Faculty of Engineering and Applied Science

CHEE 380

BIOCHEMICAL ENGINERING

Course Syllabus – Fall 2021

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

Land Acknowledgement

Queen's University is situated on traditional Anishinaabe and Haudenosaunee Territory.
See: http://www.queensu.ca/encyclopedia/t/traditional-territories

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 100 countries around the world. You belong here: https://www.queensu.ca/inclusive/.

TEACHING TEAM

COURSE INSTRUCTOR

Louise Meunier, PhD
Chemical Engineering
Queen's University

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Office: Dupuis 211

Please check the course website for an up-to-date list of Teaching Assistants (TAs) and other course personnel.

COURSE INFORMATION

COURSE DESCRIPTION[1]

Biochemical Engineering involves the application of Chemical Engineering principles and approaches to biologically based systems and processes. Biochemical Engineering is central to the area of environmental engineering, and to biotechnology processes which produce pharmaceuticals, fine chemicals, and genetically engineered products. The course involves a systematic and quantitative description of medium formulation and sterilization, microbial kinetics and bioreactor design, product isolation and purification, and examples of current industrial practices and processes (0/0/0/30/12).

COURSE LEARNING OUTCOMES (CLO)

The objective of this course is to develop a systematic and quantitative description of medium formulation, medium and equipment sterilization, cell growth kinetics, bioreactor and bioprocess design, and product isolation and purification. Students will be introduced to several current biochemical engineering-based processes.
Specific course learning outcomes include:

CLO	DESCRIPTION	INDICATORS
CLO 1	Design culture medium based on nutritional requirements of microbial cells.	KB-ES-Biochem (a)
CLO 2	Specify design criteria for medium sterilization and solve problems involving both batch and continuous sterilization.	KB-ES-Biochem (b)
CLO 3	Apply the principles of microbial growth kinetics in bioreactors.	KB-ES-Biochem (b) KB-ES-Process (b)
CLO 4	Simulate and evaluate bioreactor performance.	KB-ES-Biochem (b) KB-ES-TrPh (b)
CLO 5	Apply mass and heat transfer correlations to bioreactor design.	KB-ES-Process (c) KB-ES-TrPh (a)
CLO 6	Design a complete bioreactor based on targets, constraints and physical properties.	DE-Solutions DE-Assess CO-Written
CLO 7	Identify suitable process instrumentation for monitoring and control of bioreactors.	KB-ES-Biochem (b) KB-ES-TrPh (b) ET-Apply
CLO 8	Know and select process unit operations for product recovery and purification.	KB-ES-Biochem (a) DE-Solutions

[1] Course Author: L. Meunier: Biochemical Engineering, Fall 2021; Queen's University holds a license for the use of the Course Author's Intellectual Property for CHEE 380.

This course develops the following attributes at the 3rd-year level:

Knowledge base, Engineering Science (**KB-ES**): **Biochem (a)** Applies knowledge of cellular processes to engineering problems**. Biochem (b)** Applies foundations of science and engineering to analyze and solve biological, physiological, pharmaceutical, and/or environmental problems or processes. **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. **TrPh (a)** Formulates and applies integral mass, momentum, and energy balances to do engineering calculations. **TrPh (b)** Formulates and applies differential mass, momentum, and energy balances to do engineering calculations.

Problem Analysis (PA): **Evaluate** Analyze solutions to complex engineering problems to draw conclusions.

Design (DE): **Solutions** Create a product, process, or system to solve a problem, that meets specified needs, and subject to appropriate iterations. **Assess** Evaluate performance of a design, using criteria that incorporates specifications, limitations, assumptions, constraints, and other relevant factors.

Engineering Tools (ET): Apply and manage appropriate techniques, apparatus, databases, models, tools, and/or processes to accomplish a task.

Communication Skills (CO): Written Produce clear, concise, precise, and well-organized written communication with language appropriate for the audience.

