# ChE 351: Separation Process Principles

Prof. Davis

# Fall 2016 Syllabus

*Class meeting times:*

Mondays 3 – 4:50 PM in room 427
Thursdays 4 – 4:50 PM in room 503

*Prerequisites and other requirements:*

The two prerequisites for this class are ChE331 (Chemical Engineering Thermodynamics II) and ChE342 (Heat and Mass Transfer). The course has a required textbook: Separation Process Principles by Seader, Henley, and Roper (3rd ed.) ISBN# 0470481838, $38 or so (used) on Amazon.com. I will generally be following the textbook through the course; you should purchase it and **bring your copy with you to class**. It is worth buying and you will need it again as a reference for lab and for your design courses. You will need materials to take notes and do problems during class (paper, pencil, ideally two different colors of pen, a straight edge, and a calculator) and access to a computer to do certain homework problems. If you would like to prepare for class ahead of time, you can read section numbers from the text in the class schedule, but that is not essential.

*Course overview:*

This course covers some of the many, many methods used to separate chemical mixtures, particularly in industrial applications. Separation processes are often the most complicated component of real chemical process design/operation because of the many options and degrees of freedom. We will apply thermodynamic and transport concepts to the design of continuous-contact and staged separation processes and discuss the limitations of mass transfer theory and empiricism in real chemical plant design/operation. The first half of the course will cover:

- Introduction to separation processes (Chapter 1)
- Review of thermodynamics of mixtures and modeling chemical properties (Chapter 2)
- Review of diffusivity, Fick's law of diffusion, mass transfer mechanisms, and calculation of mass transfer coefficients (Chapter 3)
- Absorption and stripping of dilute mixtures, with an emphasis on graphical methods of solution (Chapter 6) – also extending this knowledge to multicomponent mixtures
- Binary distillation (Chapter 7)
- Creating trayed and packed column designs based on empirical data (Chapter 7)

The second half of the course (from the Midterm to the Final Exam) will cover:

- Equilibrium-based models for industrially relevant membrane separations (Chapter 14)
- Equilibrium-based models, mass transfer, and surface chemistry of adsorption, ion exchange, and chromatography (Chapter 15)

*Course goals and objectives:*

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

- Explain the role of separation operations in an industrial chemical process
- Define key vocabulary used in describing separation processes
- Identify equipment types for many common industrial separation processes and their particular applications
- Explain how each of the following systems work: partial condenser, partial reboiler, flash tank, absorber, stripper, distillation column, liquid-liquid extractor, membrane separator, adsorber, ion exchanger, chromatographic separator, and solid-liquid extractor
- Use Fick's law and other empirical relationships to calculate mass transfer rates
- Design and size columns for absorption and stripping of dilute mixtures and distillation of binary mixtures graphically and analytically
- Calculate mass transfer rates in various types of membrane separators
- Design, size, and describe the operation of a fixed-bed adsorber

*Homework assignments and exams:*

You will be given five (5) homework assignments, a preliminary exam, a midterm exam, and a final exam. Homework will be due before class on the date listed in the class schedule (usually Thursdays) and will be assigned at least one week prior to its due date. **Homework must be hand-written**; you may not use a computer to create any part of your submission unless specifically authorized by me. Typed or computer-printed answers will be given zero credit. Assignments will consist of problems and essay questions which reinforce concepts from class and the text. Some assignments will take longer to complete than others, though I will do as much as I can to minimize this. This is a three credit class, so I expect that you will spend about six hours per week outside of class on work for this class. I will have you submit how many hours per week you spend working on material for this course on your homework assignments. This data has no bearing on your grade; it's for my records and may eventually be published anonymously.

The Preliminary Exam will not count towards your grade and will cover topics which you should already know before starting this class. The Midterm Exam will cover the material from class and homework problems from chapters 1, 2, 3, 6, and 7 of the book. The Final Exam will be cumulative, cover the parts of chapters 7, 14, and 15 we get to in the second half of the course, and will also include questions on the lesser understood topics covered on the Midterm Exam. The portions of the exams corresponding to each topic will be approximately equal to the amount of time spent in class on each topic. The preliminary exam will be one hour long and the other two exams will be three hours long. The midterm will use one extra hour before or after class time and the final exam will be in its assigned slot in December.

*Groups:*

You will be assigned a new homework group at three (3) points in this class. You will work together on all homework assignments and be graded together on those assignments. Groups will be assigned by me in the second week of class for the first two homework assignments. After HW2 has been submitted by each group, groups will be reassigned by me for HW3 and HW4. After HW4 has been submitted, you may choose your own partner to work with (subject to my approval of your group) for HW5. I reserve the right to reassign groups at any time without consent of any members of that group based on the following criteria: performance on homework assignments or the Midterm Exam (either too low or too high), well-founded complaints by any members of the group, or the need to split up another group (and thus break up two groups to form two new groups).

Homework assignments will be done in groups but each group member must submit THEIR OWN work. Only one of the assignments (chosen randomly by me) will be graded. The grade on that submission AND ONLY THAT SUBMISSION will be given to all group members. It is the responsibility of each group member to ensure that all assignments are of similar quality.

