COURSE OVERVIEW

ChBE 3225B: Separations Processes - Spring 2012
Monday, Wednesday, Friday: 9:05-9:55 AM, L1105 ES&T Building

Instructor

Professor Sankar Nair
Office: 2224 Environmental Science & Technology Building
E-mail: sankar.nair@chbe.gatech.edu
Telephone: 404 894 4826

Teaching Assistant

Mr. Steven Burgess: sburgess3@gatech.edu

Office Hours

You are highly encouraged to attend office hours (scheduled by both Instructor and TA) if you have questions or need assistance with course materials (including class notes, textbook material, your graded exams, or homework assignments).

Prof. Nair's office hours are on **Tuesdays 4:30 – 6:00 PM, in EST 2224.**

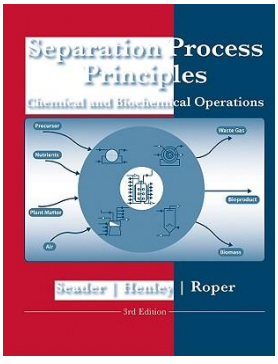
Mr. Burgess' office hours are on **Thursdays 1:00-2:30 PM, in EST 2354.**

Course Materials and Updates

Course materials will be posted on the ChBE 3225 course webpage maintained on T-Square (http://t-square.gatech.edu). You need your OIT username and password to access T-Square. ***You are advised to visit the webpage often for downloading course materials and updates***.

Course Text

Separation Process Principles, by J. D. Seader, E. J. Henley, D. K. Roper, 3rd (or 2nd) Edition, J. Wiley & Sons Inc., New York, 2005.



Your undergraduate Thermodynamics and Transport textbooks will also be useful additional references. Additional notes will be provided for lectures on *crystallization* and *bioseparations*. These notes will be available for download on the course webpage.

Course Grade

Homework	90 points
Quizzes	50 points
Attendance	10 points
Midterm Exam	50 points
Final Exam	100 points
Total	**300 points**

Class Attendance (10 points)

Attendance is not compulsory; however, attendance will be taken in the lecture periods, and will count for ~3% of the course grade. You are strongly encouraged to attend lectures. If you miss class, you are responsible for obtaining all materials that you may have missed. Problems on exams will directly reflect the material discussed in class.

Homework Assignments (90 points)

Homework assignments are due ***at the beginning of class*** on the dates given in Page 8. Solutions will be posted on the course webpage after class. ***Late homework assignments will not be accepted unless arrangements were made in advance.*** Although no credit will be given for late homework, it may be graded at the TA's discretion.

Students are allowed to discuss the HW problems in groups, but each student must submit an **original homework solution (no copying).** Homework solutions should be formatted in accordance with the course guidelines (Page 9).

Some homework problems will involve the use of the process flowsheeting and simulation package HYSYS, available in the ChBE computer lab. A tutorial on HYSYS will be provided.

Quizzes (50 points)

There will be five in-class quizzes (15 minutes duration). Quizzes will be based on material discussed in the previous 4-5 lectures. They will include conceptual questions and short numerical problems.

Examinations (150 points)

One Midterm Exam will be given outside of normal class time. It will be held on **Monday, March 5** from **6:00-8:00 PM**. The venue will be announced later.

There will be a Final Exam on **Friday, May 4**, from **8:00-10:50 AM** in EST L1105.

The Final Exam is cumulative, but will be weighted more heavily towards material covered after the Midterm Exam.

Exams and Quizzes will be **open book, open notes, open HWs**. You may bring a programmable calculator**,** but **wireless devices are prohibited.** Any necessary information relating to conversion factors and material properties will be provided. A **Review Session** will be scheduled before each of the Exams.

Requests for exam re-grades must include a note explaining why a re-grade is required, and be submitted in writing within one week after graded exams are returned. The entire exam will be re-graded, not only the section or problem requested.

Deadline Conflicts

Late HW submissions will not be accepted unless special arrangements have been made with the instructor.

Missed exams can be made up only if an emergency prevents you from attending. Missed quizzes cannot be made up, but can be exempted from your grade calculation only if an emergency prevents you from attending.

As soon as you know that you will miss or have missed an exam or quiz, you are requested to notify the instructor (a telephone or email message is fine). If a medical emergency prevents you from turning in homework on time or taking an exam or quiz, a letter from the health center will be required.

Academic Misconduct and the Honor Code

Students in this class are expected to abide by the Georgia Tech Honor Code at all times and avoid all instances of academic misconduct including, but not limited to:

- Possessing, using, or exchanging improperly acquired written or oral information in preparation for exams or the final.
- Copying homework solutions from classmates, previous students, solution manuals, or otherwise representing the work of others as their own.
- Using prohibited materials or means to complete homeworks, exams or the final.

