ChE221: Material and Energy Balances

PROFESSOR BENJAMIN DAVIS

Fall 2022 Syllabus

Tuesdays 2-2:50 pm
Rm 504

Thursdays 1-2:50 pm
Rm 506

Introduction to the principles and techniques used in chemical engineering. Basic concepts of mathematics, physics, and chemistry are applied to solving problems involving stoichiometry, analysis of chemical process systems, and material and energy conservation equations. Also includes methods for estimation of thermodynamic and chemical properties of real fluids for engineering calculations, basic chemical equilibrium, and unsteady-state balances.

PREREQUISITES AND OTHER REQUIREMENTS:

This course has one prerequisite, Ch160 (Physical Principles of Chemistry)

I also assume you are familiar with Microsoft Excel, which we will use extensively to help us solve problems. The course has a required interactive, browser-based textbook: *Material and Energy Balances* by M. Liberatore, available at https://www.zybooks.com/catalog/material-and-energy-balances/. You should create an account, sign in, enter the code "COOPERCHE221DavisFall2022", then subscribe to the book ($58 in 2022). A more traditional and extensive reference which is optional is Elementary Principles of Chemical Processes by R. Felder, R. Rousseau, and L. Bullard (4th ed.) ISBN# 1118431227.

I will generally be following the zyBook through the course; you need to purchase it so I can track your completion of the Participation Activities (PA) and Challenge Activities (CA). You should prepare for class ahead of time by completing the sections of the zyBook indicated in the "Sequence of topics and class schedule" below (Table 1). You will need materials to take notes and do problems during class (access to textbook, paper, pencil, A CALCULATOR, and different colors of pen) and access to a computer with the zyBook and Excel to do homework problems.

SEQUENCE OF TOPICS

The first third of the course (before Midterm 1) will cover:

- Significant figures (SF), unit conversions, flow rates, properties and conditions, mass/mole/volume fractions, concentration, density, Pressure, and Temperature (Chapter 1)
- Process types, process units like condensers and pumps, drawing a BFD, The 12 Step Method, mass balances on single units, degree of freedom analysis, setting a basis, multiple unit operations, sub-systems, valves and splits, distillation columns, pumps, compressors, mixers, recycle/bypass (Ch. 2)
- Extent of reaction, conversion, multiple reactions, reaction equilibrium, atomic balances, and mole balances on reacting systems (Chapter 3)
- Mole balances on reactors with recycle (Chapter 3)

The second third of the course (from Midterm 2 to the end) will cover:

- Review of chemistry concepts like ideal gases, standard Temperature and Pressure (STP), real gases and Z, vapor pressure, Raoult's Law, bubble and dew points (Chapter 4)
- P-x-y and T-x-y diagrams, Vapor-Liquid Equilibrium (VLE), absorption and stripping columns, flash tanks, graphical methods for modeling separation units (Chapter 5)
- Energy balances on non-reacting systems (Chapter 6)

The final third of the course (from Midterm 2 to the end) will cover:

- Energy balances, steam tables, Enthalpy paths, Heat Capacity, Humidity (Chapter 6)
- Energy balances on reacting systems, Hess's Law, Heat of Formation Method, simultaneous mass and energy balances (Chapter 7)
- Transient mole balances, filling tank and batch reactor examples, transient energy balances (Chapter 8)

GOALS & OBJECTIVES[1]

The primary goal of this course is to prepare you to solve chemical engineering problems you will encounter in the ChE program. By the end of this course, you should be able to:

