ChE382: Process Evaluation and Chemical Systems Design II

Prof. Davis & Prof. Okorafor

Spring 2022 Syllabus

Class meeting times:

Mondays	2:00 – 3:50 PM in Room 502 or 503 or via Zoom (Project 1) or MS Teams (Project 2)
Tuesdays	2:00 – 3:50 PM in Room 504 or 505 or via Zoom (Project 1) or MS Teams (Project 2)

The course will meet regularly for these 4 hours for the first 7 weeks. After that, you will only need to give group meetings / presentations on Project 2 at your assigned time.

Course overview:

This is the capstone chemical engineering design course; you will all work in groups to scope, site, design, simulate, evaluate, and cost a chemical manufacturing facility and give a quantitative conclusion about its overall safety, sustainability, and economic value. The entire course is project-based; you will complete two process designs. The first is an ethylene production process and the second is one of two possible final projects (which vary in topic and scope from year to year).

For the ethylene project (Project 1), you will work in groups of 3-4 and each group has a different mix of raw materials (either pure propane, pure butane, or ethane/propane at a 3:1 or 1:3 ratio), different amounts of ethane recycle, and different properties of fired-heater-generated superheated steam. Each group is expected to design, size, cost, and report on the following pieces of equipment: cracking furnace, quench tower, multi-stage compressor, demethanizer, deethanizer, ethylene/ethane splitter, depropanizer, propylene/propane splitter, debutanizer, heat exchangers, flash towers, and pumps.

Other assignments for Project 1 include: a steam balance calculation, implications of "green engineering" to the process, and consideration of safety procedures. The instructor will outline the design of the plant in class in detail to demonstrate how an engineer-driven design is carried out, while you concurrently use simulation software to model and visualize the design. Each group will submit a Project 1 written report describing your process flow diagram and the calculations you did. The ethylene plant capacity will be 700 metric tons per day of 99.95% purity with a stream factor of 8400 operating hours/year.

For the second project (Project 2) you will remain in the same groups, subject to team member evaluations and instructor approval. Project 2 will be similar in type and scope to the first, but there will be limited in-class instruction and each group will present on their progress four times and have three formal meetings. There will be different design problems assigned to different groups, but all groups will be designing a manufacturing facility for SARS-CoV-2 vaccine.

Prerequisites and other requirements:

The prerequisite for this course is ChE381: Process Evaluation and Design I. The course has an optional textbook: Analysis, Synthesis, and Design of Chemical Processes by Bailie, Whiting, Shaeiwitz, and Turton (4th ed.) ISBN#9788120349612. You should purchase it (or another chemical engineering design textbook) and use it as your primary reference for performing your technical design and writing your memos, reports, and presentations. You will need access to a computer with a spreadsheet program and Aspen Plus to do your two design projects. SuperPro Designer is another piece of software that will be very helpful for Project 2. It should be available for you to download through the IT department. Material and energy balances are essential to both projects; your group should spend the majority of your time developing a spreadsheet BFD/PFD during the first two weeks of each project.

Groups:

The group assignments, feed compositions, recycle rates of ethane to the cracking unit, generated steam pressures in psig, and generated steam temperatures in ^{o}F for Project 1 are below:

Group	1	2	3	4	5	6
Feed	75E/25P	100P	100B	25E/75P	100P	100B
Recycle	50%	100%	100%	100%	75%	50%
Steam P	1600	1600	1750	1750	1650	1500
Steam T	950	800	875	900	850	750
	Ibrahim	Poorna	Tiffany	Jillian	Catherine	Peter
	Chris	Joey	Jessica	Angela	Iven	Walee
	Johnathan	Pia	Seemee	Marisa	Ryle	Juan
	Aleco		Emily	Sanjna	Joanna	Sunny

You are REQUIRED to submit a group member evaluation form via MS Teams for each team member you have during the semester at the end of both projects (1 and 2).

