas service, rupture disc relief.
6) Event trees, faults trees, probability theory, HAZOP analysis, layered investigation, investigation process, investigation summary, aids for diagnosis, aids for recommendation.
7) Case histories
8) Sustainability: Appreciation of the cause of environmental problems, climate changes and ozone depletion due to industrialization as well as energy efficiency and renewable energy for chemical industry,
CH4102 Special Topics in Pharmaceutical Manufacturing

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The aim of this course is to introduce students to the regulation processes in pharmaceutical manufacturing; and to expose students to the technology transfer of pharmaceutical manufacturing.

Student Learning Outcomes

At the end of the course, students should not only have knowledge in the specific technological areas in pharmaceutical manufacturing but also gained an overview of how scientific and engineering research can translate into new industrial enterprise.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Federal drug administration (FDA) and pharmaceutical industry
2) Good manufacturing practice (GMP) for pharmaceutical products
3) Patents and regulations in pharmaceutical industries
4) Pharmaceutical analytical chemistry
5) Pharmaceutical biotechnology
CH4103 Chemistry of Heterocyclic Compounds

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The objective of the course is to give students an insight into heterocyclic chemistry and the use of different classes of these compounds in active pharmaceutical ingredients. Heterocyclic compounds are of prime importance in the chemical industry, and heterocyclic chemistry is therefore a fundamental topic in the undergraduate courses. The emphasis of this course is on synthetic aspects, and it covers the essential details and basic principles with reference to all the important classes of heterocyclic compounds. It is the study of Heterocyclic organic compounds including their methods of synthesis, reactions and their mechanisms. Three- four-five- and six- membered heterocyclic compounds with one heteroatom as well as five- and six- membered with two or three heteroatoms, particularly those containing nitrogen will be taught. The course includes the synthesis of some naturally occurring heterocyclic compounds.

Student Learning Outcomes

At the end of the course students should:

1) Have learnt the fundamentals of heterocyclic compounds, reactivity and synthesis.
2) Have studied some pharmaceutical applications of heterocyclic compounds.
3) Have extended knowledge on heterocyclic compounds to multi-ring and multi-heteroatom systems.
4) Be able to apply heterocyclic compounds in industrial and biological processes.
5) Be able to review the chemistry of pyrrole and pyridine.
6) Recognise the common reactions involved in heterocyclic synthesis.
7) Describe mechanistically the reactions and synthesis of benzofurans and indoles.
8) Be able to review the reactions of imidazole and be capable of applying synthetic methods to the preparation of 1,3-and 1,2-diazoles and oxazoles.
9) Understand the reactions of pyrimidines and be capable of explaining the synthesis of diazines, purines and pteridines.
10) Appreciate the chemistry of oxygen heterocyclic compounds including pyrylium salts, pyrones, coumarins and chromones.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References

1) Aromatic heterocyclic chemistry by David T. Davies, OUP, UK.

Topics

1) Introduction To Heterocyclic Chemistry Structure And Main Physical Properties Of Aromatic Heterocycles
2) Pyrroles, Thiophenes And Furans
3) Indoles, Benzothiophenes And Benzofurans
4) Imidazoles And Pyrazoles
5) Oxazoles AndIsoxazoles
6) Thiazoles AndIsothiazoles
7) Oxadiazoles, Triazines, And Tetrazines
8) Pyridines And Diazines
9) Pyrones, Chromones, And Coumarins
10) Purines, Pyrimidines, And Pteridines
11) Reduced Heterocycles
CH4104 Principles of Drug Discovery & Design

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The aim of this course is to teach the principles that govern the process of modern drug discovery and development. Students will follow a path similar to that taken by real-life drug developers by learning important elements of the drug design process in a logical order.

Student Learning Outcomes

By the end of this course, students will have an understanding of the methods and strategies involved in the drug discovery process including (1) methods used to identify potential drug targets, (2) approaches to screening for lead molecules, (3) sources of lead molecules, including natural products, synthetic libraries, and in silico structure-based molecules, (4) lead optimization, and (5) the future directions of drug development, including the promise of personalized medicine. Students will also become acquainted with the grant writing process and will write a grant application to obtain funding for developing a drug to modulate a protein of interest.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Drug design and discovery: An overview
2) Approaches to new drug discovery
3) Role of molecular recognition in drug design
4) Stereochemistry in drug design
5) Quantitative structure-activity relationships & experimental design
6) Computer-aided drug design
7) Combinatorial chemistry
8) Project-case study on development of one drug
9) Pyrones, chromones, and coumarins
10) Purines, pyrimidines, and pteridines
11) Reduced heterocycles
CH4106 Formulation of Active Pharmaceutical Ingredients Dosage Forms

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The objective of the course is to give students an insight in drug formulation and the setting of quality specifications. Thus, the course is devoted to the objectives involved in bringing an active pharmaceutical ingredient into an effective and safe dosage form.

Student Learning Outcomes

On completion of the course the students are expected to have a broad knowledge of the activities involved in the development of pharmaceutical dosage forms. The students will have an insight in the principles employed in drug formulation, the influence of the formulation on the bioavailability, and uses of pharmaceutical excipients, pharmacopoeia methods for quality evaluation.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (60%)
2) Continuous assessment (40%)

Textbooks/References


Topics

1) Principles Of Dosage Form Design And Development
2) Solid Dosage Forms And Modified-Release Drug Delivery Systems
3) Semi-Solid And Transdermal Systems
4) Pharmaceutical Inserts
5) Liquid Dosage Forms
6) Sterile Dosage Forms And Delivery Systems
7) Novel And Advanced Dosage Forms, Delivery Systems And Devices
CH4201 Genetic Engineering

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

This course aims to instruct students in the theory and application of classical and molecular genetic analysis of prokaryotic and eukaryotic microorganisms; and to go through case studies that will demonstrate how modern approaches in microbial genetic engineering impact human health and society.

Student Learning Outcomes

At the end of the course, students will:

Have gained a general understanding of the concept and approach of genetic engineering;

Be able to apply genetic engineering principles in biotechnology industry; and

Have gained the foundation for going for further studies in chemical engineering and biotechnology.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) The Basis Of Genetic Engineering
2) Methodology Of Gene Manipulation
3) Recombinant DNA Technology
4) Genes And Genomes
5) Genetic Engineering And Biotechnology
6) Applications Of Gene Manipulation
7) Transgenic Species, Cloning And Ethical Issues
CH4202 Gene Therapy & Drug Delivery

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims:

1) To provide engineering students with an in-depth description of the synthesis, fabrication, properties, and biomedical applications of nanobiomaterials pertaining to the applications of gene and drug delivery.
2) To introduce of biomaterials, nanobiomaterials, synthetic nanobiomaterials, biological nanobiomaterials (DNA nanomaterials, protein and peptide nanomaterials, etc), biofunctionalization of nanobiomaterials, use of nanobiomaterials in tissue engineering, drug delivery, gene delivery, cancer therapy, and bioimaging.

Student Learning Outcomes

At the end of the course:

1) Students should be able to understand the basic principles and features of nanobiomaterials, identify and understand key structure-property-processing relationship of those materials. They should understand the roles of the nanobiomaterials play in the biomedical applications. Students should be able to master the trend of nanobiomaterials and communicate with the people in the field.
2) They will have gained proficiency in scientific presentation and writing skills in the forms of a written project as well as oral presentations to the entire class.

Course Assessment

Students will be assessed by:

1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References

1) No recommended text.
2) Pharmaceutical Perspectives of Nucleic Acid-Based Therapeutics (Mahato RI and Kim SW, eds), Francis and Taylor, London (2002).
7) Peptide and Protein Delivery, 2nd Ed (Lee, VHL) Marcel Dekker (2002).
9) Challenges of Turning Nucleic Acids Into Therapeutics (Mahato RI, Theme Issue Editor), Advanced Drug Delivery Reviews 44: 79-207.
11) Pharmaceutical Perspectives of Nonviral Gene Therapy (Mahato RI) Advances in Genetics 41: 95-156.

Topics

1) Design, synthesis and characterization of polymer systems
2) Delivery systems and issues
3) Gene delivery
4) Special topics
CH4203 Bioinformatics

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The aims of the course are:

1) To introduce bioinformatics at a level appropriate for engineering majors with an interest in biotechnology.
2) To allow the students to evolve with the topics of interest in bioinformatics over time.
3) To learn to use conventional software, web-based applications, and software which they download to their machine.
4) To use the well-tested and successful approach of problem-based learning through applying the strategies and tools used in bioinformatics to topical problems drawn from ongoing research and applications in a variety of fields.

Student Learning Outcomes

At the end of the course, the students should be able:

1) To develop a solid understanding of the scope of bioinformatics.
2) To exploit the basic knowledge to many different fields of interest.
3) To gain substantial competency in content, skills, and awareness within the field of bioinformatics.
4) To make further inquiry and exploration as they move on into other courses.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References

1) David W Mount, Bioinformatics, Sequence and Genome Analysis, CSHL Press.

