CHEMICAL ENGINEERING 170A Syllabus

Biochemical Engineering, Fall 2016
Moffitt Library 101, MWF 10:00 – 11:00 am

Instructor: Wenjun Zhang
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Graduate Student Instructor: Jeffrey Li
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Guest Lecturers: Brian Maiorella, Adjunct Professor
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Reference Texts (on reserve in the Chemistry Library)

Biochemical Engineering (1996) by Harvey W. Blanch and Douglas S. Clark (For reading assignment)
Voet, D.; Voet, J. G. Biochemistry, 4th ed.; Wiley: New York, 2010.
Alberts, B., et al. Molecular Biology of the Cell, 5th ed.; Garland Publishing, Inc.: New York, 2007.
Nester, E. W., et al. Microbiology, 7th ed.; Saunder College Publishing: New York, 2011.

Course Description:

The 170A/B series is a two semester sequence intended to introduce chemical engineers to the basic concepts of biochemical engineering. The course focuses on the use of chemical engineering skills and principles in the analysis and design of biologically-based processes. The emphases of 170A will be on enzyme kinetics, fermentation, bioreactors, and bioseparations, while the 170B lectures will cover topics such as protein engineering, synthetic biology, pharmacokinetics, drug discovery, drug delivery, etc. The combined course provides a comprehensive view of the role of chemical engineering in the development of biological products.

Prerequisites:

Chemical Engineering 150B and Biology 1A (or equivalent), or consent of instructor. It is highly recommended that students complete Chemical Engineering 142 prior to the start of this class.

Syllabus: Chm Eng 170A – Biochemical Engineering (cont.)

Course Objectives:

By the end of this course, students will have learned:

- the fundamental properties of amino acids and proteins; DNA structure, transcription, and translation; the terminology of biochemical engineering;
- mechanisms of enzymatic reactions; how to derive rate equations for single-substrate enzymatic reactions; transition-state theory and enzyme inhibition; design principles for enzyme inhibitors;
- theory of external and internal mass transfer effects on immobilized enzyme and cell kinetics; determination of external and internal effectiveness factors for immobilized biocatalysts;
- stoichiometry and energetics of cellular growth; unstructured growth models; kinetics of substrate consumption and bioproduct formation;
- design and analysis of batch and continuous stirred tank bioreactors (chemostats); packed bed bioreactors; understanding of the biohazards and resulting engineering controls required for bioreactors;
- formulation of two-phase (gas-liquid) mass balances for continuous bioreactors; estimation of the mass transfer coefficient kLa;
- basic principles of sterilization, its role with respect to reactor sterilization, product safety, and biohazard mitigation, and how to design batch and continuous sterilizers;
- general methods of downstream processing for bioproduct purification, including removal of trace amounts of biohazardous contaminants;
- theory of centrifugation and filtration (ordinary and tangential flow); sizing of centrifuges and filtration modules;
- principles of chromatography and fixed-bed adsorption; isotherms; differential mass balance equations.

Course Outcomes:

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

- Derive rate equations from the mechanisms of enzymatic reactions and determine the primary kinetic and inhibition parameters;
- Determine whether an immobilized enzyme reaction is limited by mass transfer and estimate the corresponding effectiveness factor(s);
- Apply mass and energy conservation criteria to balance stoichiometric equations for microbial growth and product formation, and calculate relevant yield coefficients;
- Analyze microbial growth, substrate consumption, and product formation in batch reactors and chemostats; calculate steady-state concentrations in a chemostat; calculate steady-state conversions for enzymatic reactions in a packed bed reactor;
- Derive material balances for two-phase bioreactors and estimate kLa values; determine power requirements for mixing multi-phase bioreactors;
- Analyze and design batch and continuous sterilization processes;
- Set-up and solve conservation equations for centrifugation, filtration, and chromatography; solve for relevant process parameters in each case; estimate retention times and resolutions in chromatographic processes; formulate and critically assess product recovery schemes.

Grading:

15% Homework Sets
25% Midterm Exam 1 (September 21)
25% Midterm Exam 2 (November 2)
35% Final Exam

Exams will be challenging and you will need to study extensively to perform well. All exams will be written and consist of problem sets, short answer, multiple choice, and/or true/false questions. Midterm exams will be held during normal class hours according to the schedule below. The exams will be closed book and closed notes. Only **NON-graphing** calculators will be allowed. All cell phones must be stored away during exams. Use of a cell phone or texting during an exam will lead to an automatic F. **Exams cannot be made up** - if an exam must be missed due to illness or family crisis then the Final Exam score will be substituted for the missed exam. This can only be done once and students that must miss more than one exam should consider dropping the course.

The Final Exam is scheduled for Monday, December 12, from 8:00 am to 11:00 am.

