Course Mechanics and Syllabus

Course Number: CHBE444

Course Name: Process Engineering Economics and Design I

Semester: Fall 2018

Class Times and Venues

Lectures: Tu, Th 3:30 to 4:45, **Discussion:** We 10:00 to 10:50 (Sec. 0101), We 2:00 to 2:50 (Sec. 0102).

Venues: All Tu and Th sessions (3:30 pm) will be held in ESJ 2208, including exams. All We sessions (10:00 am or 2:00 pm) will be held in CHE 2108.

Teaching Team

Instructor: Dr. Ganesh Sriram
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Website: http://openwetware.org/wiki/User:GSriram
Office hour/Learning Community: Mo 4:00 to 6:00 in AJC 2134, Th 5:00 to 6:00 in ESJ 2309

Graduate Teaching Assistant (TA): Ms. Leah Borden
Ph.D. Student, Department of Chemical and Biomolecular Engineering
Email: lkborden@umd.edu
Office hour: Fri 1:00 to 2:00 in CHE 1124

Undergraduate Teaching Fellow (UTF): Mr. Kirellos Abou Elsaad
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Office hour/learning community: Mon 11:00 to 12:00 in AJC 2119

Office Hours and Learning Community

Office hours and locations were determined on the basis a survey and finalized after the add-drop period. See the listing above.

Course Listing, Pre- and Co- Requisites

As per the University's description of this course, CHBE424, CHBE426 and CHBE 440 are prerequisites. A further restriction is that the student must be in the chemical engineering undergraduate program or have permission from the ChBE department.

Textbook, Software and Other Requirements/Resources

Textbook (Required)

This year's textbook is a customized compilation consisting of the following:

Chapters 1, 2, 4-14, 16-18, 23, 26-27 of: **Seider WD, Lewin DR, Seader JD, Widagdo S, Gani R, Ng KM (2016)** Product and Process Design Principles: Synthesis, Analysis and Evaluation, 4th ed., John Wiley and Sons.

Chapter 22 of: **Kreyszig E (2011)** Advanced Engineering Mathematics, 10th ed., John Wiley and Sons.

Chapter 3 of: **Smith R (2016)** Chemical Process Design and Integration, 2nd ed., John Wiley and Sons.

This custom book may be purchased as follows:

A. Print book: Available at the campus bookstore and can be ordered online.

B. E-book: Available directly from VitalSource with immediate access upon purchase. Since exams in this course will only be open-notes (not open-book), students will not need to print the book for exams. Thus, students comfortable with reading e-books are recommended to purchase this portable and less expensive version. Students are advise not to rent the book as the rental term is only 120 days, and the book is needed CHBE446.

This textbook was selected in consultation with Design II instructors and after exploring which books other well-recognized chemical engineering departments use for their design sequence. See this Google Sheet if you are interested to know which books other institutions use.

Software (Required)

This course will principally require the use of three software packages:

A. Aspen is a state-of-the-art process simulator that is used industrially and has extensive capabilities for process design and evaluation. Aspen is available free of charge from the Clark School Virtual Computing Library (VCL) . Students should have already become familiar with Aspen in CHBE426.

B. MATLAB will be required for some computational problems and is available free of charge via the UMD Terpware Store (needs installation) or via the Clark School VCL.

C. Excel will be necessary for light computation and can be installed with the Microsoft Office suite, free of charge, via the UMD Terpware Store.

D. Solstice Client enables students to connect their computer to the classroom displays in ESJ and will be necessary for occasional sharing of Aspen results with the class.

Poster (Required)

This is a deliverable for the team project and a portion of the final assessment. Teams are responsible for printing their own posters. To the best of our knowledge, the TLC desk in the McKeldin Library offers the best pricing ($15+, depending on size).

Stationery (Recommended)

- For writing notes: Frixion pen (multicolor erasable pen) + refills or multicolored pencils
- For organizing notes: ring binder, staple remover, three hole punch
- For HW: plain letter paper or engineering paper

Other Resources

A. Textbook Used Prior to 2017. Towler G, Sinnott RK (2013) Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 2nd ed., Elsevier. *This book was used as the textbook for this course until last year and will continue to be used as a reference for select topics.* This book is available free of charge in electronic form via our library at this link.