Topics

1) Introduction
2) Sequence and phylo-genetic analysis
3) Database searching and gene predictions
4) Protein structures and molecular modelling
5) Genome analysis
CH4205 Bioethics

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

Interdisciplinary thinking is solidly rooted in the processes of scientific thinking and, simultaneously, is solidly rooted in the processes of philosophical thinking. As the piers of a suspension bridge stand solidly on firmament to support the span between them, so also do the disciplinary ways of knowing biology and ethics serve as solid foundations to support the interdisciplinary thinking of bioethics. The aims of this course are to introduce students to bioethics as an interdisciplinary subject through critical thinking, writing, and discussing contemporary issues and to demonstrate to them that bioethical thinking is neither biology nor ethics but, rather, a melding of both of them.

Student Learning Outcomes

At the end of the course, students should be able to

1) Recognize, compare, and contrast the general "ways of thinking" of science (biology) and of philosophy (ethics);
2) Approach bioethical problems, break them into smaller, component parts (analysis), and discuss those analyses through oral and written communication, both individually and in groups;
3) Approach bioethical problems and propose solutions to them that transcend the disciplines of biology and philosophy, yet are solidly rooted in their respective ways-of-knowing.
4) Acquire and separate factual knowledge from opinion in the areas of science and philosophy. Demonstrate good critical thinking (that is, clear, logical (coherent and relevant), broad, deep, and discriminating) in bioethics through speaking and writing.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Introduction to ethics and bioethics
2) Ethics and the natural world
3) Ethical issues in agriculture and food production
4) Ethical issues in biomedical sciences
5) Reshaping human nature
Proposal on Undergraduate Curriculum Matters

Name of Programme : Bachelor of Engineering
Submitted by : College of Engineering
CN Yang Scholars Programme
Endorsed by : College of Engineering
Date : 8 Aug 2017

<table>
<thead>
<tr>
<th>Action Items</th>
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<tbody>
<tr>
<td>A Introduction of new course</td>
<td></td>
</tr>
<tr>
<td>B Withdrawal of existing course</td>
<td></td>
</tr>
<tr>
<td>C Change in course title</td>
<td>✔ CY4002 Final Year Project will be changed to “CNYSP Overseas Final Year Project” with a unique course code for each applicable engineering programme.</td>
</tr>
<tr>
<td>D Change in course/programme AU</td>
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<tr>
<td>E Change in learning objective/content</td>
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</tr>
<tr>
<td>F Change in pre-requisite</td>
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<tr>
<td>G Change in assessment component</td>
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<tr>
<td>H Others (please specify):</td>
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Overall rationale for proposed change(s)

Final Year Project is critical to all BEng programmes\(^1\) as it forms part of the criteria for First Class Honours / Honours (Highest Distinction) classification. Hence, it is important that the engineering schools retain ownership of the Overseas Final Year Project (OFYP) undertaken by BEng students in the CN Yang Scholars Programme (CNYSP). In order to reflect schools’ ownership and allow schools to preside over the BOE for OFYP, CY4002 Final Year Project will be re-titled “CNYSP Overseas Final Year Project” and replaced by a new set of school course codes, with retrospective effect for CNYSP students admitted from AY2015-16 onwards.

\(^1\) Except for Bachelor of Engineering (Chemical and Biomolecular Engineering) for which CH4801 Final Year Design Project is part of the criteria for First Class Honours / Honours (Highest Distinction) classification instead of Overseas Final Year Project.
(C) Change in Course Title

It is proposed to revise the title for the following course:

<table>
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<tr>
<th>Type</th>
<th>Current Course Code and Title</th>
<th>Proposed Course Code and Title</th>
<th>Proposed Date of Change</th>
<th>Justifications</th>
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<td>Core</td>
<td>CY4002 Final Year Project</td>
<td>CNYSP Overseas Final Year Project; please see unique course code for each applicable engineering programme in Table 1 below</td>
<td>With retrospective effect for CNYSP students admitted from AY2015-16 onwards</td>
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Table 1: New Course Code for CNYSP Overseas Final Year Project

<table>
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<th>Programme</th>
<th>New Course Code for CNYSP Overseas Final Year Project</th>
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References:

1) Annex A – Course content updated with the new title and course codes; OBTL format will be submitted by 2020.

2) Annex B – Course content for CY4002 Final Year Project.
COURSE CONTENT

Academic Year : AY2018-19

Study Year : Year 4, Semester 1

Course Code & Title : CNYSP Overseas Final Year Project

<table>
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Academic Unit : 8 AU

Pre-requisite : None

No. of Hours Per Week : 40 hours per week
(Scholars are expected to work full time, i.e. 8 hours/day, 5 days/week)

Learning Objective
a. Understand the processes involved in the design, development and implementation of a research project.
b. Learn to critically review the scientific literature in a specialized area of study.
c. Learn to critically analyse results.
d. Gain insight into the breadth and diversity of research work within international university.

Learning Outcomes
a. Develop and gain oral and written communication skills.
b. Develop problem-solving and critical thinking skills in the research context.
c. Students will be prepared for higher degree studies (PhD).
Content
The course provides students with experience in independent supervised research in a chosen field of study. The specific content is dependent on the field of study. Students will be supervised by the faculty from overseas universities (Overseas Supervisor) and the Academic Supervisor from their respective home schools.

Student Assessment
Students will be assessed by the Academic Supervisor, with input from the Overseas Supervisor, following the assessment criteria for Final Year Project in their respective schools. Schools may also appoint an independent examiner/moderator, if necessary, based on current FYP assessment criteria.

Textbooks/References
None
COURSE CONTENT

Academic Year : AY2018-19
Study Year : Year 4, Semester 1
Course Code & Title : CY4002 Final Year Project 2
Academic Unit : 8 AU
Pre-requisite : None
Course Description : Lab: 40 hours per week

(Applicable for scholars with Professional Attachment)

Learning Objective

- Understand the processes involved in the design, development and implementation of a research project.
- Learn to critically review the scientific literature in a specialized area of study.
- Learn to critically analyse results.
- Gain insight into the breadth and diversity of research work within international university.

Learning Outcomes

- Develop and gain oral and written communication skills.
- Develop problem-solving and critical thinking skills in the research context.
- Students will be prepared for higher degree studies (PhD).

Content

The course provides students with experience in independent supervised research in a chosen field of study. The specific content is dependent on the field of study. The students will be supervised by the faculty from overseas universities.

Student Assessment

Students will be assessed by:
- Assessment by supervisor from overseas university and Director of CN Yang Scholars Programme (50% FYP report & 50% oral presentation)

Textbooks/References

None
CH4213 Pharmacokinetics & Biopharmaceutics
[Lectures: 39 hours; Tutorials: 0 hours; Pre-requisites: CH1131; Academic Unit: 3.0]

Objectives
This course is designed to provide the students with a basic understanding on the importance of the drug actions, including administration, absorption, distribution, therapeutic effects, metabolism and toxicity. Basic principles in pharmacodynamics and pharmacokinetics will be examined. In addition, the interplay between pharmacogenetics and pharmacokinetics will also be analysed. The impact of such dynamic interplay on future drug design and targeted delivery will be discussed.

Student Learning Outcomes
Upon successful completion of the course, students should be able to:
1) Understand the background of pharmacokinetics
2) Understand the correlation between pharmacogenetics and pharmacokinetics
3) Understand drug metabolism and drug toxicity
4) Understand the future trend of drug development and targeted delivery

Course Assessment
Students will be assessed by
(1) 40% CA

- CA1 (20%): Project assignment based on technical publications related to first part of course, and 15-page group report with written indication of individual contributions

- CA2 (20%): Project assignment based on technical publications related to second part of course, and 15-page group report with written indication of individual contributions.

(2) 60% Final Written Examination (closed book, 2.5hrs)

Course Outline

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<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hours</th>
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<tr>
<td>1</td>
<td>Basics of Pharmacokinetics</td>
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<tr>
<td>2</td>
<td>Pharmacokinetics of Intravenous Bolus Dose</td>
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<td>3</td>
<td>Pharmacokinetics of Constant Rate Intravenous Infusions</td>
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<tr>
<td>4</td>
<td>Pharmacokinetics of Extravascular Drug Administration</td>
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<td>Basics of Pharmacogenetics I</td>
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<td>6</td>
<td>Basics of Pharmacogenetics II</td>
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<td>7</td>
<td>Clinical Applications of Pharmacogenetics</td>
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<td>8</td>
<td>Applications In Clinical Trials</td>
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<td>Introduction to drug metabolism</td>
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<td>Drug metabolism – part I</td>
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<td>Drug metabolism – part III</td>
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<td>Drug discovery</td>
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<td>15</td>
<td>Targeted drug delivery</td>
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</table>
Textbooks/References
Leon Shargel and Andrew B C Yu, Applied Biopharmaceutics and Pharmacokinetics, Appleton & Lange, Norwalk, CT, 1993.
CH4220 Special Topics in Industrial Chemistry & Green Processing

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to teach students special topics of current interest in the area of industrial chemistry and green processing.

Student Learning Outcomes

At the end of the course, students should not only have knowledge in the specific technological areas but also have gained an overview of how scientific and engineering research can translate into new industrial enterprise.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (50%)
2) Continuous assessment (50%)

References

Nil

Topics

This course is an introduction to key areas in Industrial Chemistry and Green processing such as:
1) Industrial Chemistry
2) Food chemistry and processing
3) Food additives
4) Flavour and Flagrances
5) Chemical processes
6) Environmental friendly processes
CH4221 Colloids Science & Particle Technology

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to provide students with a basic understanding of colloidal systems in industry and research; and to introduce them to the correlation between molecular properties and macroscopic behavior in colloidal systems and particle technology.