- **Demonstrate professional behavior** including behaving in the classroom, being punctual, and completing problems in an organized and timely manner
- Define and properly use "chemical engineering vocabulary" words
- Write and solve material and energy balance equations for single-units, multi-unit processes, processes with recycle and bypass, and reactive processes
- Solve material balance problems for processes which contain multiphase equilibria
- Convert quantities from one set of units to another quickly and accurately
- Define, calculate, and estimate properties of process materials including fluid density, flow rate, chemical composition variables (mass and mole fractions, concentrations), fluid pressure, and temperature
- Draw and label process flowcharts from verbal process descriptions
- Carry out degree-of-freedom analyses
- Perform vapor-liquid equilibrium calculations for systems containing condensable components and for ideal multi-component solutions
- Calculate the change in enthalpy for process fluids undergoing specified changes in temperature, pressure, phase, and chemical composition
- Solve combined mass and energy balance problems for processes involving external heat and work in open and closed non-reacting steady-state and transient systems.
- Incorporate the results of these calculations into process material and energy calculations
- Use spreadsheets (EXCEL) to solve material and energy balance problems
- Evaluate potential safety hazards in chemical processes

[1]These course objectives were modified from syllabi by M. Liberatore at the University of Toledo and L. Bullard from North Carolina State University

HOMEWORK

ASSIGNMENTS AND EXAMS

You will be given six (6) homework assignments (HWs), two midterm examinations (Midterms), and must complete the zyBook. The HWs will be due ***before class*** on the date listed on the assignment and will be assigned at least one week prior to their due date. HWs will consist of problems and essay questions which reinforce concepts from class and the text. I expect that you will spend about 6 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 has no bearing on your grade; it's for my records and may eventually be published anonymously. ***All homework submissions must be hand-written unless otherwise specified*** (not typed); this does not include spreadsheets. If you are unsure, please ask.

The Midterm Exams will be two hours long and cover the material in the zyBook which I go over in class and on the homework assignments.
The portion of each exam corresponding to each topic will be approximately equal to the amount of time spent in class on each topic.
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HOMEWORK GROUPS

You will be assigned a group at three (3) points in this class. The first two assignments (HW1 and HW2) will be individual assignments and be graded individually. After HW2, you will work in groups on all HWs and ***be graded together on those assignments***. Groups will be assigned by me for HW1 and HW2 on the first day of class. After HW2 has been submitted by each group, groups will be reassigned by me for HW3 and HW4. After HW4 has been submitted by each group, groups will be reassigned by me for HW5 and HW6. 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 a Midterm Exam (either too low or too high), well-founded complaints by one or many members of the group, or the need to split up another group (and thus break up two groups to form two new groups).

The HWs will be done in groups of two or three but each group member must submit THEIR OWN work. The same homework grade will be given to all group members. It is the responsibility of each group member to ensure that all assignments are of similar quality.

Please put the names of ALL members of your group on your submissions. If any names do not appear on any submission, I can give a zero grade to a person whose name does not appear at my discretion. You must submit a group member evaluation form for each group member you have during the semester. The evaluation form will be available on MS Teams.

ATTENDANCE & GRADING

Attendance in class is mandatory. Please email me before class if you cannot attend for whatever reason. If you miss class, please come to my office hours to find out what you missed. There will be no make-up or extra credit work associated with this class. Please ensure that you hand in your 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	Participation Activities	Challenge Activities	Midterm 1	Midterm 2
% OF GRADE	30	10	10	25	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.

I will grade homework assignments and exams based on what you have written on your paper. All answers must be written in coherent, proper English. I can and will give you less credit for an answer which is illegible, poorly formed, unclear, or lacks basic information which is essential to the question at hand. ***Failure to follow directions is the most common mistake that students make on my assignments and exams.*** If you disagree with a grade I have given on a question or an assignment, please do come see me; I am often wrong. However, I typically only give credit back to students on an assignment if I have clearly made a mistake in my evaluation (added up points incorrectly, forgot to grade your answer, etc.)

OFFICE HOURS

Office hours are hours I set aside in my schedule for you. If you have a question about the homework, want me to review the class material, are confused about what a homework question means, etc., please come to my office hours. That is why I have them; they are for you.

Tuesdays	**3–4 pm** | Rm 419 or on MS Teams
Wednesdays	**1–2 pm** | Rm 419 or on MS Teams
Thursdays	**11 am–Noon** | Rm 419 or on MS Teams

Please do your best to bring questions to me ***during those times only***. My E-mail address is **ben.davis@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 "ChE221" as the start of the subject, e.g. "ChE221 HW1 Question."