B. Perry's Handbook. Green D, Perry R (2007) Perry's Chemical Engineers' Handbook, 8th edition. McGraw-Hill Professional. This handbook is available free of charge (UM campus only) at this link; ISBN 978-0-071-42294-9.

C. Kirk-Othmer Encyclopedia. Seidel A, Kirk R, Othmer D, Kroschwitz J, Howe-Grant M (2014) Kirk-Othmer Encyclopedia of Chemical Technology. Wiley. Selected sections of this encyclopedia are available free of charge (UM campus only) at this link; ISBN 978-0-471-23896-6.

Learning Management System

Canvas, https://umd.instructure.com. The instructor will post course material such as this course mechanics document, homework (HW) sets and resources for major assignments such as the project as well as your grades on this website. Your grades will be accessible only through your login. This website will also host an online forum for course-related discussions.

Computer (Required in Certain Class Sessions)

Throughout the course, students will need access to a computer (preferable) or a mobile internet device (does not replace a computer, but may be used temporarily) to perform hands-on work with computer programs including Aspen, MATLAB, GAMS and Excel. Notably, certain class sessions will involve hands-on work with computer programs or databases. Therefore, students are expected to bring a laptop computer with the Solstice Client installed. The instructor will inform students about these sessions 24 hours or more in advance. Students experiencing issues with availability of computers or devices are encouraged to see the instructor to work out a solution. **In class, these devices should be used solely for academic purposes during**

designated "Computer ON" times. The use of other electronic devices (e.g. phone calls or text messaging) is not permitted during class (see policy on Electronic devices in class, below). Clickers or other automatic response recorders will **not** be required.

Browser with SVG Support

This course website will display images using the scalable vector graphics (SVG) format. Most browsers are natively capable of rendering SVG, but some may require addons for this.

Arrangements for Students with Disabilities

Any students with learning disabilities will be provided the necessary accommodation(s). To ensure that this is done in a timely manner, students needing accommodation(s) must see the instructor by Monday, 2018-09-10.

Course Description and Outcomes

Description. CHBE444, along with CHBE446, caps off students' chemical engineering curriculum by covering optimization, integrated process design, process simulation and economic analysis. Specific topics to be covered include reaction decisions and heuristics, linear and nonlinear programming with applications to process design, design of reactors, design of separators, heat integration and process economics.

Outcomes. Upon successfully completing CHBE444, students should be able to:

- Identify the principal steps in chemical process design and prepare a draft flowsheet by factoring yield or profit targets, safety and heuristics.
- Perform linear and nonlinear optimization manually or by using appropriate software and apply the results to chemical process design.
- Perform material and energy balances, thermodynamic analyses and kinetic analyses on a process manually and via Aspen.
- Perform reactor design by addressing non-ideal flow, attainable region, separator placement, optimal recycle and optimal conversion.
- Perform separator design by addressing distillation column sequencing as well as distillation of non-ideal and reactive mixtures.
- Perform second-law analysis and heat integration on chemical processes.
- Perform heat exchanger network synthesis by addressing pinch, maximum energy recovery and using optimization tools.
- Perform economic analyses on processes by addressing capital, operating costs and profitability.
- Use Aspen to perform economic analysis and optimization.