Student Learning Outcomes

At the end of the course, students will be familiar with the molecular interactions that determine the properties of colloid systems; understand various theoretical approaches (Regular solution, Gouy – Chapman, and DVLO theory) which are necessary for a molecular understanding of phenomena like surface tension, and molecular forces at interfaces and between colloidal bodies; and will be familiar with techniques and systems as used in industry, such as micellar, bilayer systems, polymers, sols and micro/macro emulsion.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (50%)
2) Continuous assessment (50%)

Textbooks/References


Topics

1) Characterisation of colloidal dispersions
2) Surface thermodynamics and interfacial phenomena
3) Adsorption at interfaces
4) Surface charge and electrokinetic phenomena
5) Colloidal forces and interactions
6) Determination of particle size
7) Flow behaviour
8) Colloidal particles in suspension
9) Applications of colloid science
10) Fundamental of biomolecule/bioparticle interactions
11) Characterisation of particle systems
12) Fundamental physical processes and particle metrology
13) Processes
14) Physics and chemistry of nano-sized particles
15) Nano-sized particle manufacturing processes
**CH4222 Industrial Chemical Processes**

[Lectures: 39 hours; Pre-requisites: CH2102; Academic Unit: 3]

**Objectives**

This course aims to teach students about the interconnectivity of chemical industry and its importance to Singapore and the world; and to appreciate the various industrial chemical processes and technology options involved in the whole spectrum of chemical industry and the current trend of green processes.

**Student Learning Outcomes**

On successful completion of this course the student will

1) Be able to discuss about the important of chemical industry for Singapore and the world
2) Be able to discuss how the various chemical companies are interconnected
3) Understand the chemical processes and technology options in the chemical industry
4) Be able to appreciate green processes

**Course Assessment**

Students will be assessed by:

1) Final examination (70%)
2) Continuous assessment (30%)

**Textbooks/References**

6) *Green Chemistry An Introductory Text*, M. Lancaster, RSC

**Topics**

1) Introduction to industrial chemical processes
2) Chemical processes in petroleum refining
3) Chemical processes in synthesis gas, hydrogen and base chemical productions
4) Chemical processes in ethane, propene and intermediates and speciality chemical productions
5) Green processes
CH4223 Petroleum Refining
[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives
The objective of this course is to introduce CBE students to the hydrocarbon/ refining/ petrochemical industry. By the end of the course, students should understand and be able to describe the standard processes. They should be able to apply concepts and perform simple calculations. They will be made aware of renewable technologies and have knowledge of environmental issues. They will be able to appreciate the current challenges the industry faces.

Student Learning Outcomes
Upon successful completion of the course, students will be able to:
1) Understand and be able to describe the standard processes
2) Apply concepts and perform simple calculations
3) Be aware of renewable technologies and have knowledge of environmental issues
4) Appreciate the current challenges the industry faces

Topics
1) Introduction
2) Processes in petroleum refining
3) Other topics

<table>
<thead>
<tr>
<th>Lecture no.</th>
<th>Lecture title</th>
<th>Lecture hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a) Introduction of petroleum refining industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Introduction to exploration and production. Characterisation of crude oils</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and specification of refinery products</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>a) Crude and vacuum distillation units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Diesel and kerosene treatment/LPG and offgas treatment</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>a) Hydrocracker</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>b) Thermal cracking</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Catalytic cracking</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>a) Hydrotreating/hydrodesulphurisation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>b) SWS/ SRU/ Amine</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Catalytic reforming</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Storage/Product blending</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Ethylene Cracker Complex</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Air and water pollution control, HSE</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Alternative energy/CO2/LEAN</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>Refinery economics and scheduling</td>
<td>3</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td>39</td>
</tr>
</tbody>
</table>
Assessment
Students will be assessed by:

1) CA (40%)
   a. Class participation 10%
      - Students will be assessed on their participation in class discussions and showing of initiative and response in class activities.
   b. Graded assignment 15%
      (a) Introduction of petroleum refining industry
      (b) Introduction to exploration production. Characterization of crude oils and specification of refinery products.
      (c) Refinery configuration and utilities integration
   c. Quiz 15% (MCQs)
      a) Crude and vacuum distillation units
      b) Diesel and kerosene treatment/LPG and offgas treatment
      c) Hydrocracker
      d) Thermal cracking and Visbreaking
      e) Catalytic cracking
      f) Hydrotreating/hydrosulphurisation
      g) Sour Water Stripping/ Sulphur Recovery / Amine Treating
      h) Catalytic reforming
      i) Storage/Product blending
      j) Ethylene Cracker Complex

(2) Final exams 60% (closed book), 2.5 hours written examination.

Textbooks/References
CH4240 Special Topics in Nanotechnology & Reaction Engineering

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to expose students to emerging topics in various areas of nanotechnology and reaction engineering.

Student Learning Outcomes

At the end of the course, students should not only have knowledge in the specific technological areas but also have gained an overview of how scientific and engineering research can translate into new industrial enterprise.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (50%)
2) Continuous assessment (50%)

Textbooks/References

Nil

Topics

1) Nanotechnology
2) Nanoparticles
3) Catalysts and support materials
4) Reaction engineering
5) Reactor design
CH4241 Surface Science in Catalysis and Nanotechnology

[Lectures: 39 hours; Academic Unit: 3.0]

Objectives

Students in chemical engineering major should have a comprehensive, modern molecular view of surface science. They should understand basic theoretical concepts in surface science, as well as physical principles of experimental techniques. They should able to link the relevance of surface chemistry to industrial processes.

Student Learning Outcomes

At the end of the course, students will have a comprehensive, modern molecular view of surface science. They will understand basic theoretical concepts in surface science, as well as physical principles of experimental techniques. They will be able to link the relevance of surface chemistry to industrial processes.

Course Assessment

Students will be assessed by:
1) 50% Continuous assessment
2) 50% Final Exam

Textbooks/References

2) Gary Attard, Colin Barnes, Surfaces, Oxford University Press, 1998
3) Gabor A. Somorjai, Introduction to Surface Chemistry and Catalysis, Wiley-Interscience, 1994

Topics

1) Surface Structure
2) Experimental Probes Of Surface And Adsorbate Structure
3) Chemisorption, Physisorption And Dynamics
4) Thermodynamics And Kinetics Of Surface Process
5) Complex Surface Reaction: Catalyst And Etching
6) Growth And Epitaxy
CH4243 Advanced Reaction Engineering

[Lectures: 39 hours; Pre-requisites: CH3002; Academic Unit: 3]

Objectives

The objective of this course is to impart and to continue the rigorous study of reaction engineering. In this course, particular emphasis will be given to chemical kinetics and transport phenomena, a review of the elements of reaction kinetics, rate processes in heterogeneous reacting systems, design of fluid-fluid and fluid-solid reactors, scale-up, and the stability of chemical reactors and residence time analysis of heterogeneous chemical reactors.

Student Learning Outcomes

Upon successful completion of this course the students will be able to:

1) Propose reaction mechanism for multiple reactions and obtain rate law and rate parameters
2) Design bio reactors involving different kinds of bio reactions
3) Describe transport mechanism and reaction in catalysts and design packed bed reactors
4) Understand residence time distribution and design non ideal reactors
5) Design non isothermal reactors
6) Design non ideal, non isothermal reactors for complex reactions

Assessment

Students will be assessed by:
1) Final examination (50%)
2) Continuous assessment (50%)

Textbooks/References


Topics

1) Elements of reaction kinetics:
2) Rate processes in heterogeneous reaction system:
3) Analysis and design of chemical reactors:
4) Operation and dynamics of chemical reactors:
COURSE CONTENT

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>2018/19</th>
<th>Semester</th>
<th>1</th>
</tr>
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<tbody>
<tr>
<td>Course Coordinator</td>
<td>Ni Ran</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course Code</td>
<td>CH4244</td>
<td></td>
<td></td>
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<tr>
<td>Course Title</td>
<td>Numerical Methods and Data Analytics</td>
<td></td>
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<tr>
<td>Pre-requisites</td>
<td>CH2107 or BG2111</td>
<td></td>
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<tr>
<td>No of AUs</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact Hours</td>
<td>26 Lecture hours and 13 tutorial hours</td>
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<td></td>
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<tr>
<td>Proposal Date</td>
<td>22 May 2017</td>
<td></td>
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</table>

Course Aims
The objective of this course is to introduce the concept of Data Analytics to solve problems encountered in engineering and non-engineering fields. After completing the course, you will be able to use numerical approaches learnt in this course to gain understanding, optimize and make decision from data.

Intended Learning Outcomes (ILO)
Upon successful completion of this course, you will be able to:
1. Develop and use numerical algorithms to solve integration and differential equations.
2. Develop linear regression models and evaluate its goodness of fit criteria and common pitfalls.
3. Apply machine learning to regression and classification problems.
4. Apply neural network to both numerical modelling and machine learning.