Memos, Meetings, Invoices, and Project Presentations:

There will be one homework, two written project reports, three meetings, three memos, four project presentations, and no exams in this class. The memos will be summaries of what you communicate to your "supervisor" in meetings and are usually a follow-up on that weeks' part of the design. They should be one page long, formatted correctly (e.g. one page long, dated, addressed, have a greeting, signed/initialed by each group member), and may include relevant appendices. The written reports for projects 1 and 2 should include detailed technical descriptions of your processes, with emphasis on the economics, environmental impact, and safety. A rubric for such reports can be found in any design textbook and up on MS Teams. Your presentations should be concise oral descriptions of the current state of your plant design; they should focus on the aspects of the design your group completed on in the past week based on requests from your "supervisor". These presentations are formal; business attire and demeanor are expected. **You are required to submit an invoice for your "consulting team" for each week of project 2.** This is a four credit class, so we expect that you will each spend about 8 hours per week outside of class on project 1. For project 2, we expect that you will spend about 12 hours per week on work for this class.

Attendance and Grading Policy:

Attendance for meetings and presentations is mandatory; please E-mail Professor Okorafor and Professor Davis well before class time if you cannot attend. There will be no make-up or extra credit work associated with this class. Please ensure that you hand in your assignments on time; all assignments must be completed for a passing grade in this class. Scores will be weighted as follows:

	MEB HW	Proj 1 Report	Memos	Meetings	Presentations	Proj 2 Report
% of grade	5	10	15	15	30	25

Each group will be assigned a grade for their Project 1 material and energy balances, Project 1 report, each of their written submissions for Project 2 (memos and final report), and for each of the three meetings. Meeting grades will be based on how well the group presents the information requested the previous week, using a rubric based on the assignment memo.

Presentations are graded individually and evaluated similarly to meetings based on technical content and communication quality. Group presentations are evaluated like meetings and count for 10% of your final score (groups of three only).

Group grades above will be combined to determine the group's grade for Project 2. These Project 2 group grades (50-60% of the raw score) may be adjusted based on group member evaluations and individual presentations in order to encourage equal participation by all group members on all assignments. Letter grades will be determined at the end of the semester using each student's group score from above, the average group score for the class, their individual presentation grade, and the instructors' discretion. Additionally, each group should submit a brief write-up of their project for the end of the year show; these projects are novel and will be very interesting to the Cooper Community.

Course goals and objectives:

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

- Design, size, and cost columns for absorption and stripping of dilute mixtures and distillation of concentrated mixtures graphically, analytically, and computationally
- Calculate material and energy requirements for a real production plant
- Describe how to perform manual sizing and simulation of standard chemical engineering unit operations
- Design, size, and cost a fired heater
- Select, size, and cost heat transfer equipment with and/or without mass transfer
- Manually calculate, with a Mollier Chart, the relevant design criteria for a multistage compressor system using the Elliot design methodology
- Select the appropriate number of compressor stages for a given compression task, calculate BHP for each stage, and find the overall BHP
- Design, size, and cost a multistage refrigeration system
- Perform a utility balance for a chemical process and determine an overall utility cost
- Perform an economic analysis of a project and determine the cash flow and the DCFROR/IRR through detailed calculations on plant costs
- Write a detailed report on a chemical process design which addresses aspects of engineering fundamentals, economics, health and safety, environmental performance, and management
- Present technical information in a concise and authoritative manner

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 acquired by students who have taken the 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 most closely associated with this course (taken from the ABET website) are:

2. an ability to apply eng. design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and econ. factors
3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
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

Office Hours:

You can E-mail Professor Okorafor at ogbonnaya.okorafor@cooper.edu. His office hours are M 1-2 PM, T 12-2 PM, and W 12-3 PM. Please E-mail him to set up an appointment through Zoom.

You can E-mail Professor Davis at ben.davis@cooper.edu. His office hours are M 12-1 PM, T 4:30-5:30 PM, and F 1-2 PM in room 419 (starting 1/31/22) or via MS Teams.

