Faculty of Engineering and Applied Science

CHEE 321 – CHEMICAL REACTION ENGINEERING

Course Syllabus – Fall 2020

This is your course syllabus. Please download the file and keep it for future reference.

TEACHING TEAM

COURSE INSTRUCTOR

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CHEE 321 (F 3-0-0.5 3.5)

COURSE DESCRIPTION[1]

This course provides a detailed and in-depth analysis to the principles of chemical kinetics, and reactor analysis and design. The topics in chemical kinetics include: rate constants, reaction order, rate equations for elementary and complex reactions, kinetic data analysis, and product distribution. In reactor analysis and design, discussion is focused on ideal reactor systems and arrangements, including batch reactors, plug flow reactors, continuous stirred tank reactors, and recycle reactors. The last part of the course considers homogeneous and heterogeneous catalytic reactions. The design component consists of how to make an appropriate choice of reactor type and operating conditions to optimize a desired product; sizing such reactors and determining conversion levels under various conditions of temperature and pressure; determination of reaction kinetics from experimental data. (0/0/0/30/12)

Prerequisites: CHEE 210, (CHEE 222 or MINE 201), or permission of the department.

COURSE LEARNING OUTCOMES (CLO)

The objective of this course is to develop general methodologies for analysis and design of a variety of systems (chemical, biochemical/biological, polymer, electrochemical) for which engineering of reactions is needed. In the first part of the course, basic concepts of chemical kinetics and chemical reactor design as related to simple reaction systems will be introduced. Topics covered will include the general mole balance, reactor types, conversion and reactor sizing, rate laws and stoichiometry and isothermal reactor design. In the second part of the course, we will build upon the concepts developed in the first half of the course to describe real systems that deal with complex reactions and non-ideal reactors. Topics to be covered will include non-isothermal reaction design (energy balances), multiple reactions and reaction pathways, non-ideal reactors/residence time distribution (time permitting), and heterogeneous reactions (time permitting).

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[1] Course Author(s): Michael Cunningham. 1st Edition (initial development): Fall 2020; Queen's University holds a license for the use of the Course Author's Intellectual Property for MNTC 000.

By the end of this course, students should be able to:

CLO	DESCRIPTION	INDICATOR
CLO 1	Calculate operating parameters (size, flowrates, conversion, etc.) for isothermal and non-isothermal operation of ideal well-mixed batch and continuous reactors, and for ideal plug-flow reactors.	KB-ES-Process (c)
CLO 2	Formulate a set of consistent material and energy balance equations to describe operation of batch, semi-continuous and continuous reactor systems with single or multiple reactions, operating with and without heat exchange.	KB-ES-Process (a)
CLO 3	Develop stoichiometric tables and formulate an overall rate expression from a series of elementary mechanistic steps, taking into account the dependence of temperature, pressure and concentration, as well as the requirement of thermodynamic consistency for reversible equations.	KB-ES-Process (b)
CLO 4	Choose an appropriate reactor type and operating conditions to achieve a desired output such as reactant conversion, selectivity and yield.	KB-ES-Process (c) DE Solutions

This course assesses the following attributes at the 3rd year level:

Knowledge base, Engineering Science (**KB-ES**): **Process (a)** Formulates and solves steady-state and dynamic mass and energy balances for a chemical process. **Process (b)** Analyzes kinetic mechanisms, identifies rate limiting steps and develops expressions to describe reaction rates for non-catalytic, catalytic, or electrochemical processes. **Process (c)** Applies engineering principles to do engineering calculations and size various unit operations, including pumps, heat exchangers, separation processes, and reactors.

Design (DE): **Solutions** Create a product, process or system to solve a problem, that meets specified needs, and subject to appropriate iterations

Relevance to the Program

This 3rd year course is the main course covering the engineering science of chemical kinetics, reactor analysis, as well as reactor design. The engineering science and reactor design skills taught in this course are considered essential for any practicing Chemical Engineer. The knowledge acquired in this course is required in CHEE 323 "Industrial Catalysis" and CHEE 470 "Design of Manufacturing Processes". The course assumes knowledge of 2nd year thermodynamics, as well as knowledge of material covered in CHEE 222, process dynamics and numerical methods.

Course Structure and Activities

3 lecture hours + 1 tutorial hour per week. Times and locations can be found in SOLUS.