Course Content
Key topics taught:
1. Optimization – 1D
2. Optimization – 2D
3. Parameter estimation
4. Numerical Integration
5. Numerical ODE
6. Numerical PDE
7. Regression modelling
   a. Exploratory data analysis.
   b. Regression essentials: key goodness statistics and common pitfalls.
8. Briefing on fundamental modelling and business analytics—broadened applications of 'models' in non-engineering business.
9. New modelling paradigms and applications
   a. Supervised Machine Learning-Regression
   b. Supervised Machine Learning-Classification
   c. Neural Network for numerical modelling and machine learning.
   d. Unsupervised Machine Learning and deep learning

Assessment (includes both continuous and summative assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Course</th>
<th>Related</th>
<th>Weighting</th>
<th>Team/</th>
<th>Assessment</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>LO Tested</td>
<td>Programme LO or Graduate Attributes</td>
<td>Individual</td>
<td>rubrics</td>
<td></td>
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<tr>
<td>-----------</td>
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<td>------------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Continuous Assessment 1 (CA1): Assignment</td>
<td>1, 2</td>
<td>EAB SLO* a, b, c, d</td>
<td>25%</td>
<td>Individual</td>
<td>Appendix 1</td>
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<tr>
<td>2. Continuous Assessment 2 (CA2): Quiz</td>
<td>1, 2</td>
<td>EAB SLO* a, b</td>
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<td>Individual</td>
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<tr>
<td>3. Continuous Assessment 3 (CA3): Quiz</td>
<td>3, 4</td>
<td>EAB SLO* a, b</td>
<td>25%</td>
<td>Individual</td>
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<tr>
<td>4. Continuous Assessment 4 (CA4): Quiz</td>
<td>3, 4</td>
<td>EAB SLO* a, b</td>
<td>25%</td>
<td>Individual</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>100%</td>
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</table>

**Formative feedback**

During tutorials, the instructor will communicate expected learning outcomes in detail. After each CA, the instructor will go through the problems during tutorials. Common mistakes and misunderstanding in concepts will also be addressed. Specific feedback to project work will be returned you in writing. General feedback to project work will be published online.

**Learning and Teaching approach**

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>LECTURE</td>
<td>Course materials covering all topics</td>
</tr>
<tr>
<td>TUTORIAL</td>
<td>12 classroom discussion sessions on tutorial questions and related topics</td>
</tr>
</tbody>
</table>
Course Policies and Student Responsibilities

You are responsible for meeting all course requirements, observing all deadlines, examination times, and other course procedures.

You will be awarded ZERO mark for being absence from quizzes unless it is due to the following reasons:

- Illness (valid medical certificate is required, not from Chinese doctor)
- Passing away of immediate family member (parents, siblings or grandparents)
- Participate in an activity representing NTU (support letter from participating organization)

There will be no makeup given for missed quizzes. Final grade will be determined based on the participated quiz and final examination.

You are responsible for following the university regulations for final examination as indicated here:
http://www.ntu.edu.sg/Students/Undergraduate/AcademicServices/Examination/Pages/Instructionstoexamcand.aspx

You are responsible for being on time for all lectures and tutorials. Sufficient efforts should be put into solving or attempting the tutorial problems prior to attending the respective tutorial classes.

You might be awarded an “F” for a component or expelled from the university if you are caught cheating.

You are responsible for seeking academic help in a timely fashion.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU’s shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors
<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
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<tbody>
<tr>
<td>Ni Ran</td>
<td>N1.2-B1-12</td>
<td>67906737</td>
<td><a href="mailto:r.ni@ntu.edu.sg">r.ni@ntu.edu.sg</a></td>
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## Planned Weekly Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Optimization – 1D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Optimization – 2D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Parameter estimation</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Numerical Integration</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Numerical ODE</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Numerical PDE</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Quiz</td>
<td>1 &amp; 2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Modelling framework, Data exploration, Linear</td>
<td>3</td>
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</tr>
<tr>
<td></td>
<td>Regression</td>
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<td>9</td>
<td>Linear regression</td>
<td>3</td>
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<td>10</td>
<td>Introduction to Machine Learning(ML), ML for</td>
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<td>regression. CA3</td>
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<td>11</td>
<td>ML for classification</td>
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<td>12</td>
<td>Neural network</td>
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<td>13</td>
<td>Unsupervised learning and additional ML</td>
<td>6</td>
<td></td>
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<tr>
<td></td>
<td>subjects. CA4</td>
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**Appendix 1: Assignment**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Exceed Expectations</th>
<th>Meet Expectations</th>
<th>Meet Baseline Expectations</th>
<th>Below Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO 1 and 2</td>
<td>Choose an appropriate numerical algorithm to solve specific engineering problems.</td>
<td>Choose an appropriate numerical algorithm to solve specific engineering problems.</td>
<td>Choose an appropriate numerical algorithm to solve specific engineering problems.</td>
<td>Unable to correctly choose and implement proper numerical algorithms for solving specific engineering problems.</td>
</tr>
<tr>
<td></td>
<td>Implement the proper algorithm correctly in computer program and obtain the results.</td>
<td>Implement the proper algorithm correctly in computer program and obtain the results.</td>
<td>Implement the proper algorithm correctly in computer program and obtain the results.</td>
<td>No result and/or interpretation to showcase.</td>
</tr>
<tr>
<td></td>
<td>The results were interpreted clearly and conclusion was drawn in highly articulate numerical and English language.</td>
<td>The results were interpreted clearly but the conclusion can be drawn in a more technical language.</td>
<td>The results interpretation are acceptable but the conclusion was not supported by the appropriate numerical results</td>
<td></td>
</tr>
</tbody>
</table>
Learning Objective
1. Students will gain a general overview on the importance of macromolecules in the field of nanoscience and nanotechnology.
2. Students will learn chemistry and methods including radical polymerization, ionic polymerization, ring-opening polymerization and polycondensation involved in synthesis of polymers.
3. Students will understand physical properties of polymers including molecular weight, glass transition temperature, crystallization and mechanical properties.
4. They will be familiar with techniques and working principles of gel-permeation chromatography, light scattering, viscosity and osmotic pressure to quantify the molecular weight of polymers.
5. They will learn the concept of self-assembly, and the relationship of polymer architecture and various nanostructures produced from the self-assembly process.
6. Students will be able to differential the top-down and bottom-up manufacturing processes, and how macromolecules can be used to facilitate these developments.
7. Students will learn special polymers including synthesis, characterization and applications of dendrimers, metallic and semiconducting polymers and biodegradable polymers.
8. They will understand the applications of polymer-based nanostructures for biomedical applications including bioimaging, tissue engineering and cancer therapy.
9. Students will understand the importance of polymer nanocomposites, and various potential applications that this field will contribute to enhancing the properties of engineering materials.

Course Content
This course aims to provide an overview on the types of polymeric systems that are relevant to the emerging field of nanotechnology. Most of the materials covered are at the cutting edge of emerging technology that utilise polymers for applications in nanotechnology.

Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Number of Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to polymers and nanotechnology</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Polymer synthesis</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Polymer properties and characterization</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Hyperbranched polymers and dendrimers</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Block copolymers: Synthesis, self-assembly and applications</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Middle-term review/quiz</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Metallic and semiconducting polymers</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Biodegradable and sustainable polymers</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Polymer-based nanostructures for biomedical applications</td>
<td>3</td>
</tr>
</tbody>
</table>
Learning Outcome
The goal of this course is to introduce the importance and relevance of macromolecules in Nanoscience and Nanotechnology Engineering. Students will gain knowledge of polymer chemistry and physics and applications of macromolecules in various emerging innovations in the field of nanotechnology, materials science and biomedical engineering. Students will also gain soft skills of literatures searching/reviewing, team-working, and communication/presentation that are crucial for future careers in either academics or industry.

Student Assessment
Students will be assessed by 100% continuous assessment: Quiz (40%: short/essay questions); Project (50%: based on a specific topic, optional for group work): term paper (30%), oral presentation (20%), both of which are graded based on the contents of materials, critical analysis, and clarity of the presentation; Participation (10%: online discussion on topics + in-class discussion)

Textbooks/References
Introduction to Soft Matter: Polymers, Colloids, Amphiphiles and Liquid Crystals by Ian W. Hamley, John Wiley & Sons, 2000. (on reserve shelf)
CH4251 Process Systems Engineering

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The aims of the course are:

1) To introduce to students process systems engineering concepts including process modelling and design, process operation and control, and process system case studies.
2) To teach process engineering fundamentals: Classification of unit operations and transport processes, flow sheets, dimensional analysis, dimensionless groups, mass and energy balances. To teach knowledge process control fundamentals: Purpose and necessity of control.
3) To help students establish sample control strategies, determine plant operating conditions and benefits and to understand the importance of control engineering.
4) To teach students process measurement fundamentals: The role of measurement in process engineering, elements of a measurement system, common methods of temperature, pressure and flow measurement, and measurement systems case studies.