Group Work and Academic Integrity Policy:

The Cooper Union School of Engineering Policy on Academic Integrity is posted here:

https://cooper.edu/engineering/curriculum/academic-standards-regulations

We believe group work is important to learning; you will work in groups on your projects and we understand that your submissions are a team effort. However, each student MUST contribute as equally as possible to the group's submissions. Plagiarism is the presentation of another person's "work product" (ideas, words, equations, pictures, slides, 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 and <u>not your own</u>
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
3. The help and contributions of other individuals are not acknowledged in writing on your submission (by writing their names or citing their published work)
4. You submit as part of your project submission material that has been copied from any source (including, but not limited to: a textbook, a periodical, an encyclopedia, a journal article, Wikipedia, another internet source) 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 includes text, pictures or graphics (computer or otherwise), or computer source code.

If we have a strong suspicion that you have plagiarized your submission or not contributed to your groups' effort, you will be reported to the Dean's Office and likely receive a zero for the assignment due that week. Other prohibited acts of academic dishonesty include (but are not limited to):

5. Dishonesty in dealing with professors, such as misrepresenting the statements of another professor
6. Bringing any device, electronic or otherwise, into class at any time when not expressly permitted (e.g. laptop or cell phone use must be approved)

Resources which will be useful for your projects:

- Separation Process Principles by Seader, Henley, and Roper (3rd ed.) ISBN# 0470481838
- Perry's Chemical Engineers' Handbook by Don Green and Robert Perry (8th ed.)
- Fundamentals of Momentum, Heat, and Mass Transfer by Welty et al. (5th ed.) ISBN# 0470128682
- 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
- Plant Design and Economics for Chemical Engineers by Peters, Timmerhaus, and West (5th ed.)
- Stone and Webster's Ethylene Manufacture write-up (available on Moodle)
- Shreve's Chemical Process Industries by G. T. Austin (5th ed.) ISBN# 0070571473
- Chemical Process Equipment - Selection and Design by S. M. Walas ISBN# 9780750693851
- Yaws' Critical Property Data for Chemical Engineers and Chemists ISBN# 9781613449325
- Ullmann's Encyclopedia of Industrial Chemistry by Fritz Ullmann ISBN# 9783527306732
- Kirk-Othmer Encyclopedia of Chemical Technology by Raymond Kirk ISBN# 9780471238966
- ICIS Chemical Business (good source for market information on different chemicals, fuels, etc.)
- Process Plant Simulation by B. Babu (2004) – available online through Knovel
- DIPPR Project 801 – available online through Knovel
- Pinch Analysis and Process Integration by I. Kemp (2011) ISBN# 0750682604
- Online Pinch Analysis Tool by Jeff Umbach at UIC
- "How to Estimate Utility Costs" by Ulrich and Vasudevan *Chemical Engineering* April 2006 (p. 66)
- Transport Processes and Separation Process Principles by Geankoplis, Hersel, and Lepek (5th ed.)

Resources specifically for this year:

- SuperPro Designer: https://www.intelligen.com/products/superpro-overview/
- A good article on scaling the COVID vaccine problem from BMJ: *BMJ 2020;371:m4750* https://www.bmj.com/content/371/bmj.m4750
- "How are RNA vaccines made?" from CEN: https://cen.acs.org/pharmaceuticals/vaccines/Periodic-Graphics-RNA-vaccines-made/99/i1
- "The promise of mRNA vaccines: a biotech and industrial perspective" from npj Vaccines: https://www.nature.com/articles/s41541-020-0159-8 or https://doi.org/10.1038/s41541-020-0159-8
- Polymun Scientific (an Austrian company) does lipid nanoparticles (they call them liposomes); link to their patents and papers: https://www.polymun.com/liposomes/patents-publications/
- "How to Ship a Vaccine at –80°C, and Other Obstacles in the Covid Fight" from the NYT: https://nyti.ms/32HOf8S
- "How the Pfizer-BioNTech Vaccine Works" from the NYT: https://www.nytimes.com/interactive/2020/health/pfizer-biontech-covid-19-vaccine.html
- "How Moderna's Vaccine Works" from the NYT: https://www.nytimes.com/interactive/2020/health/moderna-covid-19-vaccine.html
- "Coronavirus Vaccine Tracker" from the NYT: https://www.nytimes.com/interactive/2020/science/coronavirus-vaccine-tracker.html
- "How the Oxford-AstraZeneca Vaccine Works" from the NYT: https://www.nytimes.com/interactive/2020/health/oxford-astrazeneca-covid-19-vaccine.html
- "How the Johnson & Johnson Vaccine Works" from the NYT: https://www.nytimes.com/interactive/2020/health/johnson-johnson-covid-19-vaccine.html
- "Mammalian Cell Culture Reactors, Scale-Up" from the Encyclopedia of Industrial Biotechnology: Bioprocess, Bioseparation, and Cell Technology: https://doi.org/10.1002/9780470054581.eib396

