C&PE 211
Material and Energy Balances
Fall 2009

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Class Times:	Lecture: 3:00 – 3:50 M,W,F, 2 Eaton Calculation Laboratory: 4:00-5:45 M, 2 Eaton
Textbook:	Felder, R.M. and Rousseau, R.W., 2005. *Elementary Principles of Chemical Processes, 3rd Ed. (2005 edition)*, John Wiley and Sons, Inc., Hoboken, NJ, 675 pp.
Required:	Engineering paper for assignments
Recommended:	Flowsheet Template (Timely Flowplanner T-60 or similar)

Blackboard: I will use Blackboard Course Management System to post course documents, lecture notes, assignments, and other course material. If you are enrolled in this class you will have access to the CPE 211 Blackboard site.

Office Hours: Tentative office hours are Monday 9:30-10:30 and Thursday 1:30-2:30. If there are conflicts with a majority of the people in the class we can change the times. Also, I have an open door policy for questions and help. You may stop by my office at any time and if I am free I will be happy to help. If you want to set up an appointment, please feel free to email or call me and we can schedule a time to meet. You may call me at home, if needed, before 8:00 P.M. or in the case of an emergency.

Course Description: The application of the laws of chemistry, physics, and mathematics to the solution of material and energy balance problems occurring in the process industries. You will get an idea for the types of problems that are encountered by chemical engineers working with individual chemical units and complete processes. More importantly, you will develop a methodology or approach to solving engineering process-related problems including: 1) how to break-down a process into components; 2) establish a relationship between known and unknown variables; 3) how to solve for the unknown variables using a combination of experimentation, empiricism, and natural laws; and 4) finally, how to put all of the information together to obtain the desired solution to the problem. This class will help you develop a way of thinking that will be necessary for further development and problem solving in future engineering classes and your career.

Attendance: Attendance at the scheduled classes is strongly encouraged. There will be occasional in-class problems and assignments that are to be completed during class time. In-class work and assignments missed due to unexcused absences will negatively affect your grade. You are responsible for all information transmitted in class and for homework assignments due (when they are due) regardless of your attendance.

Attendance at scheduled exams is mandatory. Absence from an exam because of illness or injury will be excused only if a physician confirms in writing that you were unable to attend because of the illness or injury. Absence from an exam may be excused for other pressing reasons, but only if the instructor is notified **before the exam** and agrees to the absence. In extreme emergencies, a student may be excused from an exam after the fact but only if the instructor is contacted promptly after the exam.

Respectful Classroom Environment: Keep noise and distractions to a minimum out of respect for your classmates. This is really just a common sense issue. You are expected to silence cell phones and pagers, not talk on cell phones during class, and arrive to class on time. Conversations with classmates should not be disruptive to others.

Examinations: Three exams and a final will be given in this course. The final exam is scheduled for Wednesday, December 16 from 1:30-4:00 P.M. The material to be covered on the exams will be specified before each exam and will be announced at least one week before the examination date. The examinations will take place on Mondays during the class and calculation laboratory sessions. More information about the exams will be discussed as they approach.

Homework: An important component of this course is the work to be completed outside of the class meetings. That work includes reading and homework assignments. Note that a significant component of the grade for this course is directly dependent on work to be accomplished outside of the scheduled classes.

Nearly every class has a reading assignment. The majority of the reading is in the textbook, but some material may be handed out in class. Occasionally some material from sources on the World Wide Web or in the University Library will also be assigned. Every student is expected to prepare for each class by reading the assignments and completing the homework. Reading the assignments is more than a casual skimming of the material; it is making a serious effort to learn the material assigned.

Homework problems will be assigned and are due **at the beginning of the class on the due date**. Late homework will not be accepted unless there is an illness or other excused absence. The following format must be used.

Homework Formats and Regulations

1. Engineering paper must be used (except for software printouts).
   a. Write on the front side only. The back side will not be graded.
   b. Write your name, HW #, and date on page 1. Initial and number all other pages.
2. Staple multiple pages together (no paperclips or folded corners).
3. All of the following must be included in every problem:
   a. Flow chart and given values (use to start every problem).
   b. List all assumptions, if any, at the beginning.
   c. Write what you are trying to find at the beginning, so that the purpose of the problem is clear. For example, “Find: y_A.”
   d. Include units throughout, especially in your final answer.
   e. Report a reasonable number of significant figures in your answer.
   f. Box your answers.
4. Group work is strongly encouraged, unless specified otherwise. However, each student is expected to submit his or her own work unless the assignment has been designated as a group exercise. If you have worked with others, you must identify the names of the peers you have worked with.
5. Write and draw legibly.

