The University of Iowa
Department of Chemical and Biochemical Engineering

CBE:2105—Process Calculations — Fall, 2016

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Office Hours: Tu, 11:00 AM – 12:00 PM
W, 2:30-3:30 PM (shared with EPSI)

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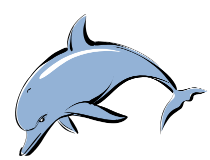
Office Hours: Th, 3:30-4:30 PM

Discussion Section: Mondays, 4:30-5:20 PM, 2217 Seamans Center
The discussion section is mandatory for asynchronous students, but optional for students attending the MWF classes. It is used to provide an overview of the main concepts that will be covered in the class during the coming week, as well as to work additional examples. Questions from the previous week will also be addressed.

Course Description:
This course will introduce you to the fundamental principles of chemical process analysis. It will equip you with problem solving techniques and will give you experience in the application of these techniques to a wide variety of process-related problems. During this course you will: i) learn to synthesize and integrate process information; ii) develop critical thinking and analytical skills; iii) develop the ability to explain engineering concepts in your own words; and iv) gain valuable experience in teamwork.

Textbook: *Elementary Principles of Chemical Processes*, 4th Edition, R.M. Felder, R.W. Rousseau and L.G. Bullard, John Wiley and Sons, 2016.

On-line Quizzes, In-class Activities, and Homework: (15% of grade)
Since Process Calculations is a "flipped" course, the lecture and out-of-class elements are reversed. You will review course content (see attached schedule) and complete an on-line quiz that will test your understanding of the concepts presented and solicit questions for review in the first 15 minutes of class. Note that the on-line quizzes must be completed before 10 AM the day of class and are to be done individually (i.e., no collaboration or group work allowed).



I am pleased that we are able to have our classes in a TILE classroom. The room setup and technologies will enable us to cover concepts at a deeper level than in a traditional classroom format. In-class activities will include both individual and group assignments. Attendance and participation are required for credit. Preparation before class is essential to make the most of the class time. You should expect to spend *at least* 2-3 hours in outside preparation for every hour in class.[1] Tangible outputs of in-class activities will be collected in various formats (e.g., Excel spreadsheets and photos of whiteboard work uploaded to the ICON Dropbox; flipchart sheets and notebook papers submitted physically; etc.).

Homework is due at the **beginning** of class on the day it is due. Late homework will not be accepted.

True learning of the course concepts must begin with practice, and the homework provides you with the opportunity to apply the course concepts to realistic (although in some cases simplistic) engineering problems.

[1] http://www.collegeparents.org/members/resources/articles/your-college-student-investing-enough-time-studying

Group discussion of the problems is allowed (and encouraged); however, homework is to be completed individually and professionally. Homework that has been copied, either from another student or from a solutions set, will be assigned a zero and a report of academic misconduct[2] will be filed with the Associate Dean for Academic Programs in the College of Engineering.

For all assignments, follow homework presentation guidelines listed on ICON Content page, including:

- Always show all of your work (it should be clear how the problem was solved)
- Always carry along units in your calculations
- Always display an appropriate number of significant figures in your final answer
- Always box in or underline your final answer and include units

Homework not adhering to these guidelines will be returned with a warning for the first offense, with a grade penalty for the second offense, and with no grade for any offenses thereafter.

Exams: (three exams, 65% total)
The first exam is tentatively scheduled for the **evening** of September 27 (Tuesday); the date of the second exam is tentatively scheduled for the **evening** of October 25 (Tuesday). The final exam will be given in the scheduled period during finals week. Unless otherwise announced, these exams will be closed-book, with two hours to complete the problems.

A makeup exam may be arranged if you notify me **before** the regularly scheduled exam with a valid reason for missing the exam. Verifiable illness with notification through the Associate Dean for Academic Programs or family emergencies may be valid reasons for missing an exam.

Group Projects and Reports: (15% of grade)
You will complete material and/or energy balances for various production units and prepare a report recommending the best operating procedures. You will work together in interdependent groups of 3-4, with each group member assuming a different role essential to the success of the project. Anyone not participating in these projects will automatically receive an F for CBE:2105, regardless of other grades earned in this class.

Topical Paper: (5% of grade)
This writing assignment will consist of a 500-1000 word (~1-2 single-spaced pages) report written for a general audience. Possible topics include: Sustainable energy in the future, future developments in biotechnology, or any other future development that chemical engineers are destined to impact. A draft of your paper (due September 16) will initially be evaluated by the Hanson Center for Technical Communication (25% of the final topical paper grade), and your final rewrite will be evaluated by Dr. Jessop (due October 10).

Professionalism: Since this course is the first in the chemical engineering curriculum, it is a good time to reinforce positive patterns of professionalism and class conduct. Learning should be fun and interesting, but at the same time, you should approach everything you do with high professional standards. Professional traits include honesty, integrity, courtesy to others, and a clear motivation to understand and master the subject matter of the course.