There will be no regrades. If you notice an error in totaling the points (this is NOT a regrade), attach the note to your exam and discuss the issue with the GSI. This procedure must be followed within one week of the time the exams are initially returned to the class; after that period the exam will not be retotaled. In addition, the GSI will review the entire exam when retotaling the score. If there is a disagreement with the GSI you can visit with the Instructor during office hours.

Cheating: Anyone caught cheating on an exam will receive a failing grade and will also be reported to the University Office of Student Conduct. In order to guarantee that you are not suspected of cheating, please keep your eyes on your own materials and do not converse with others during the exams.

Homework sets will be assigned approximately weekly and the lowest homework grade will be dropped. Homework is due at the *beginning of class* on the due date, and will not be accepted late. Generally homework will be assigned, and due, on Fridays.

Collaboration and Independence: Reviewing lecture and reading materials and studying for exams can be enjoyable and enriching things to do together with one's fellow students. We recommend this. However, homework assignments should be completed independently and materials turned in as homework should be the result of one's own independent work.

Syllabus: Chm Eng 170A – Biochemical Engineering (cont.)

Tentative Lecture Schedule:

Date	Section	Topic	Reading Assignment
24-Aug	Overview	Biotechnology and Biochemical Engineering	Handouts
26-Aug	Overview	Chemistry of amino acids and proteins	Handouts
29-Aug	Biocatalysis	Single Substrate kinetics	Sections 1.1-1.3
31-Aug	Biocatalysis	Graphing kinetic data	Sections 1.1-1.3
2-Sep	Biocatalysis	Transition state theory	Section 1.4
5-Sep	No class		
7-Sep	Biocatalysis	Enzyme inhibition	Section 1.5
9-Sep	Immobilized catalysis	External mass transfer effects	Sections 2.1-2.4.2
12-Sep	Immobilized catalysis	Internal mass transfer effects part I	Section 2.4.3
14-Sep	Immobilized catalysis	Internal mass transfer effects part II	Section 2.4.3-2.4.4
16-Sep	Fermentation	Stoichiometry/energetics of microbial growth part I	Sections 3.1-3.2
19-Sep	Fermentation**	Stoichiometry/energetics of microbial growth part II	Sections 3.1-3.2
21-Sep	**Midterm Exam**	**1**	
23-Sep	Fermentation	Unstructured models part I	Sections 3.3-3.3.4
26-Sep	Fermentation	Unstructured models part II	Sections 3.3.6-3.3.7
28-Sep	Bioreactors	Batch and CSTR	Sections 4.1-4.2.4
30-Sep	Bioreactors	CSTR (Chemostat)	Sections 4.1-4.2.6
3-Oct	Bioreactors	Plug flow and packed bed	Section 4.3
5-Oct	Bioreactors	Gas-liquid mass transfer	Sections 5.2-5.2.2
7-Oct	Bioreactors	Mass balances for two-phase bioreactors	Section 5.2.3
10-Oct	Bioreactors	Mass transfer coefficient kLa	Sections 5.4.1-5.4.3
12-Oct	Bioreactors	Sterilization	Section 5.5.1
14-Oct	Bioreactors*	Cell culture bioreactor scale-up: oxygen and CO2	Handouts
17-Oct	Bioreactors*	Medium development and fed-batch process control	Handouts
19-Oct	Bioreactors*	Perfusion culture process development 1	Handouts
21-Oct	Bioreactors*	Perfusion culture process development 2	Handouts
24-Oct	Bioreactors	Biosafety	Handouts
26-Oct	Bioseparations	Intro, Centrifugation	Sections 6.1-6.2.1
28-Oct	Bioseparations	Centrifugation, filtration	Sections 6.1-6.2.1
31-Oct	Bioseparations	Filtration and ultrafiltration	Sections 6.2.2,6.3.2
2-Nov	**Midterm Exam**	**2**	
4-Nov	Bioseparations	Introduction to chromatography	Pages 502-512
7-Nov	Bioseparations*	Recovery via centrifugation vs. filtration	Handouts
9-Nov	Bioseparations	Chromatography	Pages 512-520, 526-533
11-Nov	No class		
14-Nov	Bioseparations	Electrophoresis, crystallization, drying	Sections 6.4.3-6.5.2
16-Nov	Bioseparations*	Integrated purification process design 1	Handouts

Syllabus: Chm Eng 170A – Biochemical Engineering (cont.)

18-Nov	Bioseparations*	Integrated purification process design 2	Handouts
21-Nov	Bioseparations	Analytical methods	Handouts
23-Nov	No class		
25-Nov	No class		
28-Nov	Bioseparations*	Protein products from *E. coli* part I	Handouts
30-Nov	Bioseparations*	Protein products from *E. coli* part II	Handouts
2-Dec	Biomanufacturing*	Economics	Handouts

*Brian Maiorella will give this lecture

**Instructor out; guest lecturer TBA