Expectations for lectures/tutorials

Lectures

Lecture slides will be posted on the course website. Students are expected to read associated sections and study worked examples in the textbook.

Tutorials

The class is divided into two tutorial sections. Tutorial problems for the week will be posted. As well as working on the tutorial problem (solutions to be guided by the TAs), you will have the opportunity to ask the TAs questions related to assignment problems and lecture materials via email.

Assignments

A set of unmarked practice questions will be given for each course module, with solutions posted later.

COURSE EVALUATION

ASSESSMENT WEIGHTING

Assessment Tool	Date	Weight	Alignment with CLOs
Midterm	To be finalized	35%	1, 2, 3, 4
Final Exam	Exam Period	65%	1, 2, 3, 4
		100%	

ASSESSMENT DESCRIPTIONS

Midterm

Mid-term will be a 1-hour CLOSED BOOK examination part way through the course (date to be determined). You will be tested on the fundamental concepts related to course material covered to that point.

Final Exam

The final examination will be a 3-hour CLOSED BOOK examination and will cover all material covered in the class, tutorial and assignments.

Remote Proctoring - Proctortrack

The midterm and final exam in this course will use remote proctoring provided by a third-party, cloud-based service that enables the completion of a proctored exam or test from an off-campus location, through onQ or Elentra. This online proctoring solution was chosen as part of the approach to maintaining academic integrity in online assessment. When writing tests/exams using remote proctoring, you are connecting to the third-party service. Queen's has conducted a privacy and security review of the service and has entered into a binding agreement with terms that address the appropriate collection, use and disclosure of personal information in accordance with Ontario's privacy legislation. You should also take measures yourself to protect your information by keeping your NetID password and challenge questions private, closing all applications prior to starting an exam/test, and ensuring your device is updated and

safeguarded against malware. For more information about remote proctoring, see the Student FAQs on the VPTL/ITS Resource page for remote proctoring.

GRADING

All assessments in this course will receive numerical percentage marks. The final grade you receive for the course will be derived by converting your numerical course average to a letter grade according to the established Grade Point Index.

Accessing Your Final Grade

Your final grades will show on SOLUS. Official transcripts showing final grades will be available on the Official Grade Release Date. Please note that in official transcripts, a mark of IN (incomplete) is considered a grade, and your transcript is released with this grade.

COURSE MATERIALS

Required Textbook

- H. Scott Fogler, Essentials of Chemical Reaction Engineering (2nd Edition)

Course notes and other course-related material All other course material is accessible via OnQ.

Required Calculator

- A Casio 991 is required. **ONLY** this type of non-programmable, non-communicating calculator will be allowed during tests and exams.

Required Hardware/Software

Students must have a reliable internet connection and hardware that are compatible with online learning and remote proctoring system requirements.

Suggested Time Commitment

This course represents a study period of 6 weeks. Learners can expect to invest on average 14-18 hours per week in this course. Learners who adhere to a pre-determined study schedule are more likely to successfully complete the course.

HOW TO DO WELL IN THIS COURSE

Significant practice is required to solve problems efficiently and correctly in an exam setting. Students are encouraged to make use of all resources available, including the textbook and solved posted problems. Students are expected to utilize the concepts and to implement the methods taught in class to tackle a variety of problems that they may encounter in assignments/midterms/exams.

COURSE SCHEDULE

CHEE 321 || Module overview
Course learning outcomes (CLO): Students will be able to:
1. Calculate operating parameters (size, flowrates, conversion, etc.) for isothermal and non-isothermal operation of ideal well-mixed batch and continuous reactors, and for ideal plug-flow reactors. 2. Formulate a set of consistent material and energy balance equations to describe operation of batch, semi-continuous and continuous reactor systems with single or multiple reactions, operating with and without heat exchange. 3. Develop stoichiometric tables and formulation of an overall rate expression from a series of elementary mechanistic steps, taking into account the dependence of temperature, pressure and concentration, as well as the requirement of thermodynamic consistency for reversible equations. 4. Choose an appropriate reactor type and operating conditions to achieve a desired output such as reactant conversion, selectivity and yield.
Students are expected to augment lecture material through reading of associated sections of the textbook, and to practice execution of course principles by completing posted problem sets