RESOURCES

These may (or may not) be helpful:

- Link to the Material and Energy Balances zyBook: https://learn.zybooks.com/library
- A compilation of many resources for M+E Balances courses: http://cache.org/super-store/material-and-energy-balances
- D. Himmelblau and J. Riggs, *Basic Principles and Calculations in Chemical Engineering* (8th ed.) – Prentice Hall, 2012, ISBN# 0132346605
- R. Felder, R. Rousseau, and L. Bullard, *Elementary Principles of Chemical Processes* (4th ed.) – Wiley, 2015, ISBN# 1118431227
- Website for Felder, Rousseau, and Bullard: https://epcp.wordpress.ncsu.edu/
- M+E Balances at Pitt: http://pillars.che.pitt.edu/student/course.cgi?course_id=12
- Free textbook on Introduction to ChE: https://en.wikibooks.org/wiki/Introduction_to_Chemical_Engineering_Processes
- LearnChemE YouTube channel: https://www.youtube.com/channel/UCKVGxWqAcyGibKC2RKD19RQ
- Index of Learning Styles: https://www.webtools.ncsu.edu/learningstyles/

SEQUENCE OF TOPICS/CLASS SCHEDULE

Rows in BLACK are in-person weeks—class will be in our normal room | Rows in RED are remote weeks—class will be via MS Teams

Hour	Day	Date	Topic(s)	zyBook	Due
1	Tue	8/30	Introduction / overview / syllabus	1.1	
2,3	Thu	9/1	What is ChE?, Making Crayons	1.2	
4	Tue	9/6	Discuss Crayons, Significant figures (SF)	1.3	
5,6	Thu	9/8	Unit conversions, Fluids, Density, P, T	2.1-2.4	HW1
7	Tue	9/13	Flow rates, C, x, y, Setting a basis	2.5-2.12	
8,9	Thu	9/15	Systems and processes, 12 Step Method	2.13	
10	**Tue**	**9/20**	**The 12 Step Method**	2.14	
11,12	**Thu**	**9/22**	**12 Step Method, multiple units, split/recycle/bypass, reacting systems**	2.15-2.18	HW2
13	Tue	9/27	Unit operations (pump, mixer, distillation)	2.19	
14,15	Thu	9/29	Multiple rxns, conversion, equilibrium	3.1-3.3	
16	Tue	10/4	Atom balances, reacting systems	3.4	
17,18	Thu	10/6	Reacting systems with recycle	3.5	HW3
--	**Tue**	**10/11**	**Midterm Exam 1 review session**	3.6	
--	Thu	10/13	Midterm Exam 1 (IN CLASS, 2 HOURS)	3.7	Exam 1
19	Tue	10/18	Real gases and Z, P-x-y, T-x-y	4.1-4.15	
20,21	Thu	10/20	VLE for process units	5.1-5.2	
22	Tue	10/25	More VLE, flash tanks, stripping columns	6.1-6.5	
23,24	Thu	10/27	Graphical methods for VLE	6.6	HW4
25	**Tue**	**11/1**	**Energy balances**	7.1	
26,27	**Thu**	**11/3**	**Energy balances**	7.2-7.3	
28	Tue	11/8	Energy balances	7.4-7.5	
29,30	Thu	11/10	Enthalpy, heat capacity, humidity, review	7.6-7.9	HW5
--	Tue	11/15	**NO CLASS** (AIChE Annual Meeting)		
--	Thu	11/17	Midterm Exam 2 (IN CLASS, 2 HOURS)		Exam 2
--	Tue	11/22	**NO CLASS** (Friday schedule)		
--	Thu	11/24	**NO CLASS** (Thanksgiving)		
31	Tue	11/29	Hess's Law, Heat of formation, reference states	8.1-8.3	
32,33	Thu	12/1	Energy balances on reacting systems	8.4-8.7	
34	Tue	12/6	Energy balances on reacting systems	9.1	
35,36	Thu	12/8	Energy balances on reacting systems	9.2	HW6
37	**Tue**	**12/13**	**Batch / transient systems**	9.3-9.4	
38,39	**Thu**	**12/15**	**Batch / transient systems**	9.5	