Relevance to the Program

CHEE 380 is a core course for Chemical Engineering students. It is an introductory course in Biochemical Engineering and builds upon principles of fluid mechanics, thermodynamics, heat and mass transfer (CHEE 223, 210, 330), and cell biology introduced in CHEE 229 and other fundamental biology courses. The concepts learned in this course are utilized in subsequent courses dealing with environmental and biochemical processes.

Course Structure and Activities

36 lecture hours + 12 tutorial hour per term. Please refer to SOLUS for times and locations.

Expectations for Lectures, Tutorials, and Assignments

Lecture slides and relevant handouts are posted in advance on Queen's Learning Management System (LMS, online). Lectures include examples, video clips, and problem solutions. Students are expected to review the material ahead of scheduled lecture time to promote discussions and a more in-depth understanding of the concepts. Tutorials are geared toward solving problems relevant to biochemical engineering and design. For tutorial sessions, students are expected to work on a draft solution ahead of time. Maximum benefits can be gained only if students come prepared for tutorial sessions by studying the questions in advance. Additional suggested problem sets (and solutions) will be posted on the LMS to help students apply course concepts.

In group assignments, each group member is expected to contribute fairly and equitably. In the event of serious deficiencies in the contributions (*e.g.*, observed by instructor, through peer assessments, or through complaints from other group members and/or teaching assistants), the student will be issued a written warning, stating the expectations and timeline for remediation and compliance. The student may be assigned individual work to compensate for the lack of contribution. If the student does not comply within the specified time frame, a second written warning will be issued (with a copy to the Associate Head and Undergraduate Chair). Failure to comply will result in automatic expulsion from the group, and possibly a failing mark in the assignment and/or in the course. A peer evaluation form is available through the LMS. This form may be filled out by a group member at any time during the semester. The form must be submitted to the instructor, who will take appropriate action in response to this submission (response may include a request for each group member to fill out a peer evaluation, individual meetings, group meetings, and follow up action as described above).

COURSE MATERIALS

Textbook and Resources

The following textbook is recommended for CHEE 380; most lectures are supported by suggested readings from this textbook, which students are expected to complete ahead of scheduled lectures. Problem sets also refer to suggested problems and exercises from this textbook:

- *Bioprocess Engineering: Basic Concepts*, 3rd Edition. ML Shuler, F Kargi and M. DeLisa, 2017 (available at Queen's campus bookstore, or may be purchased online; may also be consulted online through Queen's Library – however only three simultaneous licences are available).

The following textbooks are available at Stauffer Library on reserve – 3-hour loan:

- *Biochemical Engineering Fundamentals*, JE Bailey, DF Ollis, 1986;
- *Bioprocess Engineering: Basic Concepts*, 2nd Edition. ML Shuler and F Kargi, 2002;
- *Bioprocess Engineering Principles*, PM Doran, 1995;
- *Biochemical Engineering.* HW Blanch, DS Clark, 1997.

Other Material

All course material is accessible through the course LMS.

Learning Support

- Instructor and TAs are available by appointment (through e-mail).
- Additional review and help sessions may be scheduled as required during the term.

COURSE EVALUATION

Deliverable	Week or Date	Weight%	CLOs
Quizzes (2)	After Module 2	15	1,2,3
	After Module 4	15	4,5,6
Written Assignments (2); may be completed individually or in groups of up to 4 students	After Module 2	10	1,2,3
	After Module 4	15	4,5,6
Final Exam	Exam period	45	All

Assessment Descriptions

Two quizzes and a final exam are scheduled in this course. Students are required to acknowledge an academic integrity statement before accessing each test. Quizzes are designed to provide learners with punctual feedback on their knowledge.

The final exam and some tests in this course will normally be administered on campus; however, some may use remote proctoring provided by Proctortrack. Proctortrack is a service that enables the completion of a proctored exam or test from an off-campus location, through the course LMS. This online proctoring solution was chosen as part of the approach to maintaining academic integrity. For more details about this tool: https://www.queensu.ca/its/remote-proctoring-solutions/proctortrack. Information about how Proctortrack will be used in this course will be posted on the course LMS.