Important Dates

Scheduling Deadlines	
Last date to drop course without a "W"	2018-09-10 (Mo, unchangeable)
Last date to drop course with a "W"	2018-11-05 (Mo, unchangeable)
Major Scheduled Grading Events (Attendance Mandatory)	
Exam 1 (Major Scheduled Grading Event)	2018-10-11 (Th, 3:30 to 4:45, tentative)
Exam 2 (Major Scheduled Grading Event)	2018-11-29 (Th, 3:30 to 4:45, tentative)
Project Poster Presentation (Major Scheduled Grading Event)	2018-12-18 (Tu, 10:30-12:30, unchangeable), venue TBD

Grading

Your grade in this course will be determined from a combination of two in-class exams, class participation, weekly regular HW, team assignments and a team project. Note that the final assessment is the project summary and presentation. Your course grade will be apportioned as follows:

Course Component	**Weight**
Exam 1	30
Exam 2	30
Reading and Class Participation	5
Individual HW (1 to 9)	9
Team HW (A to I), Includes Final Assessment	26
Total	**100**

Components of the Course Grade

Exams (60%)

The in-class exams will be **open notes, but not open-book**. During exams, students are allowed to use **self-generated, hardcopy** (handwritten or typed) notes and handouts supplied by the instructor.

Comprehensive exams. Although each exam will have a focus, it will be comprehensive. Therefore, students will always be expected to know material taught since the beginning of the semester. Furthermore, students will be responsible for knowing material covered in prerequisite courses. Grades earned by students on exams will be based on their fundamental understanding

of the course material as perceptible from their solution and their ability to present an organized and legible solution.

Makeup exam policy. All exams are Major Scheduled Grading Events (also see Attendance section below). Students who miss exams for any reason other than University-approved reasons will not be given an opportunity to make up. Students who miss exams due to University-approved reasons will qualify for one of the makeup opportunities listed below only if they (i) inform the instructor about their absence in advance of the exam, and (ii) provide timely and verifiable documentation. Normally, University-approved reasons are restricted to illness of the student or a qualified dependent that prevents attendance at the exam or participation in a University-approved event (e.g. a performance or game) at the request of the University. University-approved reasons must be accompanied by documentation such as but not restricted to a doctor's certificate for illness. Students should note that lack of proper transportation (e.g. a flat tire) or a failed alarm clock are not valid excuses for missing an exam.

Students who miss an in-semester exam due to University-approved reasons as defined in the previous paragraph will be allowed to make up as follows:

- A single makeup for Exam 1 will be given outside class during the 7-day period following the exam, at a mutually agreeable time.
- A single makeup for Exam 2 will be given outside class during the 7-day period following the exam, at a mutually agreeable time.
- Students who miss more than one in-class exam, or students who miss a makeup exam will not be given further opportunity to makeup.

Regrade policy. Exam regrades in this course will generally be rare. The instructor reserves a right to refuse regrades of exams written in pencil or erasable ink. Students who find (i) score addition errors or (ii) questions that were inadvertently not graded on an exam must submit verbal regrade requests to the instructor immediately upon receiving the graded exam. This regrade request should be accompanied by a short written justification. Students must submit all other regrade requests to the instructor within 48 hours (not counting weekends and holidays) after the class first receives the graded exam, with a typed justification specifying why the exam or question should be regraded. The instructor will not honor regrade requests that do not adhere to these deadlines or instructions. In the interest of fairness, the instructor reserves the right to regrade an entire exam even if the student requests a regrade for a portion of the exam.

Reading and Class Participation (5%)

This score will primarily reflect performance in short Canvas quizzes based on assigned reading as well as in active learning activities during class.

Active learning will be a significant feature of this course. Typically, students will be expected to first engage in a classroom activity such as database lookup, completion of a step in a problem solution, execution of a software package, open-ended discussion or brainstorming. Following the activity, the instructor will ask randomly selected students to report their answer or findings. The responding students' class participation grade will depend on the quality of their responses. Note that while the activity may have been collaborative, students are expected to be individually intellectually responsible for the answers they provide.

Voluntary participation such as asking questions or providing responses that reflect insight or advance preparation will lead to increases in class participation points. Conversely, chronic absence from class, repeated failure to meet student expectations outlined below, repeated non-academic use of electronic devices or excessive wastage of class time through questions and comments that are irrelevant to the discussion or do not reflect preparation or attention, may lead to decrease in class participation points. The sole intent of this point reduction is to establish a classroom atmosphere conducive to learning, and the instructor hopes that this option will rarely or never be exercised during the semester.

