CHEMICAL ENGINEERING 170A Syllabus

Biochemical Engineering, Spring 2016
9 Lewis, MWF 11:00 am – 12:00 pm

Instructor: Danielle Tullman-Ercek
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Office hours: Mon 1:30 – 2:30 pm, Thurs 1:30 - 2:30 pm

Graduate Student Instructor: Lisa Burdette
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Office hours: TBD
Location: TBD

Guest Lecturer: Brian Maiorella, Adjunct Professor
Email: bmaiorella@cal.berkeley.edu

Required Textbook:

Biochemical Engineering (1996) by Harvey W. Blanch and Douglas S. Clark

Reference Texts (in the Chemistry Library)

Voet, D.; Voet, J. G. Biochemistry, 2nd ed.; Wiley: New York, 1995.

Creighton, T. E. Proteins: Structures and Molecular Properties, 2nd ed.; W. H. Freeman & Co.: New York, 1993.

Alberts, B., et al. Molecular Biology of the Cell, 4th ed.; Garland Publishing, Inc.: New York, 2002.

Nester, E. W., et al. Microbiology, 3rd ed.; Saunder College Publishing: New York, 1983.

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 expression and folding, protein engineering, synthetic biology, pharmacokinetics, and drug delivery. 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
- formulation of two-phase (gas-liquid) mass balances for continuous bioreactors; estimation of the mass transfer coefficient k_La;
- the Power number and how to determine the power requirements for mixing bioreactors
- basic principles of sterilization and how to design batch and continuous sterilizers;
- general methods of downstream processing for bioproduct purification
- 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.

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

Grading:

5% Participation (Lecture and Discussion)
15% Homework Sets
22.5% Midterm Exam 1
22.5% Midterm Exam 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 outside of class 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.

Midterm Exam 1 is scheduled for Monday, February 29, for 120 minutes in the evening (TBD).

Midterm Exam 2 is scheduled for Wednesday, April 6, for 120 minutes in the evening (TBD).

The Final Exam is scheduled for Tuesday, May 10, from 7:00 to 10:00 pm.

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.

Quizzes may be given throughout the semester, at random, but are not counted toward your grade. 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.

Tentative Lecture Schedule on Following Page

*Brian Maiorella will give the lectures denoted by an asterisk

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

Date	Section	Topic	Reading Assignment
20-Jan	Overview	Biotechnology	Handouts
22-Jan	Biocatalysis	Single Substrate kinetics	Sections 1.1-1.3
25-Jan	Biocatalysis	Transition state theory	Sections 1.1-1.3
27-Jan	Biocatalysis	Enzyme inhibition	Sections 1.1-1.3
29-Jan	Immobilized catalysis	External mass transfer effects	Section 1.5 - 1.6
1-Feb	Immobilized catalysis	Internal mass transfer effects I	Sections 2.1-2.4.2
3-Feb	Immobilized catalysis	Internal mass transfer effects II	Section 2.4.3
5-Feb	Biosafety	Intro to cGMP	Handouts
8-Feb	Biosafety	Biohazard mitigation	Handouts
10-Feb	Applications	Antibodies and Enzymes	Handouts
12-Feb	Fermentation	Microbial growth: stoichiometry	Sections 3.1-3.2
15-Feb	No class	Presidents' Day	
17-Feb	Fermentation	Microbial growth: energetics	Sections 3.1-3.2
19-Feb	Fermentation	Unstructured models I	Sections 3.3-3.3.4
22-Feb	Fermentation	Unstructured models II	Sections 3.3-3.3.4
24-Feb	Review	Material on Exam 1	(Through Feb 15)
26-Feb	Bioreactors	Batch and CSTR	Sections 4.1-4.2.4
29-Feb	Bioreactors	CSTR (Chemostat)	Sections 4.1-4.2.4
2-Mar	Bioreactors	Plug flow and packed bed	Section 4.3
4-Mar	Bioreactors	Gas-liquid mass transfer	Sections 5.2-5.2.2
7-Mar	Bioreactors	Two-phase bioreactors	Section 5.2.3
9-Mar	Bioreactors	Mass transfer in bioreactors	Sections 5.4.1-5.4.3
11-Mar	Bioreactors	Sterilization	Section 5.5.1
14-Mar	Applications	Distillation	Handouts
16-Mar	Bioreactors*	Cell culture bioreactor scaleup	Section 3.4.2
18-Mar	Bioreactors*	Medium optimization	Section 3.4.2
28-Mar	Bioreactors*	Perfusion culture I	Section 4.1.1
30-Mar	Bioreactors*	Perfusion culture II	Handouts
1-Apr	Biomanufacturing*	Protein product development I	Handouts
4-Apr	Biomanufacturing*	Protein product development II	Handouts
6-Apr	Bioseparations	Intro, Centrifugation	Sections 6.1-6.2.1
8-Apr	Bioseparations	Centrifugation, filtration	Sections 6.1-6.2.1
11-Apr	Bioseparations	Filtration and ultrafiltration	Sections 6.2.2, 6.3.2
13-Apr	Bioseparations*	Recovery: applications	Handouts
15-Apr	Bioseparations	Chromatography I	Pages 502-512
18-Apr	Bioseparations	Chromatography II	Pages 512-520
20-Apr	Bioseparations*	Purification process design I	Section 6.4
22-Apr	Bioseparations*	Purification process design II	Section 6.6
25-Apr	Bioseparations	Finishing processes	Sections 6.4.3-6.5.2
27-Apr	Bioseparations	Protein purification simulator	Handouts
29-Apr	Biomanufacturing*	Economics	Sections 8.2-8.5