All work turned in for grading must be original. Copying from other students (current and former), solution manuals, web sites or any other form of word are considered violations of the Georgia Tech Honor Code. The complete text of the Honor Code is available at the following link: http://www.honor.gatech.edu

COURSE OBJECTIVES AND GENERAL TOPICS COVERED

Topics Covered

1) Overview of Separation Techniques

2) Review of Thermodynamics and Transport Fundamentals

3) Flash Separations

4) Absorption and Stripping

5) Distillation

6) Crystallization

7) Extraction

8) Adsorption

9) Membrane Separations

10) Bioseparations

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

1) **Calculate the properties** (e.g., compositions and flow rates) of product streams, as well as **energy requirements**, for **single-stage operations** such as flash tanks.

2) **Design more complex thermodynamic separation systems** (i.e., determine the number of stages, height of packing, dimensions of separations equipment etc.) for specific operations involving distillation, absorption, stripping, extraction/leaching, crystallization, and adsorption.

3) Calculate the **properties of membrane units** for separations.

4) **Identify separations equipment** of various types and their components.

5) Understand the **design fundamentals for bioseparations**.

6) Use computer modeling to **design and simulate separation systems**.

7) **Evaluate competing separation technologies** on factors such as simplicity, reliability, cost.

SYLLABUS

* HW due at beginning of class
§ In-class quiz

Lec. #	Date	Section	Topic
1	M Jan 9	Chapter 1	Introduction
2	W Jan 11	Chapter 2	Thermodynamics Review
3	F Jan 13	Chapter 3	Transport Review
4	M Jan 16	*No Class*	
5	W Jan 18	4.1-4.3	Gibbs' Rule, Phase Equilibrium, Azeotropes
6	F Jan 20	4.4	Multicomponent Flash Calculations
7	M Jan 23	4.4	Multicomponent Flash Calculations (cont'd)
*8	W Jan 25	4.8-4.9	Gas-Liquid, Gas-Solid Systems
9	F Jan 27	4.7, 4.5	Liquid-Solid Systems, Liquid-Liquid Systems
10	M Jan 30	4.5, 4.10	Liquid-Liquid Systems, Multiphase Systems
11	W Feb 1	5.1-5.3	Single-Section Cascades
12	F Feb 3	5.4	Single-Section Cascades (cont'd)
*§13	M Feb 6	5.4-5.7	Two-Section Cascades
14	W Feb 8	6.1-6.3	Absorption/Stripping: General Considerations
15	F Feb 10	6.3	Graphical and Algebraic Methods
16	M Feb 13	6.3-6.4	Stage Efficiency
17	W Feb 15	6.5	Tray Requirements
*18	F Feb 17	6.6	Tray Requirements (cont'd)
19	M Feb 20	6.7	Packed Columns
20	W Feb 22	6.7-6.8	Packed Columns (cont'd)
§21	F Feb 24	Chapter 6	Additional Problems and Discussion

22	M Feb 27	7.1	Binary Distillation: Graphical Methods
23	W Feb 29	7.2	Graphical methods (cont'd)
			MIDTERM EXAM: 6:00-8:00 PM Chapters 1-6
24	F Mar 2	7.3, 7.4	Stage Efficiency, Tray Requirements, Reflux Drums
*25	M Mar 5	7.5	Packed Columns
26	W Mar 7	9.1	Multicomponent Approximate Methods
27	F Mar 9	9.2	Multicomponent Approximate Methods (cont'd)
28	M Mar 12	9.1-9.2	Multicomponent Approximate Methods (cont'd)
*§29	W Mar 14	Chapter 7	Additional Problems and Discussion
30	F Mar 16	8.0-8.2	Liquid Extraction: General Considerations
31	M Mar 19	*No Class*	
32	W Mar 21	*No Class*	
33	F Mar 23	*No Class*	
34	M Mar 26	Chapter 9	Additional Problems and Discussion
35	W Mar 28	8.3	Graphical Methods
*36	F Mar 30	8.3-8.4	Graphical Methods (*continued*)
37	M Apr 2	8.5	Extractor Theory and Scale-Up
§38	W Apr 4	17.1. 17.4, Notes	Crystallization - Basics, Equipment
39	F Apr 6	17.2, Notes	Crystallization - Thermodynamics
40	M Apr 9	17.3, 17.5, Notes	Crystallization – Kinetics and Modeling
41	W Apr 11	14.1-14.3	Membrane Separations: Theory
*42	F Apr 13	14.1-14.3	Membrane Theory (cont'd)
43	M Apr 16	14.1-14.3	Membrane Theory (cont'd)

44	W Apr 18	14.4, 14.5	Dialysis, Electrodialysis
§45	F Apr 20	14.6, 14.7	Reverse Osmosis, Pervaporation
46	M Apr 23	Notes	Bioseparations
47	W Apr 25	Notes	Bioseparations
*48	F Apr 27	Notes	Advanced Materials for Separations

HOMEWORK ASSIGNMENT SCHEDULE

HWs are due **beginning of class**. Solutions will be posted on T-Square soon after the deadline. Numbered problems (e.g., 2.10) are from the textbook. Other problems (e.g. P1) will be provided by Professor Nair for download from the course webpage.