[2] http://www.engineering.uiowa.edu/ess/current-students/academic-policies-standards/academic-misconduct

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Course Learning Goals:
The course activities are designed to develop your competency in the following areas:

- By the end of the course the student will be able to perform material balances on systems including, but not limited to, single unit processes, multi-unit processes, recycle, bypass, chemical reaction and combustion systems.
- By the end of the course the student will be able to choose and apply the simplest equation of state that yields accurate results for the problem under consideration, including the ideal gas law, compressibility equation of state and cubic equations of state.
- By the end of the course the student will understand and be able to apply relationships that describe phase equilibria (gas/liquid and liquid/liquid) including Raoult's Law, Henry's Law, the Gibbs Phase Rule, phase diagrams and thermodynamic tables.
- By the end of the course the student will be able to perform energy balances on closed and open systems, with and without chemical reactions, either independent of or simultaneous with mass balances.
- By the end of the course the student will have had opportunities to further his/her professional development through studying professional ethics, practicing written communication skills and being exposed to contemporary issues.

This course is given by the College of Engineering. This means that class policies on matters such as requirements, grading, and sanctions for academic dishonesty are governed by the College of Engineering. Students wishing to add or drop this course after the official deadline must receive the approval of the Dean of the College of Engineering. Details of the University policy of cross enrollments may be found at: http://www.uiowa.edu/~provost/deos/crossenroll.doc

Tentative Schedule of Topics

MWF 12:30-1:20 PM, 134 TH

Date	Textbook[1]	Lecture Capture[2]	Screencasts[3]	Web Course Lessons[4]
8/22	Ch. 1	Introduction to ChE		1.9
8/24	§ 2.1-2.6	Sections 2.1-2.6	<u>Engineering Calculations</u> Unit conversions (7:17) Systems of units (9:21) Force and weight (6:20) Significant figures (5:47) Dimensional homogeneity (6:57) Dimensionless groups (4:26)	2; 3.1-3
8/26	§ 2.7	Section 2.7	<u>Engineering Calculations</u> Linear Interpolation (4:02) Advanced interpolation (5:18) Linearization of non-linear equations (5:00) Plotting non-linear equations (7:13) Linearization example (optional)	3.4-10
8/29	§ 3.1-3.3	Sections 3.1-3.3	<u>Process Variables</u> Specific gravity (5:28) Density, Mass Flow, and Volumetric Flow (3:06) Molar conversions (6:52) Mass and mole fractions (9:02) Average molecular weight derivation (7:26) Average molecular weight calculation (6:17) Determining Concentrations of Streams (ppm) (8:17)	4.7,9-17
8/31	§ 3.4-3.5	Sections 3.4-3.5	<u>Process Variables</u> Introduction to pressure (4:26) Manometers (5:19)	4.8

[1] *Elementary Principles of Chemical Processes*, 4th Edition, R.M. Felder, R.W. Rousseau, and L.G. Bullard, John Wiley and Sons, 2016.
[2] https://engineering.uicapture.uiowa.edu
[3] http://www.learncheme.com/screencasts/mass-energy-balances
[4] http://www.engineering.uiowa.edu/~webmeb/web_course/index.html

Date	Textbook[1]	Lecture Capture[2]	Screencasts[3]	Web Course Lessons[4]
9/2	§ 4.1-4.3	Sections 4.1-4.3	Single Unit Balances General balance for material balances (3:28) General balance on a single tank (6:29) Flow chart example (4:11) Scaling a material balance (6:35) Introduction to degrees of freedom (5:11) Degree of freedom analysis on a single unit (7:30)	4.1-6; 5
9/5	Labor Day – No Class			
9/7	(§ 4.3)	(Section 4.3)	Single Unit Balances Material balance problem approach (9:58) Performing a material balance on a single unit (9:13)	(5)
9/9	§ 4.4	Section 4.4	Multiple Unit Balances Designing a flow chart (8:10) Degrees of freedom (4:31) Multiple unit system: degree of freedom analysis (9:58)	6
9/12	§ 4.5	Section 4.5	Multiple Unit Balances Multiple Unit Material Balance/Recycle - Decaf Coffee (12:31) Crystallizer Material Balance with Recycle (12:48)	(6)
9/14	§ 4.6	Section 4.6	Balances on Reactions Stoichiometry (3:44) Percent excess air (3:38) Equilibrium (5:38)	8
9/16	§ 4.7	Section 4.7	Balances on Reactions Three methods for solving reactive material balances (8:56) Molecular species balances (4:20) Atomic species balances (6:56) Extent of reaction for material balances (8:13) Two reactions (extent of reaction) (10:29) Single reaction with recycle (11:20)	9; 10.1-5