Student Learning Outcomes

At the end of the course, students are able:

1) To demonstrate a complete understanding of the concept of process systems engineering.
2) To demonstrate a familiarity with the in the fundamental principles of fluid mechanics, heat and mass transfer and chemical engineering that will be required during the course and competence in applying them.
3) To solve process flows sheeting problems.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References

3) Plant Design and Economics for Chemical Engineers (MCGRAW HILL CHEMICAL ENGINEERING SERIES) by Max Stone Peters, Klaus D. Timmerhaus

Topics

1) Process data management
2) Process synthesis
3) Chemical systems optimization
4) Applications of optimization
CH4252 Modelling Chemical and Biological Systems

[Lectures: 26 hours; Tutorials: 13 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The aim of the course is to teach students the skills in mathematical modelling and model-based analysis/optimisation of steady state and dynamic chemical/biological processes; to develop a systematic approach to model development and analysis, and an appreciation for the importance of process models in a chemical plant/process.

Student Learning Outcomes

At the end of the course, students will be able to follow the systematic and rigorous approach in order to develop and solve mathematical models for chemical/biological processes, and to analyse and use the models to facilitate the understanding, interpretation and optimisation of these processes.

Course Assessment

Students will be assessed by:
1) Final examination (50%)
2) Continuous assessment (50%)

Textbooks/References


Topics

1) Introduction To Process Modelling And Related Computational Tools
2) Static & Dynamic Process Models Based On Mass/Energy Balances
3) Models For Biochemical Reaction Mechanisms
5) Analysis Of Continuous Dynamic Models Using Linerisation
6) Distributed-Parameter Models And The Solution
7) Introduction To Mathematical Optimisation
8) Calibration & Parameter Estimation For Mechanistic Models
9) Statistical Analysis Of Model Parameters And Predictions
10) Optimal Experimental Design For Process Modelling
11) Empirical Process Models
CH4301 Molecular Biotechnology

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to:

1) Cover the basic principles of plant and animal biotechnology using current examples; gene mapping in breeding, transgenic approaches to improve crop plants and transgenic approaches to improve animals will be considered.
2) Teach the concepts of technology transfer from laboratory to marketplace.
3) Develop an understanding of gene mapping, cloning, transfer, and expression will be derived.

Student Learning Outcomes

At the end of the course, students will:

1) Have gained an understanding of the techniques and terminology of Biotechnology;
2) Understand the applicability of Agricultural Biotechnology.
3) Understand the gains attainable through Agricultural Biotechnology.
4) Appreciate the nature of environmental and ethical concerns over Biotechnology.

Course Assessment

Students will be assessed by:

1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Fundamentals of molecular biotechnology
2) Recombinant DNA technology
3) Manipulation of gene expression in prokaryotes
4) Heterologous protein production in eukaryotic cells
5) Molecular biotechnology of microbial systems
6) Genetic engineering of plants
7) Transgenic animals
8) Human molecular genetics
CH4302 Applied Microbiology

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The aims of the course are:

1) To introduce students to the characteristics and activities of microorganisms.
2) To provide them with a comprehensive survey of microbial groups with emphasis on pathogenic forms.
3) To let them learn the theories of destruction, removal and inhibition of microorganisms; relationships between infection, immunity, and allergy.
4) To let them learn general mechanisms of virulence with examples from a select number of well-studied bacterial pathogens and will emphasize the interactions and interplay between these bacteria and their hosts.

Student Learning Outcomes

At the end of the course, students will come away with a general knowledge of the various strategies that bacteria use to survive and multiply within their host, and in turn, the strategies used by the host to fend off infections by bacterial pathogens; and have certain knowledge in eukaryotic cell biology and immunology in order to fully appreciate how host defenses play a major role in "shaping" strategies used by the bacterial pathogen.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Introduction to microbiology
2) Microbial nutrition, metabolism, growth and control
3) Microbial molecular biology and genomics
4) Diversity of microbes and ecology
5) Medical microbiology
6) Industrial microbiology
7) Environmental microbiology
CH4303 Bioseparations

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

1) Understand the behaviour of proteins in solution and how their properties may be altered by changing the physical surroundings.
2) Understand operation principles of bioseparation units.
3) Employ engineering calculations and analyses to bioseparation data and problems.
4) Develop conceptual process designs for bioseparation processes.

Student Learning Outcomes

1) Understand the theory and practical techniques involved in developing a purification process.
2) Able to make correct choices for a specific separation problem.
3) Able to design bioproduction process flowsheets for manufacture of commercially valuable biological compounds.

Assessment

Students will be assessed by:
   a) Final 2.5-hour written examination (70%)
   b) Continuous assessment (30%)

Textbooks/References


Topic

1) Introduction
2) Sedimentation, centrifugation and filtration
3) Membrane separations
4) Principles of liquid chromatography
5) Bioprocess development
6) Drug metabolism
7) Group research project and presentation
**CH4305 Special Topics in Biotechnology**
[Lectures: 39 hours; Tutorials: 0 hours; Pre-requisites: NIL Academic Unit: 3]

**Objectives**
The course serves as an introduction to mixed microbial consortia, biofilms, and their biomedical and environmental applications, with the following broad objectives:
- Introduction to bacterial interactions in mixed microbial communities, in both planktonic and biofilms mode of growth.
- Understanding biomedical applications of biofilms and biofilm control
- Understanding electromicrobiology and how redox bioprocesses are applied in emerging environmental biotechnologies.
- Applications of environmental biotechnologies, e.g., detoxification and bioremediation.

**Student Learning Outcomes**
- Understanding of microstructure and activity of mixed microbial consortia
- Role of biofilms in modern biomedical applications
- Up-to-date knowledge in detoxification and bioremediation technologies
- Understanding of industrial implementation of environmental biotechnologies.
- Principles of design of detoxification and bioremediation treatments
- Review of case study from industry and applied research

**Course Assessment**
Students will be assessed on:
Continuous assessment (40%):  
- Mid-term test (Week 5) – 20% (essays and quantitative questions)  
- End-of-term test (Week 10) – 20% (essays and quantitative questions)
Final exam (60%): 2-hour final exam comprises both short essays and quantitative questions, Restricted Open book, where students can bring in 1 Page (2-sided) A4 cheat sheet.

**Course Outline**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture hours</th>
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<tbody>
<tr>
<td>1</td>
<td>Kinetics of Microbial Processes</td>
<td>4</td>
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<tr>
<td>2</td>
<td>Biofilms microstructure and characterization</td>
<td>4</td>
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<tr>
<td>3</td>
<td>Biofilm kinetics</td>
<td>4</td>
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<tr>
<td>4</td>
<td>Biofilm characterization methods</td>
<td>3</td>
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<tr>
<td>5</td>
<td>Biofilm control in biomedical applications</td>
<td>4</td>
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<tr>
<td>6</td>
<td>Detoxification of hazardous chemicals</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Bioremediation</td>
<td>3</td>
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<tr>
<td>8</td>
<td>Bioprocess involving redox reactions</td>
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<tr>
<td>9</td>
<td>Electromicrobiology</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Full-scale application of detoxification and bioremediation</td>
<td>4</td>
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<tr>
<td>11</td>
<td>Microbial Electrotechnology for Biosynthesis and wastewater</td>
<td>4</td>
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<tr>
<td></td>
<td>treatment</td>
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<tr>
<td>Total:</td>
<td></td>
<td>39</td>
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</table>

**References**


CH4306 Biotechnology Techniques
[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Learning Objective

The aims of the course are to introduce students to modern bioanalytical and analytical methods and techniques are used in the study of a host of analytes including drugs, biopharmaceuticals, cells, etc.; to exploit bioanalytical and analytical approaches which are an integral part of quantitative and qualitative analysis in chemical, biochemical and biomedical engineering; to equip students with the theoretical foundations in the interpretation of experimental data from different emerging analytical techniques in different fields of biotechnology; to link with applications of bioanalytical techniques and instrumentation for studying products resulting from biochemical and biological processes, products of metabolic activities, etc.

Course Outline

<table>
<thead>
<tr>
<th></th>
<th>Topics</th>
<th>Lecturer</th>
<th>Lect hrs</th>
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<tbody>
<tr>
<td>1</td>
<td>Biomolecules (Chapter 1)</td>
<td>Tan MH</td>
<td>4</td>
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<tr>
<td></td>
<td>The Human Genome</td>
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<tr>
<td>2</td>
<td>Electrophoresis (Chapter 3)</td>
<td>Tan MH</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Molecular Recognition (Chapter 5)</td>
<td>Tan MH</td>
<td>4</td>
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<tr>
<td>4</td>
<td>Nucleic Acids – Amplification &amp; Sequencing (Chapter 6)</td>
<td>Tan MH</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Special Topics in Functional Genomics</td>
<td>Tan MH</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Mass Spectrometry (Chapter 4)</td>
<td>Dave Ow</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Crystallography</td>
<td>Wang X</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Chromatography (Chapter 2)</td>
<td>Lim S</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Chromatography (Chapter 2)</td>
<td>Lim S</td>
<td>3</td>
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<tr>
<td>10</td>
<td>Protein sequencing (Chapter 7)</td>
<td>Lim S</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Protein sequencing (Chapter 7)</td>
<td>Lim S</td>
<td>3</td>
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<tr>
<td>12</td>
<td>Revision</td>
<td>Lim S</td>
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<td><strong>Total</strong></td>
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<td><strong>39</strong></td>
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Learning Outcome

Upon completion of the course, students will have:

1) A greater understanding of how each of the bio-instrumental techniques covered functions (i.e. what are the components of the instrument and how does each component operate).
2) Better knowledge of where each technique might be applied to yield useful information (i.e. what is measured using the instrument, how sensitive is the technique, etc.).
3) The aptitude for making the calculations necessary for data interpretation in each of the techniques covered (i.e. what does the signal generated by the instrument mean, and how is the signal quantified).
4) An understanding of the theory underlying the operation of each of the instruments discussed (which is useful in diagnosing problems with instrumentation and in optimizing performance).
5) The ability to select an appropriate analytical method for solving a given problem in the field of biological chemistry.