This course makes use of Turnitin, a third-party application that helps maintain standards of excellence in academic integrity. Normally, students will be required to submit their course assignments to through onQ to Turnitin. In doing so, students' work will be included as source documents in the Turnitin reference database, where they will be used solely for the purpose of detecting plagiarism.

Turnitin is a suite of tools that provide instructors with information about the authenticity of submitted work and facilitates the process of grading. Turnitin compares submitted files against its extensive database of content and produces a similarity report and a similarity score for each assignment. A similarity score is the percentage of a document that is similar to content held within the database. Turnitin does not determine if an instance of plagiarism has occurred. Instead, it gives instructors the information they need to determine the authenticity of work as a part of a larger process.

Please read Turnitin's Privacy Pledge, Privacy Policy, and Terms of Service, which governs users' relationship with Turnitin. Also, please note that Turnitin uses cookies and other tracking technologies; however, in its service contract with Queen's Turnitin has agreed that neither Turnitin nor its third-party partners will use data collected through cookies or other tracking technologies for marketing or advertising purposes. For further information about how you can exercise control over cookies, see Turnitin's Privacy Policy.

Turnitin may provide other services that are not connected to the purpose for which Queen's University has engaged Turnitin. Your independent use of Turnitin's other services is subject solely to Turnitin's Terms of Service and Privacy Policy, and Queen's University has no liability for any independent interaction you choose to have with Turnitin.

GRADING

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

Students must pass the individual examination component (combined mark on quizzes + final) to pass the course, as stated in Departmental Policy. Attendance at mid-term (quizzes) and final exam is mandatory. No make-up mid-terms will be provided. Marks assigned to the mid-term may be transferred to the final exam for a medical reason supported with proper documentation following the stipulations of the departmental policy.

Practice problems, tutorials, and assignments will be completed during the term. The aim of these exercises is to apply the theory presented in the course. Assignments completed on paper (see specific assignment instructions) must be scanned and combined into a single PDF (see detailed schedule below). Only one submission per group, with the name of each group member clearly indicated. Each member of a group is responsible for the entire contents of their group assignment submission. Group submissions will be graded as a whole, and each group member will receive the same mark. Assignment solutions and reports may be hand-written (pen or pencil), or typed, but must be complete and fully support the answers.

Feedback on Assessments

The teaching team will provide feedback on graded activities. Markers will take the time necessary to provide detailed feedback on assessed tasks and tests; the goal is to return marked activities within seven days following the due date.

To be eligible for mark reassessment (of assignments or tests), a request must be submitted within one weeks of the initial return date along with a mark reassessment form (available on the course LMS) and the complete original submission. Please note that a selection of marked assignments and quizzes will be archived.

Accessing Final Grade

Final grades will be posted 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.

HOW TO DO WELL IN THIS COURSE

This course introduces important concepts in biochemical engineering that range from simple to complex. Students are expected to apply the concepts and to implement the methods taught in class and presented in the textbook. These concepts will be tested in assignments, quizzes, and a final exam, and students must be capable of extrapolating the applications to a variety of problems in the context of this course. As such, significant practice is required to formulate and solve problems efficiently and correctly. Students should plan on attending lectures and tutorials having prepared for the session as detailed on the course LMS. Students are expected to assimilate new concepts and methodologies presented, to practice by solving suggested problem set questions, and to seek help from the teaching team when they do not understand the concepts. Students are expected to remember and apply concepts taught in previous courses.

To obtain full marks, problem solutions must include the complete methodology, as well as clearly labeled diagrams where appropriate. For questions involving multiple parts, partial credit may be given for correct

methodology, but the final answer must also be correct. If the answer does not reflect the expected outcome, or if it is not physically representative, then the student is encouraged to provide comments, using critical analysis skills, to point out any outstanding issue. All relevant assumptions must be stated, and proper units must be included.