Individual HW Assignments (9%)

HW will usually be due on certain Tuesdays at 3:30 pm as (tentatively) indicated on the Syllabus. Any deviations from this schedule with either be verbally announced in class or communicated through a Canvas announcement.

Each assignment will be assigned approximately a week prior to its deadline. Students must adhere to the posted deadline. Late submissions will, in general, not be accepted. Submissions received a few minutes after the deadline may be accepted at the instructor's discretion, with a significant (~10%) grade penalty.

Students must submit HW according to instructions furnished in the HW Guidelines Document. HW that is not submitted according to these instructions may not be graded. The instructor will not make any exceptions to the HW submission or lateness policies.

The instructor and teaching team will answer questions about the HW during office hours, although they will not provide final answers to numerical problems. Students have to attempt solving the problem before requesting help in the office hour.

Team HW Assignments Including Final Assessment (26%)

Team assignments, primarily involving Aspen, will be due on certain Tuesdays at 3:30 pm as (tentatively) indicated on the Syllabus. Although teams are expected to work on team HW collaboratively and submit the final product as a team, each team member must contribute to and approve each final product. Team members will periodically take CATME surveys to peer-review their teammates. A single CATME survey may be administered for a group of team HW assignments. These CATME scores will be quantitatively factored into each teammate's grade for each assignment. This system fairly rewards teammates who do over and beyond their fair share of work and penalizes teammates who do not contribute their fair share. Thus, different members of a team may receive different scores for the same team HW assignment.

Instructor and Student Expectations

Instructor Expectations

Students can expect the instructor to:

- Be professional.
- Explain new and previously unlearned concepts and information during lectures and answer questions related to the new concepts.
- Hold office hours for additional explanation or clarification of concepts taught in the lectures and/or relevant concepts from prerequisite courses, and assistance with the HW problem interpretation and solution methodology.
- Return graded material within reasonable time
- Respond to students' course-related emails/discussion board postings within a reasonable amount of time (two business days).
- Address student concerns provided that the concerns are raised in a timely manner, the concerns relate to the class as a whole, and addressing the concerns has a positive impact on student learning.
- Accommodate students with learning disabilities.
- Assist students with their professional development especially as relevant to this course and as reasonably possible.

Student Expectations

Students are expected to:

- Be professional.
- Follow the guidelines in this document in matters relating to this course.
- Peer-review their teammates in a fair and objective manner and reveal any conflicts of interest to the instructor in advance.
- Follow the University's Code of Academic Integrity.
- Come to class prepared by reading the relevant textbook sections and any posted handouts in advance and bringing the textbook to class.
- Be aware of deadlines and therefore plan ahead.
- Maintain an atmosphere conducive to learning and not disrupt the class, e.g. by arriving and leaving the class on time, raising one's hand before asking questions, refraining from consuming food in class (a beverage is acceptable), and refraining from using electronic devices meant for communication/entertainment in class. (See policy on electronic devices in class below.)

Course Policies

Academic Integrity

The University of Maryland, the Department of Chemical and Biomolecular Engineering (ChBE) as well as the professional societies American Institute of Chemical Engineers (AIChE) uphold and follow the highest ethical standards. The University has a Code of Academic Integrity (hereafter, code) that prohibits students from cheating or consulting their colleagues during exams, cheating or plagiarizing on HW, buying papers, submitting fraudulent documents and forging signatures. Additionally, the ChBE Department has a policy on academic integrity (to be provided separately). The instructor will follow the University code and the ChBE policy in all matters relating to academic integrity.

Serious violations of academic integrity are exemplified by, though not restricted to, the following:

- Any kind of information exchange between students during exams.
- Altering a graded exam and then requesting regrading (to prevent this, the instructor will routinely photocopy and file graded exams).
- "Copying" a quiz, homework response, computer code or simulation file, either from a classmate or from previous years' student solutions or the instructor solution manual (unauthorized for students), without intellectually contributing to the assignment. (See paragraph below for what constitutes academic dishonesty on quizzes and HW.)
- Contributing computer code or simulation files developed by persons outside one's team toward the product developed by one's own team.
- Using or consulting material that is not available to the entire class or to which students do not have authorized access, e.g. the instructor solution manual to the textbook.