You are REQUIRED to put the names of ALL members of your group on your submissions. If your name or your group members' names do not appear on any submission, I reserve the right to give a zero grade to any person whose name does not appear at my discretion. You are also REQUIRED to submit a group member evaluation form for each group member you have during the semester. The evaluation form will be available to print out on Moodle.

*Attendance and grading policy:*

Attendance in class is mandatory. Please E-mail me before class if you cannot attend. If you miss class, please come to my office hours to find out what you missed. In-class activities are also mandatory; they are an important part of learning the material and skipping or not trying your best on them is not recommended. There will be no make-up or extra credit work associated with this class. Please ensure that you complete assignments on time and that you can attend all exams. All assignments and exams must be completed for a passing grade in the class.

Students will be graded as follows:

| | **Homework** | **Midterm Exam** | **Final Exam** |
|---|---|---|---|
| **% of grade** | 25 | 50 | 25 |

Letter grades will be determined at the end of the semester using each student's raw score from above, the average raw score for the class, and my discretion (in that order). My discretion will be based on class attendance / participation, effort on homework assignments, and improvement over the course of the semester. Generally, I have given anyone who gets 85% or better an A in my classes, though that is not a guarantee.

*ABET outcomes for this course:*

ABET is a nonprofit, non-governmental organization that accredits college and university programs in the disciplines of applied science, computing, engineering, and engineering technology. As part of the accreditation process, engineering colleges are required to select, for each required course, student outcomes which are acquired by students who have taken that course. Student outcomes are succinct statements that describe what students are expected to know and be able to do by the time of graduation. These outcomes relate to skills, knowledge and behaviors that students acquire as they progress through the program. The outcomes I've associated with this course are:

**(a) an ability to apply knowledge of mathematics, science, and engineering**

**(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability**

**(e) an ability to identify, formulate, and solve engineering problems**

**(g) an ability to communicate effectively**

**(j) a knowledge of contemporary issues**

**(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice**

The above definitions and outcomes were taken from the ABET website.

*Office hours:*

| | |
|---|---|
| Tuesdays | 2 – 3 PM in room 419 |
| Wednesdays | 4 – 5 PM in room 419 |
| Thursdays | 1 – 2 PM in room 419 |

Please do your best to bring questions to me during those times only. My E-mail address is bdavis@cooper.edu if you have a question which is brief or if you need to let me know you're going to be absent, late, etc. If you send me an E-mail, please put "ChE351" as the start of the subject, e.g. "ChE351: HW1 Question".

*Sequence of topics and class schedule:*

Numbers in the "Topic" column indicate the approximate chapter/section from Seader and Henley which will be covered in class that day. Homework assignment due dates are indicated on the right. Assuming we stay on schedule, HW1 will be on Chapter 1, HW2 on Chapters 2 and 3, HW3 on Chapter 6, HW4 on Chapter 7, and HW5 on Chapter 14.

| Week | Hour # | Day | Date | Topic / Seader and Henley Section | Due |
|---|---|---|---|---|---|
| 1 | -- | Thu | 9/8 | Introduction to the Class | |
| 2 | 1 | Mon | 9/12 | Preliminary Examination, Chapter 1 | |
| 2 | 2 | Thu | 9/15 | Introduction to 1, 1.1, 1.2, 1.3 | |
| 3 | 3,4 | Mon | 9/19 | 1.3 to 1.6 | |
| 3 | 5 | Thu | 9/22 | 1.7, 1.8, 1.10 | |
| 4 | 6,7 | Mon | 9/26 | 2.1 to 2.3, 2.8 | |
| 4 | 8 | Thu | 9/29 | 3.1.1, 3.2, 3.5.2, 3.7.1 | HW1 |
| 5 | 9,10 | Mon | 10/3 | Introduction to ABsorbers/Strippers, 6.1, 6.2 | |
| 5 | 11 | Thu | 10/6 | 6.1, 6.2, 6.3 (Graphical Method) | HW2 |
| 6 | 12,13 | Mon | 10/10 | 6.3 (Graphical Method) | |
| 6 | 14 | Thu | 10/13 | 6.4 (Algebraic Method) | |
| 7 | 15,16 | Mon | 10/17 | 6.4, 6.5.1, 6.5.4, 6.6.1, 6.6.3 | |
| 7 | 17 | Thu | 10/20 | 6.7 | |
| 7 | 18,19 | Mon | 10/24 | Introduction to Binary Distillation, 7.1 | |
| 8 | 20 | Thu | 10/27 | 7.2 | HW3 |
| 8 | 21,22 | Mon | 10/31 | 7.2, 7.3.1, 7.3.2, 7.3.4, 7.3.7, 7.3.9 | |
| 9 | 23 | Thu | 11/3 | 7.4.3, 7.5.1, 7.6.1 | |
| 9 | 24,25 | Mon | 11/7 | Introduction to Membranes, 14.1, 14.2 | HW4 |
| 10 | -- | Thu | 11/10 | Review for Midterm Examination | |
| 10 | -- | Mon | 11/14 | Midterm Exam, in class (3 HOURS) | |
| 11 | -- | Thu | 11/17 | NO CLASS – AIChE Annual Meeting | |
| 11 | 26,27 | Mon | 11/21 | 14.3.1, 14.3.2, 14.3.4 | |
| 12 | -- | Thu | 11/24 | NO CLASS – Thanksgiving | |
| 12 | 28,29 | Mon | 11/28 | 14.3.6, 14.3.8, 14.4, 14.6, 14.7 | |
| 13 | 30 | Thu | 12/1 | Introduction to ADsorption, 15.1 | |
| 13 | 31,32 | Mon | 12/5 | 15.1, 15.2.1, 15.3 | |
| 14 | 33 | Thu | 12/8 | 15.3.5 | HW5 |
| 14 | 34,35 | Mon | 12/12 | 15.5.3, ADsorber design, IE / C (I hope) | |
| 15 | -- | Thu | 12/15 | NO CLASS – Final Exam Week | |
| 15 | -- | ??? | ??? | Final Examination | |