Suggested Time Commitment

This course is offered through one semester, normally spanning 12 weeks. Delivery may be compressed to a six-week format. Learners can expect to invest on average 2-3 hours per lecture hour. Learners who adhere to a pre-determined study schedule are more likely to successfully complete the course.

COURSE COMMUNICATION

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

Following is a list of etiquette and *netiquette* guidelines that the teaching team and Queen's personnel has adopted. Please read them carefully and use them to guide in-person and 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 words and writings are respectful and inclusive.
4. Recognize and value the experiences, abilities, and knowledge each person brings.
5. Pay close attention to what your peers say and write before you respond. Think through your response formulation and re-read your writings before you post or send them to others.
6. Be kind and courteous. 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 teaching team will routinely post course news in the Announcements section on the course LMS. Please sign up to be automatically notified by email of these posts. Instructions on how to modify your notifications are available on the LMS platform.

Office Hours

In addition to interaction through Q&A sessions, students can interact in a synchronous fashion with either a TA or the instructor through office hours. A schedule for office hours will be determine in consultation with the class at the beginning of the term. Students may also contact the teaching team by e-mail to ask questions and/or to request an appointment. Points of contact are available on the course LMS home page.

Confidential Matters

Students who wish to discuss a confidential matter can reach the instructor by e-mail to make an appointment. The instructor will normally reply within 48 hours during workdays.

COURSE POLICIES

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

COPYRIGHT

Course materials created by the course instructor, including all slides, presentations, synchronous and asynchronous course recordings, handouts, tests, exams, and other similar course materials, are the intellectual property of the instructor. It is a departure from academic integrity to distribute, publicly post, sell, or otherwise disseminate an instructor's course materials or to provide an instructor's course materials to anyone else for distribution, posting, sale, or other means of dissemination, without the instructor's express consent. A student who engages in such conduct may be subject to penalty for a departure from academic integrity and may also face adverse legal consequences for infringement of intellectual property rights and, with respect to recordings, potentially privacy violations of other students.

ACADEMIC INTEGRITY

Engineering students have made a decision to join the profession of engineering, a long-respected profession with high standards of behaviour. As future engineers, students are expected 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 the course instructor.

Late Policy

Students are expected to complete their work on time. The course instructor will provide notification (during lectures and/or on the course LMS) of due dates and any revisions thereof.

Submissions after the due date will not be accepted without prior arrangement and may be penalized at up to 20% per day (24-hour period following due date/time) unless a suitable justification is provided.

Extenuating Circumstances

In the event of extenuating circumstances, A student may request an extension to an assignment due date without penalty. Requests must be made to the instructor prior to the original due date of the assignment, and some substantiating documentation may be 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 above and according to departmental policies.

Invalid Exams

An exam may be declared invalid in case of a significant interruption in an in-person examination; if the instructions in a remote or online exam were not followed; if the student uploads wrong materials; or if a situation arises where the integrity of the exam cannot be verified. If an exam is declared invalid, the student may be granted a re-write, subject to review and in accordance with academic integrity.

Absences (Academic Consideration) 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.

Accommodations requests must be made as soon as an issue arises, and normally well before each affected due date. Although every effort will be made to accommodate students, retroactive applications after an exam has been attempted, or past an assignment due date may not be possible.

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/
MS-Teams	https://support.microsoft.com/en-us/office/accessibility-support-for-microsoft-teams-d12ee53f-d15f-445e-be8d-f0ba2c5ee68f
Zoom	https://zoom.us/accessibility

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

Religious Observance

Students in need of accommodation for religious observance are asked to speak to their professor within a week of receiving their syllabus to adjust deliverables and schedule as required. 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

Basic hardware and software skills and online access 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.