What constitutes independence and academic dishonesty on HW. Students and teams may discuss HW with colleagues outside the team with regard to interpretation and methodology; however, individual students and their teams should exhibit independence in proceeding with the solution. If a student is doubtful about the acceptable extent of collaboration on HW, the student should check with the instructor. In general, submission of a HW problem solution that clearly demonstrates lack of intellectual input on the entire problem or part thereof, or facilitating someone else's submission of such a solution is academic dishonesty. For an example of how HW copying correlates with low grades on analytical final exams, see: Palazzo DJ, Lee Y, Warnakulasooriya R, Pritchard DE, 2010, *Phys. Rev. Spec. Topics – Phys. Ed. Res.* 6: 010104.

Violations of academic integrity or the Honor Code may entail negative consequences on the course outcome and/or disciplinary action. University of Maryland's standard penalty for an act of academic dishonesty is an "XF" grade with the annotation "failure due to academic dishonesty" on the student's transcript. More severe penalties and disciplinary action could also be imposed, depending on the intensity of the violation.

Honor Pledge. The University has a student-administered Honor Pledge:

"I pledge on my honor that I have not given or received any unauthorized assistance on this examination."

which students and teams are asked to write and sign on every exam and assignment. Failure to do so will require the student to confer with the instructor.

Attendance

Students are expected to attend all lectures, submit assignments on time and take all exams in this course. The instructor will follow the University's Policy on Attendance and Assessments/Examinations as well as the ChBE Department's Policy on Medically Necessitated Excuses, (to be provided separately), in all matters relevant to attendance. Students should note the following:

- **Two exams and one project presentation have been designated as Major Scheduled Grading Events** above and in the course calendar. Medically necessitated absences at these events must be substantiated by verifiable documentation from a medical professional that is in accordance with the University's guidelines. Any other University-approved absences at these events also require verifiable documentation. If a student fails to provide documentation in a timely manner, the student will be unable to make up for the missed event. Additionally, students should inform the instructor of absences as soon as possible in case of medically necessitated absences and in advance of the absence for non-medically necessitated absences. Makeup policies for exams are outlined above.
- Students who are absent at non-Major Scheduled Grading Events due to medically necessitated reasons at two or more non-consecutive lectures or for a prolonged period (three or more consecutive lectures) must provide verifiable documentation from a medical professional that is in accordance with the University's guidelines. Failure to provide the documentation in a timely manner will result in not being able to make up for any missed grading events such as quizzes or HW.
- Students who miss an exam, HW, or class activity without a legitimate (medically necessitated or University-approved), documented and verifiable reason will not be able to make up.
- Students who miss class are still responsible for the material covered during the absence and it is recommended that they obtain notes from classmates.

Absence due to religious observation. If the observation of a religious event occurring during the semester prevents a student from attending class, the student may be allowed to make up for missed exams or HW. However, it is the responsibility of the student to inform the instructor about the projected absence before 2018-09-10 or the date of the absence, whichever is earlier.

Inclement weather. In case of inclement weather, the instructor will abide by the University's policy on closures and delays, which will be posted at http://www.umd.edu. If the University closes on a class day because of inclement weather, any HW due on that day will become due on the next day the class meets, and any exams scheduled for that day will be postponed to a date that will be notified on the learning management system.

Other Policies

No Electronic Devices in Class Except During Designated Computer ON Times. To maintain an atmosphere conducive to learning, students should not use electronic devices for communication and/or entertainment purposes during class. Such devices include, but are not restricted to cell phones, smart watches, tablets, computers, music players and games. These devices should be put away out of sight in backpacks or pockets, and not kept on a desk or chair. Repeated reminders to put devices away may result in negative class participation points. Students may use watches or calculators that do not have communication or entertainment capability. A student with a compelling need to use an electronic device other than watch or calculator in class should discuss this need with the instructor and obtain the instructor's advance permission to use the device. **The only exceptions to the above policy will be certain class sessions with designated "Computer ON" times.** These sessions will be rare and will involve hands-on work with online databases and computer programs. During these sessions, students will be expected to use a computer or an internet browsing device solely for academic purposes.