Student Assessment

Students will be assessed by:
   a) 2 Quizzes - 20% each (No make-up)
   b) Final Exam - 60% (closed book exam)

Textbooks/References
CH4307 Biopharmaceutical Engineering

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to:

1) Introduce the basics theories of pharmacokinetics of novel bio-therapeutics
2) Give an in-depth exposes to the design and development of modern drug delivery systems
3) Exploit of the role of pharmacogenetics in drug metabolism using examples of drugs that frequently lead to drug interactions
4) Examine the impact of biopharmaceutics on Drug Product Quality and Clinical Efficacy
5) Introduce the modern applications biopharmaceutics, pharmacokinetics and drug delivery in clinical practice

Student Learning Outcomes

1) A greater understanding of how novel bio-pharmaceutics works
2) A appreciation in the uses of chemical engineering sciences to model pharmacokinetics and drug clearance
3) An aptitude for making the calculations necessary for data interpretation in clinical study
4) An understanding of the theory of drug delivery
5) Rationally design novel therapeutics based on structure-function relationship

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Basic Pharmacokinetics Of Biopharmaceuticals
2) Quantitative Analysis Of Biopharmaceuticalal Administration
3) Physiological Effects On Biopharmaceuticals
4) Drug Delivery Technology
CH4308 Therapeutic Engineering

[Lectures: 39 hours; Tutorials: 0 hours; Pre-requisites: Nil; Academic Unit: 3]

Objectives

The learning objective is to obtain fundamentals of engineered therapeutics. It covers: Basic cell and structural biology; Basic histology; Tissues and Organs; Cell culture; Transport phenomenon; Biomaterials; Tissue engineering scaffolds; Cell-biomaterials interactions; and Tissue engineering case studies.

Student Learning Outcomes

At the end of the course, students will have learnt the fundamentals of biological therapeutics and translations from biomedical engineering based therapeutic strategies to clinical practices.

Course Assessment

Students will be assessed by:
1) Final examination (70%)
2) Continuous assessment (30%)

Textbooks/References


Topics

1) Basic Cell And Structural Biology
2) Basic Histology
3) Tissues And Organs
4) Cell Culture
5) Transport Phenomenon
6) Biomaterials
7) Tissue Engineering Scaffolds
8) Cell-Biomaterials Interactions
9) Tissue Engineering Case Studies
CH4401 Self-Assembly and Nano-structured Systems

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course introduces students to the molecular principles behind self-assembly systems in chemical and biological systems.

Student Learning Outcomes

Students who successfully complete this course will have the skills to do the following:
1) Synthesize colloids and nanoparticles based on reports/recipes in the scientific literature.
2) The principles behind dynamic light scattering to measure nanoparticle sizes.
3) Learn x-ray diffraction to measure atomic structure.
4) Deposit nanoparticles on a substrate (self-assembly).
5) Measure nanoscale features using an AFM and SEM.
6) Write a scientific review paper.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (30%)
2) Continuous assessment (70%)

Textbooks/References


Topics

1) Introduction to nanotechnology
2) Solute and solvent, self assembly of amphiphiles
3) Surfactant structure and properties of micelles
4) Self-assembly of block copolymer systems
5) Self-assembly and templating processes
6) Molecular engineering of nanosystems
CH4403 Introduction to Nanoscale Characterization Methods

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to teach the principles and concepts of materials characterizations and chemical analysis of nanomaterials; and to introduce the topics include basic principles of characterization, instrumentation development, and application platforms to image and probe structural, chemical, electrical, and optical characterizations at nanometer scale.

Student Learning Outcomes

At the end of the course, students will have developed a basic understanding of the state-of-the-art techniques for nanoscale characterizations; and able to exploit the knowledge of this subject in future industrial careers.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (30%)
2) Continuous assessment (70%)

Textbooks/References

1) No recommended text yet.

Topics

1) XRD: X-ray characterization of nanoparticles
2) TEM & STEM: Transmission electron microscopy and scanning transmission electron microscopy of nanoparticles
3) SPM: Scanning probe microscopy of nanoclusters
4) IR & RAMAN: Fourier transmission infrared and Raman spectroscopy of nanoparticles
5) Electrical and electrochemical analysis of nanophase materials
6) Near-field scanning optical microscopy (NSOM)
7) Laboratory
CH4404 Microfabrication and Nanofabrication Technologies

[Lectures: 39 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

The course aims to introduce students to the area of Nanoelectronics and nanotechnology, concentrating on its nanofabrication techniques such as nanolithography, growth and assembly of nanostructures.

Student Learning Outcomes

At the end of the course, students will be able to a) design and analyze basic nanoelectronics devices such as single electron transistors and b) understand the nanofabrication techniques associated with the nanoelectronics devices such as single electron devices, carbon nanotube electronics, next generation memory and storage devices and sensor arrays.

Course Assessment

Students will be assessed by:
1) Final 2.5-hour written examination (30%)
2) Continuous assessment (70%)

Textbooks/References


Topics

1) The micro-world
2) Materials for the micro-world
3) Micro- and nano-machining
4) Metrology below the micrometer
5) Applications
6) Laboratory
1. General background and basic concepts
Introduction; history of catalysis of industrial processes; the catalytic cycle; activity, selectivity, stability; classification of catalysts, comparison of homogeneous and heterogeneous catalysis, biocatalysis; individual steps in heterogeneous catalysis; types of heterogeneous catalysts; energetic and steric aspects of catalytic activity; catalyst performance; catalyst deactivation and regeneration.

2. Heterogeneous catalyst preparation and manufacture
Preparation of catalyst supports, precipitation, sol-gel, hydrothermal synthesis, surfactant-templating synthesis; zeolite and nanoporous materials; generation of surface active components, impregnation, deposition-precipitation, grafting, ion-exchange, microemulsioin; industrial manufacturing process; monolith reactor.

3. Structural and surface characterization
Chemical composition; phase, structure and morphology; surface properties; local structure and chemical bonding.

4. Planning, development and testing of catalysts
Economic importance of catalysis; stages of catalyst development; selection and testing of catalysts in practice; catalytic reactors; catalyst discovery via high-throughput experimentations.

5. Catalysis in solutions
Introduction, Acid-Base catalysis, catalysis by electron transfer, organometallic catalysis, catalysis by macromolecules, Phase transfer catalysis, catalysis by micelles, the influence of diffusion.

6. Catalysis by enzymes
Composition and structure of enzymes, reactions catalyzed by enzymes, nature of catalytic sites: the uniqueness of enzymes as catalysts, examples of enzyme structure and catalysis, supported enzymes.

7. Catalysis by polymers
The nature of polymers, attachment of catalytic groups to polymer supports, catalysis in polymer gels, adsorption and the kinetics of polymer-catalyzed reactions, interaction of catalytic groups: the role of the support, bifunctional and multifunctional catalysis, intraparticle transport influence, Applications of polymer catalysts, Extraparticle transport influence.

8. Catalysis in molecular-scale cavities
Structures of crystalline solids, structures of zeolites, Families of zeolites, adsorption and diffusion in zeolites, the solvent-like nature of zeolites, catalysis by zeolites, nonzeolite molecular sieves, clays and other layered materials.

9. Catalysis on surfaces
Surface structures, adsorption, surface catalysis.
Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hours</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>General background and basic concepts</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Heterogeneous catalyst preparation and manufacture</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Structural and surface characterization</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Planning, development and testing of catalysts</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Catalysis in solutions</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Catalysis by enzymes</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Catalysis by polymers</td>
<td>4</td>
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<tr>
<td>8</td>
<td>Catalysis in molecular-scale cavities</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Catalysis on surfaces</td>
<td>5</td>
</tr>
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<td><strong>Total:</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>

Course Assessment

Students will be assessed on:

a) Class quiz (40%): closed-book. 1.5 h
b) Exams (60%): closed-book. 2 h

This course is for Year 4 students. The quiz weightage is set high at 40% so as to simulate exams format of the paper, to test students on knowledge acquired. Course instructor also do not wish to have too many small quizzes which impedes leaning outcome of students.

Textbook


References


CH4451: Process Engineering for Gas/LNG and Pharmaceutical Industries.
[Lectures: 26 hours; Tutorials: 13 hours; Pre-requisites: nil; Academic Unit: 3.0]

Learning Objective
To learn process engineering in a more advanced level through knowing and practising the subject matters commonly adopted in the industry, such as formulizing design basis in detail, application of the relevant API, IS, ASME codes and standards, preparation of deliverables and time sensitive deliverables, interface issues with other disciplines etc. To build further analytical skillsets to solve more complex and sophisticated industry problems. To link theories to real-life industry problems through solving case studies.