Module	Lecture approach and content	Tutorial approach and content	Assessment (CLO, and % of course grade)
Module 1	**Reactions and the GMBE** • Reaction Rates, Rate Laws and Stoichiometry • The General Mole Balance Equation (GMBE) and Ideal Reactors • Estimating Rates from Experimental Data	Worked examples, based on lecture material A set of practice problems is also posted (unmarked)	Material is included on mid-term (CLO1)
Module 2	**Isothermal Reactors: Single Reaction in Batch, CSTR, PFR** • Solving Problems using Stoichiometric Tables • Levenspiel Plots (Reactor Sizing) and Multiple Reactors • Reversible Reactions	Worked examples, based on lecture material A set of practice problems is also posted (unmarked)	Material is included on mid-term (CLO1, CLO4)
Midterm	**Covers Modules 1 and 2**		***Midterm exam:*** *2-3 questions will target CLO1, worth 25% of course grade*
Module 3	**NonIsothermal Reactor Design** • Forms of the Energy Balance (EB); Isothermal and Adiabatic • CSTR with the EB; multiple steady-states • PFR with the EB	Worked examples, based on lecture material A set of practice problems is also posted (unmarked)	Material is included on final (CLO1, CLO2, CLO4) Design assignment (15%, CLO1, CLO2, CLO4)

Module 4	**Multiple Reactions** • GMBE and EB with Multiple Reactions • Selectivity and Yield	Worked examples, based on lecture material A set of practice problems is also posted (unmarked)	Material is included on final (CLO1, CLO2, CLO4)
Module 5	**Reaction Networks and Pathways**	Worked examples, based on lecture material A set of practice problems is also posted (unmarked)	Material is included on final (CLO3)
EXAM			***Final exam:*** *One-two questions will target each CLO, worth 60% of course grade*

COURSE COMMUNICATION

NETIQUETTE

In this course, you may be expected to communicate with your peers and the teaching team through electronic communication. You are expected to use the utmost respect in your dealings with your colleagues or when participating in activities, discussions, and online communication.

Following is a list of netiquette guidelines. Please read them carefully and use them to guide your online communication in this course and beyond.

1. Make a personal commitment to learn about, understand, and support your peers.
2. Assume the best of others and expect the best of them.
3. Acknowledge the impact of oppression on the lives of other people and make sure your writing is respectful and inclusive.
4. Recognize and value the experiences, abilities, and knowledge each person brings.
5. Pay close attention to what your peers write before you respond. Think through and re-read your writings before you post or send them to others.
6. It's alright to disagree with ideas, but do not make personal attacks.
7. Be open to be challenged or confronted on your ideas and challenge others with the intent of facilitating growth. Do not demean or embarrass others.

8. Encourage others to develop and share their ideas.

Course Announcements

The instructor will routinely post course news in the Announcements section on the main course homepage on OnQ. Please sign up to be automatically notified by email when the instructor posts new information in the Announcements section. Instructions on how to modify your notifications are found in the **Begin Here** section of the class website.

Office Hours (by appointment)

Questions concerning assignments should be directed to the TAs. Conceptual questions about course material should be directed to Dr. Cunningham.

Confidential Matters

If you have a confidential matter you would like to discuss with your instructor, their contact details are on the first page of this document. Expect email replies within 48 hours.

COURSE POLICIES

Please review the following policies concerning copyright, academic integrity, absences and academic accommodations:

COPYRIGHT

The material presented in this course is intended for use as part of the course at Queen's University and is the property of the instructor unless otherwise stated. Copying this material for distribution (e.g. uploading material to a commercial third-party website) can lead to a violation of Copyright law and constitutes a violation of Academic Integrity.

ACADEMIC INTEGRITY

As an engineering student, you have made a decision to join us in the profession of engineering, a long-respected profession with high standards of behaviour. As future engineers, we expect you to behave with integrity at all times. Please note that Engineers have a duty to:

- Act at all times with devotion to the high ideals of personal honour and professional integrity.
- Give proper credit for engineering work

The standard of behaviour expected of professional engineers is explained in the Professional Engineers Ontario Code of Ethics. Information on policies concerning academic integrity is available in the Queen's University Code of Conduct, in the Senate Academic Integrity Policy Statement, on the Faculty of Engineering and Applied Science website, and from your instructor.