Assignment	Due Date	Problems
1	**Jan 25**	2.10, P1, P2, 3.36
2	**Feb 6**	4.23, P3
3	**Feb 17**	5.9, P4, 6.8
4	**Mar 5**	6.16, P5
5	**Mar 14**	P6
6	**Mar 30**	P7 (HYSYS), P8
7	**Apr 13**	8.17, P9 (HYSYS), P10
8	**Apr 27**	14.10, 14.18

All HW problems will be graded on a 10-point scale, except for the HYSYS problems which will be graded on a 20-point scale. HWs will be graded by the course TA. For questions regarding your HW grade, contact the TA during office hours or by e-mail for an appointment.

- **Excel Spreadsheets** will be used extensively to discuss examples in class, and can be used (if needed) for solving HW problem components. From the article "Enhancing the Undergraduate Computing Experience" by T.F. Edgar, *Chemical Engineering Education*, 2006, vol. 40, iss. 3, pp. 231-238: "…In the area of computing software, there is a considerable disconnect between industry and academia…Typically chemical engineering departments teach the use of MATLAB, Mathcad, Mathematica, or Maple but not the use of spreadsheets. Yet in industry, spreadsheet software (e.g., Excel) is the dominant computer package in use."

- **Perry's Chemical Engineers Handbook** is a comprehensive collection of data useful to chemical engineers. **Yaws' Handbook** is a detailed collection of physical and chemical data on over 5000 chemical compounds, including many not in Perry's Handbook. To access these online Handbooks, go to www.library.gatech.edu, and search the Catalog. You will need your OIT username and password.

- **Solver** and **Goal Seek** are two useful tools in Microsoft Excel for solving HW problems via spreadsheets. Solver is a more powerful version of Goal Seek and allows you to vary more than one cell at a time to obtain a solution to a set of equations. In Excel 2007, Solver can be accessed directly from the Data tab, and Goalseek from the "What-If Analysis" menu of the Data tab. To install Solver in older versions of Excel, go to Tools → Add-Ins → check Solver Add-In.

HOMEWORK FORMAT

Please use the following format for homework solutions.

staple ChBE 3225B Date HW Set # Your Name

Problem Number

Brief problem statement. This should be sufficient to define the problem, but need not be an exact copy of the original problem statement. A labeled process diagram with unknowns labeled will often serve as the problem statement.

Information Provided:

A list of the numerical information provided.

Solution:

Your method for solving the problem.

You must clearly list any assumptions made and any numerical information obtained from other sources, references providing the source of the information (e.g., Perry's Handbook) are required.

Solution, value with units

- Each problem must be started on a new page.
- Only plain white paper, or engineering paper with the appropriate lines, is acceptable. You can recycle used laser printer paper as long as the side on which you work is perfectly clean.
- Information printed in **Bold Type** above is required on each page.
- **All HW must be stapled. The TA is not required to grade HWs that are not stapled.**

What Are Some Reasons To Perform Separations ?

- Separate a mixture of different products or a mixture of desired and undesired products
- Purify a product by removing impurities that appear in small/ trace amounts
- Separate unreacted reactants and products so that the reactants can be recycled
- Achieve high conversion in an equilibrium-limited process by removing one or more of the products as they are formed
- Recover a valuable product from a natural substance (leaching coffee from beans, pharmaceuticals from plants, etc.)
- Analyze or identify the contents of a sample mixture by separating them into the individual components (e.g., chromatography, DNA sequencing)
- Purify biological fluids for medical applications (e.g., artificial kidney)

Conceptual Classification of Separations Processes

Thermodynamic (or Equilibrium)-based Separations

- Based on exploiting differences in thermodynamic (equilibrium) properties of mixtures
- By "thermodynamic properties" we mean things like boiling/freezing point, solubility etc.
- Two or more phases must be formed during the contacting process (liquid/vapor, liquid/liquid, gas/solid, gas/liquid)
- The desired product must be more soluble in one phase than another
- Often use large amounts of energy (especially those that use temperature changes)

Transport (Rate)-based Separations

- Based on exploiting differences in transport properties (i.e., how fast do different component molecules travel through a membrane or a similar device)
- External fields may be used
- By "transport properties" we often mean mass diffusivity
- Often do not require much energy
- However, the separation usually occurs by a combination of transport and thermodynamic properties

Classification by "Mechanism"

- Phase Addition or Phase Creation (Table 1.1)
    - Supply mass or energy to the mixture

- Barrier (Table 1.2)
    - Selectively permeable barrier (membrane)

- Solid Agent (Table 1.3)
    - Selective adsorption into a solid
    - Selective transport through a solid medium (chromatography)

- External Field or Gradient (Table 1.4)
    - Gravity, Electric Field

Selection of Feasible Separation Processes

- Feed Conditions
- Product Conditions
- Property Differences
- Required Characteristics of Separation
    - Ease of Construction
    - Ease of Scale-up
    - Size Limitations
    - Energy Requirements
    - Environmental Issues
    - Safety Issues
    - Cost