Communicating with the Teaching Team. Email or Canvas messaging is the best way to reach the instructor; alternative methods are the messaging or online discussion board features of Canvas. When electronically messaging the instructor, please use the email address gsriram+chbe444@umd.edu. This is more preferable to Canvas messaging. Email communication with the teaching team must be professional. Students can expect a reply to electronic messages within two business days. For their own privacy, students' emails to the instructor should originate from their umd.edu address or University-registered email address (if different from the umd.edu address). Students cannot expect to receive grades and exam or HW scores over email; these will have to be accessed through the learning management system.

Course Calendar (Syllabus)

Date	Lecture	Discussion
Tu Aug 28	Course Mechanics Introduction to Design: Vinyl Chloride Process, Decisions, Heuristics, Heat Integration, Optimization	Constrained Optimization in Chemical Engineering
Th Aug 30	Linear Programming (LP): Graphical Method	
Tu Sep 04	LP: Simplex Method	Aspen: Flash, Reactors, Separators
Th Sep 06	LP: Simplex Method, Infeasible Origin	
Tu Sep 11	1-D Nonlinear Programming (NLP): Examples, Golden-Section Search	LP
Th Sep 13	LP on MATLAB 1-D NLP: Golden Section Search Example	
Tu Sep 18	Multi-D NLP: Univariant Search, Nelder-Mead Amoeba Method, Simulated Annealing and Genetic Algorithm (Qualitative) Optimization on MATLAB and Aspen	NLP
Th Sep 20	Reactor Design: Rate Vectors	
Tu Sep 25	Reactor Design: Attainable Region	Reactor Design: Attainable Region
Th Sep 27	Reactor Design: Rate Vector Diagrams in C_A-τ Space	
Tu Oct 02	Reactor Design: Ammonia Bypass Process	Aspen: Optimization
Th Oct 04	Reactor Design: RTD and Nonideal Flow Introduction to Separator Design	
Tu Oct 09	Review for Exam 1	Exam 1 Review
Th Oct 11	Exam 1 (Process Design, Optimization, Reactors) (Major Scheduled Grading Event)	
Tu Oct 16	Separator Design: Multicomponent and Systems, Residue Curves	Ammonia Bypass
Th Oct 18	Residue Curves, Ternary Diagrams, Ternary Flash	
Tu Oct 23	Ternary Flash, Ternary Distillation	Aspen Reactive Distillation (Reactive Distillation) e: 216/p: 220
Th Oct 25	Ternary Distillation, Azeotropy	
Tu Oct 30	Heat Exchanger Networks (HEN): Introduction, TH Diagrams	Ternary Distillation
Th Nov 01	HEN: Examples of Design, Composite Curves, Pinch	
Tu Nov 06	HEN: Pinch, Minimal Energy Requirement (MER), Composite Curve Method. Temperature Interval (TI Method)	HEN MER

Th Nov 08	HEN Synthesis, LP Solution	
Tu Nov 13	Grand Composite Curve (GCC) and Utility Selection HEN Synthesis by NLP: Split Streams	Vinyl Acetate Project
Th Nov 15	Economics: Capital, Interest, Time Value of Money	
Tu Nov 20	Economics: Time Value of Money, Profitability	Thanksgiving
Th Nov 22	Thanksgiving	
Tu Nov 27	Review for Exam 2	Exam 2 Review
Th Nov 29	Exam 2 (Separators, HEN, Economics) (Major Scheduled Grading Event)	
Tu Dec 04	Aspen Recycling, HEN Design, HX Rigorous Design	Aspen Process Economic Analyzer
Th Dec 06	Safety, Summation	
Tu Dec 18	Project Presentation	