Table 1: Hours, Days, Dates, Topics, zyBook sections, and due dates

SPECIAL ACCOMMODATIONS

Students with disabilities or who need special accommodations for this class are required to contact The Dean of Students and me immediately so that arrangements can be made. The Cooper Union has limited resources and extra lead time is required for such arrangements to be feasible. We want to provide you with an inclusive and effective learning environment, but we need your help and input ahead of time to do that.

In order to receive accommodations for an exam, you must notify me in writing at least two weeks before the accommodations are needed and you must also be registered with the Dean of Students. Students will not be afforded any special accommodations retroactively, i.e., for academic work completed prior to disclosure of the disability to myself and the Dean. This policy is modified from Monmouth University via Professor Topper.

GROUP WORK AND ACADEMIC INTEGRITY POLICY

The Cooper Union School of Engineering Policy on Academic Integrity is posted here. 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 each week 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 completing the work 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 (ESPECIALLY SPREADSHEETS) a submission that includes the work product of your other group members
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. code from the internet)
3. You present as your own work product material from previous iterations of this course (old midterm exams, slides, old projects, homework solutions); representing my work as your own work is not only plagiarism, it keeps you from practicing forming and writing your own answers to my questions.
4. The help and contributions of other individuals are not acknowledged in writing on your submission (by writing their names or citing th published work)
5. You copy the work of other students on an in-class examination o communicate with other individuals in any fashion during an exam
6. You submit as part of a homework assignment or project 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, SPREADSHEETS, etc.

If I have a strong suspicion that you have plagiarized your submission for an assignment (homework or project,) you will be reported to the Dean's Office and likely receive a zero on that assignment. Other prohibited acts of academic dishonesty include (but are not limited to):

7. Attempting to obtain a copy of an examination before it is administered
8. Dishonesty with me or another professor, such as misrepresenting statements of another professor
9. Bringing a text or study materials of any kind into an exam when forbidden to do so
10. Using an electronic device in class at any time when not expressly permitted by me
11. Bringing a 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 be reported to the Dean's Office and likely receive a zero on that examination and a D or F in the course.

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 (taken from the ABET website) are:

1. **an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics**
5. **an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives**
7. **an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.**

TECHNOLOGY POLICY

You may use a tablet or a laptop during class to take notes and may use a computer to complete homework assignments. You may use a calculator during class. ***You may not use*** any other electronic device during class without my permission. You may not use a laptop, tablet, cell phone, or any other electronic device during class for any purpose unrelated to class; for example, you may use your laptop to look at an electronic textbook for the class, but not to look at Instagram. ***You may not use any other electronic device besides a calculator during an exam.***

COURSE POLICIES, EXPECTATIONS OF THE CLASSROOM ENVIRONMENT, AND EXPECTATIONS FOR THE PROFESSOR:

I try to create course policies that support a fair and equitable classroom and set high performance standards for all students. I hope to create an inclusive learning environment where you feel both challenged but also constantly respected and recognized within the course. Please make an appointment with me (ideally within office hours) if you are having any issues related to me, the course, or your fellow students.

While I want you to feel comfortable coming to me with issues you may be struggling with or concerns you have, please be aware that I have reporting requirements that are part of my responsibilities as a member of the faculty. If you inform me of an issue of sexual harassment, sexual assault, or discrimination, I will keep the information as private as I can, but I am required to report the basic facts of the incident to Cooper's Title IX Coordinator. The Cooper Union Title IX policy on sexual misconduct can be found **here**.

Counseling Services at The Cooper Union are coordinated through the Office of Student Affairs.
The Cooper Union counseling and mental health services website can be found **here**.

Please see previous page for policies on technology, student accommodations, and group work/academic integrity.