*Group work and academic integrity policy:*

I believe group work is important to learning; I am requiring you to work in groups on your homework assignments. However, each student MUST submit their own work product for each HW. I will choose randomly which group member's homework submission I will grade. This means that you must work closely with your group members to ensure that you are all doing the work and that you are doing it correctly.

Plagiarism is the presentation of another person's "work product" (ideas, words, equations, computer code, etc.) as one's own. Whether done intentionally or unintentionally, plagiarism will not be tolerated in this class. You are plagiarizing if:

1. You present as your own work product a submission that includes the work product of your other group members (i.e. copying and not doing it yourself)
2. You present as your own work product a submission that contains the efforts or work product of other individuals aside from your other group members (i.e. plagiarism)
3. The help and contributions of other individuals are not acknowledged in writing on your submission (by writing their names)
4. You copy the work of other students on an in-class examination or communicate with other individuals in any fashion during an exam
5. You submit as part of a homework assignment material that has been copied from any source (including, but not limited to, a textbook, a periodical, an encyclopedia, the internet) without properly citing the source, and/or without using quotation marks. It is also prohibited to submit such materials in a minimally altered form without proper attribution. Improperly copied material might include text, graphics (computer or otherwise), computer source code, etc.

If I have a strong suspicion that you have plagiarized your submission for an assignment, you will receive a zero on that assignment. If you commit another act of plagiarism during the course after this first act, I will refer the matter to the Dean's office. Other prohibited acts of academic dishonesty include (but are not limited to):

6. Attempting to obtain a copy of an examination before it is administered
7. Dishonesty in dealing with me or another professor, such as misrepresenting the statements of another professor
8. Looking at a text or study materials of any kind (including electronically) during an exam when forbidden to do so (e.g. checking your phone during a bathroom break)
9. Bringing any device, electronic or otherwise, into class at any time when not expressly permitted by me (e.g. playing with your phone or laptop during class time)
10. Bringing any device into an examination that allows communication with other individuals or computers or computer databases (i.e. no cell phones or laptops during exams)

If I have a strong suspicion that you have cheated on an examination, you will receive a zero on that examination and likely receive a D or F in the course. The above was modified from the course catalog from the 2009-10 academic year.

*Resources which may (or may not) be helpful:*

- http://www.wiley.com/college/seader – Website for the textbook which has study questions, answers to some odd numbered problems, and problem solving tips
- Perry's Chemical Engineers' Handbook by Don Green and Robert Perry (8th ed.) ISBN# 0071422943
- Transport Processes and Separation Process Principles by Geankoplis (4th ed.) ISBN# 013101367X
- Separation Process Engineering by Wankat (3rd ed.) ISBN# 0131382276
- http://webbook.nist.gov – Thermodynamic and other data for lots of common chemicals
- http://www.matche.com – Gives capital cost estimates for a wide variety of process units
- DIPPR database (Design Institute for Physical Properties) – Data on physical, thermodynamic, and transport properties for industrially important chemicals used in chemical process and equipment design (available through the library on Knovel)
- http://www.youtube.com/watch?v=vscX_zawdQw - Crude Oil Distillation Process Part 1
- http://www.youtube.com/watch?v=Nd_pybvuIgc - Crude Oil Distillation Process Part 2
- Chemical Process Equipment - Selection and Design by S. M. Walas ISBN# 978-0-7506-9385-1 (available electronically on Knovel)
- Yaws' Critical Property Data for Chemical Engineers and Chemists by C. L. Yaws ISBN# 978-1-61344-932-5 (available electronically on Knovel)
- http://www.youtube.com/user/LearnChemE/ - Videos on selected ChE topics (there's a whole section of videos on Mass Transfer and Separations)
- Olsen, T. "An Oil Refinery Walk-Through" *Chemical Engineering Progress*, May 2014 (p. 34)
- http://people.clarkson.edu/~wwilcox/Design/thermodl.htm - Website for selecting a proper equation of state in a process simulator