Date	Textbook[1]	Lecture Capture[2]	Screencasts[3]	Web Course Lessons[4]
9/19	§ 4.8	Section 4.8	Combustion Overview of Combustion Chemistry (8:21) Percent Excess Air (Combustion) (8:18) Material Balances on Complete Combustion of Methane (6:46) Complete and Partial Combustion of Ethane (9:57)	10.6-11
9/21	Engineering Ethics – Class Discussion			16
9/23	Review Session for Test 1			
9/26	§ 5.1-5.2	Sections 5.1-5.2	Single-Phase Systems Ideal gas law: lung example (9:33) Standard temperature and pressure: ideal gas law (4:21) Ideal gas mixture characterization (6:26) Ideal gas mixtures example (optional)	11
9/28	§ 5.3-5.4	Sections 5.3-5.4	Single-Phase Systems Critical properties (T and P) (5:11) SRK equation of state example (8:20) Compressibility factor equation of state (8:37)	12
9/30	ChE Advisory Board – Class Discussion			
10/3	Introduction of Design Project			
10/5	§ 6.1-6.2	Sections 6.1-6.2	Single-Component Phase Equilibrium Gibbs phase rule (4:02)	
10/7	§ 6.3	Section 6.3	Multi-Component Phase Equilibrium Raoult's Law (water as condensable component) (4:20) Single-Component Phase Equilibrium Single condensable species balance (8:53) Relative and absolute humidity (3:51)	14.1-5
10/10	Go over Test 1			
10/12	§ 6.4	Section 6.4	Multi-Component Phase Equilibrium Multicondensable species in VLE (4:58) Multicondensable species balance (Excel Solver) (9:40) Binary vapor: partial condensation (3:12) Balances w/ Phase Equilibrium Gas stripping (Henry and Raoult's laws) (11:14)	14.6-10

Date	Textbook[1]	Lecture Capture[2]	Screencasts[3]	Web Course Lessons[4]
10/14	(§ 6.4)	(Section 6.4)	Multi-Component Phase Equilibrium Raoult's law explanation (3:11) Dew temperature calculation (7:06) Bubble point calculation for condenser (2:55) Phase equilibrium: Txy diagram (5:46) Lever rule (1:13) Condense a binary mixture (2:42)	(14.6-10)
10/17	§ 6.5a,b	Section 6.5	Multi-Component Phase Equilibrium Solubility introduction (4:26) Using solubility diagrams for material balances (8:13)	15.1-6
10/19	§ 6.6	Section 6.6	Multi-Component Phase Equilibrium Using a triangular (ternary) phase diagram (4:23) Interpolating tie lines on a ternary diagram (5:02) Balances w/ Phase Equilibrium Triangular (ternary phase diagram example (7:26)	15.7-11
10/21	Review Session for Test 2			
10/24	§ 7.1-7.3	Sections 7.1-7.3	Energy Balances Introduction to energy (5:10) Open and closed systems (6:54)	17
10/26	§ 7.4-7.5	Sections 7.4-7.5	Energy Balances Flow work (6:51) Balances on Nonreactive Processes What is enthalpy? (4:31) Tables/Charts How to Use Steam Tables (5:57) Steam Tables: Interpolation (4:49) Steam Table Example (7:42) Steam Tables: Constant Volume Process (optional) Energy balance on heat exchanger (6:33)	18
10/28	§ 7.6	Section 7.6	Energy Balances Problem solving approach (3:54) Adiabatic Compression of an Ideal Gas (9:17) Energy balance on open system (8:21)	19

Date	Textbook[1]	Lecture Capture[2]	Screencasts[3]	Web Course Lessons[4]
10/31	§ 8.1-8.3a,b	Sections 8.1-8.3	Enthalpy Changes Reference states in enthalpy calculations (7:29) Choosing a reference state example (8:52)	20.1-3
11/2	§ 8.3	Section 8.3		20.3
11/4	Go over Test 2			
11/7	§ 8.4a,b,c	Section 8.4	Enthalpy Changes Including a phase change in an energy balance (7:43) Heat of vaporization: Clausius-Clapeyron (2:18)	20.4-11
11/9	§ 9.1-9.4	Sections 9.1-9.4	Energy Balances with Reactions Hess's law (4:54) Heat of combustion (6:55) Enthalpy Changes Heats of formation (2:56) Heat of reaction (from heat of formation) (6:29)	21.1-4
11/11	§ 9.5a	Section 9.5	Energy Balances with Reactions Calculating enthalpy changes using heat of reaction… (8:33) Calculating enthalpy change using heats of formation… (8:47)	21.5-9; 23
11/14	§ 9.5b	(Section 9.5)	Energy Balances with Reactions Energy balances with unknown outlet conditions (7:54) Heat removal from a chemical reactor (8:23) Steam reformer balances (9:20)	(21.5-9; 23)
11/16	§ 9.6	Section 9.6	Energy Balances with Reactions Adiabatic flame temperature (5:59)	22
11/18	(§ 9.6)	(Section 9.6)		(22)
Week of 11/21	Thanksgiving Break – No Class			
Week of 11/28	Schedule to be determined			
12/5	§ 10.1-10.2	Sections 10.1-10.2		
12/7	(§ 10.1-10.2)	(Sections 10.1-10.2)		
12/9	Review Session for Final Exam			
Week of 12/2	Final Exam – TBD			