This course would enable students to embark on their professional careers without much on-the-job training and have satisfaction in early stage of their careers being able to deliver products independently. More importantly, this course will help the students to find suitable employment easily in Singapore and other countries.

Content
This course introduces the students to the industry-led process engineering aspects at a more advanced level. The key contents of the course are:

1. Detailed exposure in Gas/LNG driven energy and pharmaceutical industries.
2. Description of the process systems and subsystem of the relevant industries.
3. Reservoir fluid characterization and advanced process simulation with case studies.
4. List of deliverables and its dependency with other disciplines’ deliverables.
5. Preparation of key deliverables in an advanced level with reference to case studies.
6. Awareness of relevant codes and standards that support process engineering deliverables.

Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Lecture Hours</th>
<th>Tutorial hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The opportunities and the industry exposures that help chemical engineers to know roles and responsibilities in their professional career as Process Engineer.</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Process description of various systems and subsystems with reference to the industry types (upstream facilities + export terminals + import terminal+ pretreatment + liquefaction + common + pharma plants etc)</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Well-fluid/FEED characterization and advanced simulation to develop heat and material balance sheets</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Different types of process deliverables and their relative importance and need in project environment.</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>Familiarisation with various codes and standards applicable in the preparation</td>
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</tbody>
</table>
Learning Outcome
This course will help to develop the skillsets needed to become an industry-enabled process engineer. Upon completing this course, the students are expected to be more knowledgeable in process engineering, results-oriented and future-ready to fast forward their professional career.

Student Assessment
Students will be assessed by:
a. Final 2.5-hour, open book written examination (30%)
b. Continuous assessment (70%)
   i) Assignment. Problem sets and case studies will be assigned to students to practise the principles they learned in the class. (30%)
   ii) Group Wise Project Work. Each group of students is expected to solve a specific case study by preparing the assigned process engineering deliverables. This assessment will be based on how well the students understand the various aspects of process engineering with reference to the actual demands in industries, and how insightful and comprehensive in making their analysis. (40%)

Textbooks/References
1. Hand book of Liquefied Natural Gas
   Authors: Saeid Mokhtatab, John Mak, Jaleel Valappil and David A. Wood
   Release date: 24th October 2013, Gulf Publishing company
   ISBN: 978-0-12-404585-9,

   AUTHOR Guo, Boyun; Ghalambor, Ali
   PUBLISHER: Gulf Publishing Company,

3. Pharmaceutical Process Engineering, 2nd Edition (Drugs and Pharmaceutical Science), by Anthony J. Hickey and David Ganderton (Editor)
CH4701/4801 Final Year Design Project

[Lectures: 56hrs; Tutorials: 0hrs; Practicals: 260hrs; Prerequisites: CH3820 or equivalent, Year 4 status; Academic Unit: 8]

Objectives

Students are introduced to the application of chemical and biomolecular engineering principles in chemical design. The projects will include feasibility study, chemical engineering calculations, simulation and modeling of chemical unit operations, process flow chart. Topics include: Introduction to chemical product design; Projects in chemical product design; Introduction to chemical process design; Molecular structure design; Process Creation and Synthesis; Development of Base-Case and Flow Diagrams; Introduction to Simulation software; Heuristics for Process Synthesis; Reactor Design; Synthesis of Separation Trains; Heat and Power Integration; Pinch Analysis; Projects in Process Synthesis.

Students are also introduced to the concepts and methods of plant design and economic evaluation: planning, cost estimation, fixed capital investments, working capital, production costs, depreciation, rate of return, profitability analysis, discounted cash flow analysis. The course also covers computer-aided design, cost estimation, interest and investment costs, profitability analysis, design and cost estimation of equipment, detailed process synthesis and sustainability.

The course aims to raise the awareness of the students to the concepts of supply and demand of raw materials, commodity, and specialty chemicals. Introduce the students to the available computational tools for process flow design and economic evaluation. The emphasis is in motivating students to learn, undertake and manage projects as a team successfully, and to write good technical reports. The importance of professional ethics, honesty, and integrity will be stressed.

Student Learning Outcomes

At the end of the course students will:

1) Work on this capstone design project that utilizes the fundamentals of chemical engineering (material balances, energy balances, transport phenomena, thermodynamics, kinetics, separations, unit operations, and safety) in the design and operation of chemical plants.
2) Be able to undertake and manage projects as a team to its successful completion and to write good technical reports.

Assessment

100% continuous assessment.

Textbooks/References

3) R. Turton, R. C. Bailie, W. B. Whiting, and J. A. Shaeiwitz, Analysis, Synthesis, and

Topics

1) Introduction to Chemical Product Design
2) Introduction to Chemical Process Design
3) Introduction to Simulation software
4) Detailed Process Synthesis
5) Computer-aided design
6) Cost estimation and economic analysis
7) Design and Cost Estimation of Equipment
CH4702 Independent Research Project

[Lab: 117 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

This course allows students to conduct independent research in a topic related to chemical and biomolecular engineering.

Student Learning Outcomes

The students will be able to do independent research in a topic related to chemical and biomolecular engineering.

Course Assessment

Continuous assessment (100%)

Textbooks/References

Nil

Topic

Independent research project
CH4703 Independent Research Project

[Lab: 117 hours; Pre-requisites: Nil; Academic Unit: 3.0]

Objectives

This course allows students to do independent research in a topic related to chemical and biomolecular engineering.

Learning Outcomes

The students will be able to do independent research in a topic related to chemical and biomolecular engineering.

Course Assessment

Continuous assessment (100%)

Textbooks/References

Nil

Topic

Independent research project
CH4901/4911 Engineers & Society

Rowland

[Lectures: 26 hours; Tutorials: 12 hours; Academic Unit: 3.0]

Objectives

This course aims to teach the social, economic, historical and political environment that the engineering profession operates in and the current issues relevant to them. The students will also be required to present and discuss these issues during tutorials and participate in community projects.

Student Learning Outcomes

At the end of the course students would be able to appreciate:

1) How Singapore transited from being a 3rd World to 1st World country and lessons to be learnt.
2) The role engineers play in the development of Singapore and future challenges.
3) Significance of professional ethics and
4) The importance of environmental management to Singapore.

Assessment

1) Final 2.5-hour written examination (50%)
2) Continuous assessment (50%)

Textbooks/References


Topics

1) Evolution of modern Singapore and current issues
2) Technology & Society
3) Ethics & Professionalism
4) The Environment
CH9220 Food Standards – in Food Production

[Lectures and Tutorials: 39 hrs; Pre-requisite: NIL; Academic Units: 3.0; Most of the weeks, 1 hr tutorial session will be combined with 2 hr lectures. Only few weeks, the 1 hr tutorial will be conducted separately.]

Learning Objective

This course will give an introduction into the principles behind as well as the different existing national and international systems for food safety, food control and food standard setting. The increasing globalisation of the food trade, changing consumption patterns, the intensification of agriculture, increasing travel and tourism, and new types of production and manufacturing systems are just some of the trends that are having a serious impact on food production and food safety in many countries. At the same time, a number of existing and new food safety hazards are of increasing concern and new pathogens are frequently emerging and being transferred from animal to human populations, primarily through food. These new challenges are best dealt with in new regulatory frameworks; these frameworks and their background will be explained and described.

Major theoretical topics of the course include:

- Risk Analysis as the basis for food standards
- Risk Assessment – Chemical and Microbiological Hazards
- HACCP – A standardized system for Hazard Control in food production
- Key international and national Food Safety Policies
- ONE HEALTH – Farm-to-Table – Managing risks in the full food production chain
- ASEAN Food Safety Policy and a future ASEAN Regulatory Food Safety Framework
- Singapore Food Standards and Food Control System

Content

Introduction to Food Production, Food Control and Food standard setting. Description of the Risk concept as well as international food policy based on the Risk Analysis framework and the HACCP (Hazard Analysis Critical Control Points) principles for industrial own control. Explanation of the holistic One Health concept, combining animal and human disease prevention and the methodology of science-based risk assessment and stochastic modelling as the basis for food safety improvement. Description of ASEAN and Singapore Food Safety Policies and Control systems.

The increasing globalisation of the food trade, changing consumption patterns, the intensification of agriculture, increasing travel and tourism, and new types of production and manufacturing systems are just some of the trends that are having a serious impact on food production and food safety in many countries. At the same time, a number of existing and new food safety hazards are of increasing concern and new pathogens are frequently emerging and being transferred from animal to human populations, primarily through food. These new challenges are best dealt with in new regulatory frameworks; these frameworks and their background will be explained and described.

A large number of Engineers will be exposed to the use of regulatory systems based on scientific and engineering knowledge. This means that Engineers in a number of areas will be involved in regulatory developments as well as regulatory decisions. It is thus relevant for Engineers to understand the set-up of regulatory systems, such as food safety regulatory
systems – both in under to understand the risk assessment background as well as the risk management decisions relevant to mitigate such risks. The food safety regulatory system is relevant in international, regional and national setting and the understanding of such systems will enable a more coherent knowledge base not only related to food production but also to other related areas, including water technology, drug production, chemical engineering etc.

Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Weeks</th>
<th>Lecture hr</th>
<th>Tutorial hr</th>
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<tbody>
<tr>
<td>1</td>
<td>Introduction to food production chains and food control</td>
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<td>3</td>
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<td></td>
<td>Food control systems – chemical and microbiological</td>
<td>2</td>
<td>3</td>
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<td>2</td>
<td>Principles of Risk analysis</td>
<td>3</td>
<td>3</td>
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<td></td>
<td>Performance of stochastic risk assessment</td>
<td>4</td>
<td>2</td>
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<td></td>
<td>Hazard Analysis Critical Control Points (HACCP)</td>
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<td>3</td>
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<td>3</td>
<td>Int. food safety policies – international Organizations</td>
<td>6</td>
<td>3</td>
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<td></td>
<td>Codex Alimentarius Commission – int. food standards</td>
<td>7</td>
<td>3</td>
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<td></td>
<td>The One Health paradigm – animal / human diseases</td>
<td>8</td>
<td>2</td>
<td>1</td>
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<td>4</td>
<td>ASEAN food safety policies</td>
<td>9</td>
<td>3</td>
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<td></td>
<td>Singapore Food Control System</td>
<td>10</td>
<td>3</td>
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<td>5</td>
<td>Foodborne disease outbreaks,</td>
<td>11</td>
<td>3</td>
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<td></td>
<td>International food contamination events – food scandals</td>
<td>12</td>
<td>2</td>
<td>1</td>
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<tr>
<td></td>
<td>Food safety system break-downs – and recovery</td>
<td>13</td>
<td>3</td>
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</table>

Learning Outcomes

At the end of this course a student is expected to be able to:

- Understand food production chains and the background for hazards and risks in food
- Use science-based risk modelling to understand food safety problems and solutions
- Understand major principles guiding food control systems, including One Health paradigm
- Link food standards from regulatory authority and industry to foodborne disease prevention
- Know the set-up of the Food Control System in Singapore
**Student Assessment**

Students will be assessed on:

a) Individual Written Assignment (25%): Extended essay in which a case study would be analysed under the concepts studied in the course;

b) Class Participation (15%): Students will be assessed on their participation in class discussions and showing of initiative in class activities.

c) Exams (60%): closed-book. 2 hours

**Textbook**


A course reader will be provided.

**Reference**


Food Industry Seminar Series
[Lectures: 39 hours; Tutorials: NA; Pre-requisites: NA; Academic Unit: 3.0]

Learning Objective
This course is aimed to raise awareness among students about real world challenges in food industry around the world and in Singapore.

Content
This seminar course will introduce the students to the Food Industry in Singapore, Asia and beyond. Prominent speakers from various Food MNCs, local SMEs, and regulatory bodies (AVA and/or WHO) will be invited to present every week on various topics and food issues. This will also give the students a valuable opportunity to interact personally with food industries and have a deeper understanding of the food policies and issues around the world.

This course is aimed to raise awareness among students about real world challenges in food industry around the world and in Singapore. Subjects such as food security, food sustainability and food waste management will be the main focus for every week’s seminar.

A convergence of factors has made food security one of the most important global issues. An increasing population wants a more varied diet, but is trying to grow more food on less land with limited access to water, all the time facing increased costs for fertiliser, and fuel for storage and transport.

Even after food is grown, stored and transported, serious losses can occur, and in developing nations where ‘plentiful’ food is wasted. A review of food waste in the US calculated that around 20% of the amount available to consume, was lost from retailing onwards. This translate to 20% of the land, water, labour, seed, pesticide and fertiliser are wasted in the process and thus this is also a financial and environmental loss too.

In view of the growing world population and thus a growing demand in food, most of the food produced today is reflective of an unsustainable food system. This food is dependent on foreign oil, is destroying soil, contaminates water, has caused disease outbreaks, and may be robbing our future generations of the ability to grow food at all.

Course Outline

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Speaker 1: Presentation on Food Security</th>
<th>6 hours</th>
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<tbody>
<tr>
<td>Week 2</td>
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<tr>
<td>Week 3</td>
<td>Speaker 2: Presentation on Food Security</td>
<td>6 hours</td>
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<td>Week 4</td>
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<td>Week 5</td>
<td>Speaker 3: Presentation on Food Sustainability</td>
<td>6 hours</td>
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<td>Week 6</td>
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<td>Week 7</td>
<td>Mid-Term Projects Presentations</td>
<td>3 hours</td>
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<tr>
<td>Week 8</td>
<td>Speaker 4: Presentation on Food Sustainability</td>
<td>3 hours</td>
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<tr>
<td>Week 9</td>
<td>Speaker 5: Presentation on Food Waste Management</td>
<td>6 hours</td>
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<td>Week 10</td>
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<tr>
<td>Week 11</td>
<td>Speaker 6: Presentation on Food Waste Management</td>
<td>6 hours</td>
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<td>Week 12</td>
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<tr>
<td>Week 13</td>
<td>Final Projects Presentations</td>
<td>3 hours</td>
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</table>
Learning Outcome
Students will be more aware of global food issues from the perspectives food MNCs and food regulatory bodies from around the world. Students will learn to identify and recognize important food issues such as:

Food Security
• Smart technology for primary production
• Enhance process in house capabilities
• Ensure food is safe for consumption

Food Sustainability
• Novel technology for prolonged food shelf life
• Nutrition profiling for healthy lifestyle

Food Waste Management
• Food waste conversion to food ingredients
• Food waste utilization for wider applications

Student Assessment
Students will be assessed by Continuous Assessments (100 %):
CA may consist of projects, assays and/or assignments and will be based on the contents of the seminars/lectures within the scope of food security, food sustainability and food waste.

Weekly Individual Assays/Assignments: 20% (Report writing of project assignments)
Mid-term Group Project/Presentation: 40% (Report writing of project assignments)
Final Group Project/Presentation: 40% (Report writing of project assignments)

Textbooks/References
NA.
COURSE CONTENT

Date : 7 June 2017
Academic Year : AY16/17 (Special Semester Term II)
Study Year (if applicable) : NA
Course Code & Title : CH9301: Emerging Technologies in Energy Conversion and Storage
Academic Unit : 3 AU
Pre-requisite : nil

Course Description : The course aims to provide students with the fundamental knowledge on the emerging energy technologies. This includes technologies that are expected to be the next state-of-the-art in the near future, from innovative clean energy conversion to energy storage. The acquired knowledge shall equip students for the rapidly evolving energy frontiers, and serve as a common ground for potential innovations in these technologies.

CH9301: Emerging Technologies in Energy Conversion and Storage
[Lectures: 26 hours; Tutorials: 13 hours; Pre-requisites: nil; Academic Unit: 3.0]

Learning Objective
Students will learn the concept of ultraclean fuel processing and apply the principles of chemical equilibria, understanding the principles of semiconductor and the operation of different type of solar cells, using Gibbs free energy to predict the performance of fuel cells and batteries, and finally the designing materials for the storage of hydrogen.

Content
- Reactions and principles of chemical equilibria involved in gas-to-liquid conversion, clean coal technologies, and carbon capture and storage
- First, second and third generation solar cells, p-n junction, liquid junction solar cells
- Gibbs free energy, hydrogen fuel cells, direct methanol fuel cells, solid oxide fuel cells
- Rechargeable and non-rechargeable batteries, Li-ion batteries
- Symmetrical and non-symmetrical supercapacitors, electrical double layer
- Hydrogen storage, metal hydrides, carbon-based storage materials

Course Outline
| Day | Morning class (0930-1230) |
Learning Outcome
After successful completion of the course, the students should be able to:

- Describe basic principles in the conversion of fossil fuel (coal and natural gas) to ultraclean fuel, as well as their importance in the future energy equation; describe the process of carbon capture and storage and its importance in the integration of fossil fuel utilization;

- Describe the various means of solar energy conversion from first to third generation photovoltaic solar cells, and photoelectrochemical conversion; describe the working principles of different fuel cells, namely hydrogen fuel cell, direct methanol fuel cell and solid oxide fuel cell; and

- Describe the principles of energy storage through lithium ion batteries and supercapacitors, and their advantages; describe the principles of hydrogen storage such as metal hydrides and carbon nanotubes.

Student Assessment
Student will be assessed based on 100% continual assessments consisting of:

(i) Continuous assessment 1, 2 & 3
   a. CA1 (1hr), 25%
      Topic 1: Ultraclean fuel processing and Reaction equilibria (4hr lecture, 2hr tutorial)
      Topic 2: Solar cells (3hr lecture, 2 hr tutorial)
   b. CA2 (1hr), 25%
      Topic 3: Fuel cells (4hr lecture, 2hr tutorial)
      Topic 4: Batteries (3hr lecture, 2 hr tutorial)
   c. CA3 (1hr), 25%
      Topic 5: Supercapacitors (4hr lecture, 2hr tutorial)
      Topic 6: Hydrogen storage (3hr lecture, 2hr tutorial)

(ii) Literature review on selected topics (25%)

Continuous assessment (assignment) will be handed out in Classes 4, 8 and 12. Review (3hr).

Textbooks/References

Course coordinator: A/Prof Timothy Tan (SCBE, NTU)
Course Instructor: A/Prof Wey Yang Teoh (City University, Hong Kong)