Departures from academic integrity include plagiarism, use of unauthorized materials or services, facilitation, forgery, falsification, unauthorized use of intellectual property, and collaboration, and are antithetical to the development of an academic community at Queen's. Given the seriousness of these matters, actions which contravene the regulation on academic integrity carry sanctions that can range from a warning or the loss of grades on an assignment to the failure of a course to a requirement to withdraw from the University. In the case of online exams, impersonating another student, copying from another student, making information available to another student about the exam questions or possible answers, communicating with another person during an exam or about an

exam during the exam window, or accessing unauthorized materials, including smart devices, are actions in contravention of academic integrity.

Late Policy

Any applicable late penalties are described in the details for each assessment. In the event of extenuating circumstances, you may request an extension to an assignment due date without penalty. Requests must be made to your instructor prior to the original due date of the assignment, and some substantiating documentation is often required (see information below on absences). Note that unacceptable reasons include extra-curricular activities, travel plans, generally behind on schoolwork, etc. In the absence of substantiating documentation, the normal late penalty will apply as described in the assignment or departmental policies.

Absences (Academic Considerations) and Academic Accommodations

For absences and academic accommodations please review the information on the FEAS website.

ACADEMIC AND STUDENT SUPPORT

Queen's has a robust set of supports available to you including the Library, Student Academic Success Services (Learning Strategies and Writing Centre), and Career Services. Learners are encouraged to visit the Faculty of Engineering and Applied Science Current Students web portal for information about various other policies such as academic advisors, registration, student exchanges, awards and scholarships, etc.

Individual Needs and Support

If you have a disability or health-related condition that may require academic accommodations, please approach the Queen's Accessibility Services. The staff at Accessibility Services are available by appointment to develop individualized accommodation plans, provide referrals, and assist with advocacy. The sooner you let us know your needs, the better we can assist you in achieving

your learning goals. For questions or assistance with requesting Academic Consideration or Accommodation, contact the FEAS Academic Accommodation Coordinator at engineering.aac@queensu.ca

Every effort has been made to provide course materials that are accessible. For further information on accessibility compliance of the educational technologies used in this course, please consult the links below.

EDUCATIONAL TECHNOLOGY	ACCESSIBILITY COMPLIANCE INFORMATION
onQ (Brightspace Learning Management System by D2L)	https://www.d2l.com/accessibility/standards/
RocScience	https://www.rocscience.com/
Google Spreadsheets	https://www.google.com/accessibility/products-features/

If you find any element of this course difficult to access, please discuss with your instructor how you can obtain an accommodation.

ACCOMMODATIONS RELATED TO REMOTE ASSESSMENT

To have your accommodations applied to a remote-proctored exam please follow the instructions for submitting your information, as outlined on the QSAS website. Your accommodations will be incorporated into your exam session by the Queen's University exam coordinators, on behalf of your course instructor. This information is uploaded automatically to Examity/ Proctortrack. Please note that exam accommodations that are uploaded for a specific exam are not visible to students. For example, extra time is calculated and added automatically to the exam duration but is only visible to students once they begin their exam in the Exam Portal.

If you are already registered with QSAS and you require additional accommodations related to remote-proctored exams, please consult with your QSAS advisor to update your Letter of accommodation as appropriate.

Religious Observance

Students in need of accommodation for religious observance are asked to speak to their professor within a week of receiving their syllabus. Please note that Rosh Hashanah falls on the eve of September 18, 2020 so students in need of accommodation should speak to their professors right away. Note also that alternative assignments are considered a "reasonable accommodation" under the Ontario Human Rights Code. Students with questions about their rights and responsibilities regarding religious accommodation should contact Chaplain Kate Johnson via Chaplain@queensu.ca.

Technical Support

Some basic comfort level with basic hardware and software skills are required for this course. If you require technical assistance, please contact Technical Support.

Supportive Personal Counselling

If at any time you find yourself feeling overwhelmed, anxious, sad, lonely, or distressed, consider confidential supportive counselling offered by the embedded counselors at the Student Wellness Service Faculty of Engineering and Applied Science.

Inclusivity Statement

Queen's students, faculty, and staff come from every imaginable background – small towns and suburbs, urban high rises, Indigenous communities, and from more than 109 countries around the world. You belong here: https://www.queensu.ca/inclusive/.