COURSE OVERVIEW

CHEE 380 || Module overview			
Course learning outcomes (CLO): Students will be able to: **1. Design culture medium based on nutritional requirements of microbial cells.** **2. Specify design criterion for medium sterilization and solve problems involving both batch and continuous sterilization.** **3. Apply the principles of microbial growth kinetics in bioreactors.** **4. Simulate and evaluate bioreactor performance.** **5. Apply mass and heat transfer correlations to bioreactor design.** **6. Design a complete bioreactor based on targets, constraints, and physical properties.** **7. Identify suitable process instrumentation for monitoring and control of bioreactors.** **8. Knowledge and selection of process unit operations for product recovery and purification.**			
Students are expected to augment lecture material through applied work in tutorials, and to practice execution of course principles by completing suggested problem sets			
Hours	Lecture approach* and content	Practice**	Assessment***
9 lectures 3 tutorials	**MODULE 1: Medium Formulation, Batch and Continuous Sterilization.** • Nutritional requirements and sources. • Cellular elemental composition and cell yields. • Microbial death kinetics. Design criterion for sterilization. • Batch and continuous sterilization of medium. Air sterilization. Lectures: 1. Outline (1 lecture) 2. Introduction (1 lecture) 3. Products and Background Review (3 lectures) 4. Medium Formulation (4 lectures) 5. Sterilization (3 lectures)	Tutorials 1,2,3 Problem Sets 0,1,2	*Material is included in Quiz 1 and on final exam (CLO 1,2)*

Time	Lecture approach* and content	Practice**	Assessment***
5 lectures 2 tutorials	**MODULE 2: Growth Kinetics.** • Phases of batch growth. • Monod kinetics. • Volumetric rates, specific rates, and yields. • Continuous bioreactors and bioreactor performance. Lectures: 6. Growth Kinetics (3 lectures)	Tutorials 4,5 Problem Set 3	*Material is included in part in Quizzes 1 and 2 and on final exam (CLO 3,4)* Assignment 1 due end of Module 2 *(CLO 1,2,3)*
1 hour **Quiz 1**	**Modules 1 and 2**	Review	*CLO 1-3*
8 lectures 2 tutorials	**MODULE 3: Transport Phenomena in Bioreactors.** **Design of Bioreactors.** • Oxygen transport. • Agitation and power requirements for mixing. • Bioreactor design based on oxygen demand and supply. • Heat transfer. • Solving bioreactor design problems Lectures: 7. Transport in Bioreactors (5 lectures)	Tutorials 6,7 Problem Sets 4,5	*Material is included in Quiz 2 and on final exam (CLO 5,6)*
9 lectures 2 tutorials	**MODULE 4: Bioreactor Monitoring and Control.** **Product Recovery.** • Physical and chemical sensors for monitoring and control. • Cell separation. • Product isolation and purification. • Examples of Industrial processes. Lectures: 8. Monitoring, Control and Design Considerations (1 lecture) 9. Recovery (4 lectures) 10. Industrial Processes (examples, 1 lecture)) Module 4 (continued) 11. Process Validation & Good Manufacturing Practices (1 lecture)	Tutorials 8,9 Problem Sets 5,6	*Material is included in part in Quiz 2 and on final exam* *(CLO 7,8)* Assignment 2 due end of Module 4 *(CLO 4,5,6)*

Time	Lecture approach* and content	Practice**	Assessment***
1 hour **Quiz 2**	**Module 3 and parts of Module 4**	Review	*CLO 5-7*
3 hours **Final Exam**	**Covers the entire semester**	Review	*All CLOs*

Notes:
* Lecture content delivery through lecture materials available in power-point, including examples and solutions, and true or false trivia.
** Review lectures are sometimes presented during the tutorial time slots. Quizzes will be held during tutorial periods or their equivalent.
*** Course Learning Objective addressed; Quizzes and Final Exam may include multiple choice, true or false, definitions, descriptions of applications, short answers, as well as problems requiring full procedural solutions and calculations.