Sequence of topics and class schedule:

Below is the schedule for classes for the semester. We will have you sign up for specific meeting / presentation times for Project 2; each group will have a meeting or presentation on Monday OR Tuesday. Assignment due dates are indicated in the right-most column:

Week	Hours	Day	Date	Topic(s)	Due
1	1,2	Tues	1/18	Intro to Course, Syllabus, Project 1 Intro NOTE: MONDAY SCHEDULE	
2	3,4	Mon	1/24	Ethylene Plant Design / Project 1	
2	5,6	Tues	1/25	Ethylene Plant Design / Project 1	
3	7,8	Mon	1/31	Ethylene Plant Design / Project 1	
3	9,10	Tues	2/1	Ethylene Plant Design / Project 1	
4	11,12	Mon	2/7	Ethylene Plant Design / Project 1	
4	13,14	Tues	2/8	Ethylene Plant Design / Project 1	
5	15,16	Mon	2/14	Ethylene Plant Design / Project 1	
5	17,18	Tues	2/15	Ethylene Plant Design / Project 1	MEB
6	X	Mon	2/21	**NO CLASS:** Founder's Day / Presidents' Day	
6	19,20	Tues	2/22	Ethylene Plant Design / Project 1	
7	21,22	Mon	2/28	Ethylene Plant Design / Project 1	
7	23,24	Tues	3/1	Last class for Project 1	
8	X	Mon	3/7	**GUEST LECTURE:** Bill Cafiero	
8	25,26	Tues	3/8	Introduction to Project 2 / Kickoff Meeting	Project 1
9	X	Mon	3/14	**NO CLASS:** Spring Break	
9	X	Tues	3/15	**NO CLASS:** Spring Break	
10	X	Mon	3/21	Meeting 1: Basis for study – II	
10	X	Tues	3/22	Meeting 1: Basis for study – II	Evals
11	X	Mon	3/28	Presentation 1: BFD and cost estimates – I	
11	X	Tues	3/29	Presentation 1: BFD and cost estimates – II	Memo 1
12	X	Mon	4/4	Meeting 2: Reactor systems – I	
12	X	Tues	4/5	Meeting 2: Reactor systems – II	
13	X	Mon	4/11	Presentation 2: Separation systems – I	
13	X	Tues	4/12	Presentation 2: Separation systems – II	Memo 2
14	X	Mon	4/18	Meeting 3: Schedule/Safety/Waste – I	
14	X	Tues	4/19	Meeting 3: Schedule/Safety/Waste – II	
15	X	Mon	4/25	Presentation 3: Plant layout / Labor – I	
15	X	Tues	4/26	Presentation 3: Plant layout / Labor – II	Memo 3
16	X	Mon	5/2	Final presentation: Economics and go/no go – I	
16	X	Tues	5/3	Final presentation: Economics and go/no go – II	
17	X	Mon	5/9	**NO CLASS** – Project 2 due Thursday 5/12	
17	X	Tues	5/10	**NO CLASS** – Grades due by May 16	
17	X	Thu	5/12	**NO CLASS:** Project 2 due by 11:59 PM ET	Project 2
17	X	Fri	5/13	**NO CLASS:** Evaluation forms due	Evals