Grading: The grades for the course will be calculated based on the following:

Three Exams (100 points each)	300
Final Exam	200
Homework and lab assignments	100
Project(s)	50
Quiz	50
In class Problems	25

A final grade of 90% or higher guarantees an A, 80% or higher guarantees at least a B, 70% or higher guarantees at least a C, 60% or higher guarantees at least a D. Besides these lower limits, final letter grades may be based on a curved distribution.

Religious Holidays: Contact me at least one class period in advance if you need to miss a class or exam in observance of a religious holiday. Arrangements will be made for the missed work to be completed.

Students with Disabilities: Any student in the course who has a disabilities which prevents him or her from fully demonstrating his or her ability should contact me personally as soon as possible so we can discuss accommodations necessary to ensure full participation and facilitate the educational opportunity.

Academic Misconduct: I do not expect academic misconduct to occur in this class. But, regulations require that I inform you of the University Student Handbook Definition and my expectations. The following two paragraphs are taken from www.studenthandbook.ku.edu.

- **2.6.1 Academic misconduct by a student** shall include, but not be limited to, disruption of classes; threatening an instructor or fellow student in an academic setting; giving or receiving of unauthorized aid on examinations or in the preparation of notebooks, themes, reports or other assignments; knowingly misrepresenting the source of any academic work; unauthorized changing of grades; unauthorized use of University approvals or forging of signatures; falsification of research results; plagiarizing of another's work; violation of regulations or ethical codes for the treatment of human and animal subjects; or otherwise acting dishonestly in research.

- **2.6.2 After consultation with the department chairperson,** an instructor may, with due notice to the student, treat as unsatisfactory (1) any student work that is a product of academic misconduct, or (2) a student's performance for a course as unsatisfactory when there are severe or repeated instances of academic misconduct as defined in Section 2.6.1. If an instructor deems other sanctions for academic misconduct by a student to be advisable, or if a student wishes to protest a grade based upon work judged by an instructor to be a product of academic misconduct, or if a faculty member is charged with academic misconduct in connection with the assignment of a grade or otherwise, the case shall be reported to the Dean of the College or School in which the course is offered and processed in accord with applicable procedures.

For this class:

- For examinations, you may use only permitted materials.

- All individual assignments turned in must be your own work. You are encouraged to help each other with homework and with the preparation of projects. However, copying of other students' work and turning it in as your own is not permitted. Allowing another person to copy your work will also be treated as academic misconduct. All work submitted will be inspected for originality.

- Group assignments should be the result of full participation by each individual. For each group assignment, the group is required to submit a signed memo giving the relative contribution of each group member. After the project score is assigned, individual scores will be calculated based on the student contribution given in the memo.

Academic misconduct will be penalized by the assignment of a zero grade for the examination or assignment involved. Any further instances will result in the failure of the student of the course with a final grade of "F" being assigned. All cases of academic misconduct will be reported to the Chair of the Chemical and Petroleum Engineering Department and the Dean of the School of Engineering.

Unit	**Chapter**	**Topic**	**Class Periods**
1	1	Introduction to Chemical Engineering	1
	2	Engineering Calculations	2
	3	Processes and Process Variables	3
2	4	Fundamentals of Material Balances	10
	5	Single Phase Systems	4
	6	Multiphase Systems	3
3	7	Energy and Energy Balances	5
	8	Balances on Nonreactive Processes	3
	9-11	Balances on Reactive and Transient Processes	7

Important Dates

Sept 7 - No Classes Labor Day Holiday
Oct 15 – 18 – No Class Fall Break
Nov 25 - 29 - No Classes Thanksgiving Holiday
Dec 11 - No Classes Stop Day
Dec 16 - Final Exam

Learning Goals

<u>Knowledge</u>

Foundation

Students will become familiar with engineering units.
- Students will:
  - Use a diverse set of engineering units
  - Learn to convert among these units

Students will learn to plot, interpret and determine physical property data.
- Student will:
  - Be introduced to molecular weight
  - Be introduced to vapor pressure
  - Be introduced to density
  - Be introduced to enthalpy and internal energy
  - Be introduced to heat of formation
  - Be introduced to heat of combustion
  - Be introduced to heat of reaction
  - Be introduced to heat of mixing
  - Develop xy graphs by hand including proper labeling
  - Develop xy graphs by software
  - Determine values for properties from physical property tables
  - Determine values for properties from descriptive equations

Students will understand the concept of control volume (system boundary).
- Students will:
  - Understand that a control volume is an aid to solving complex problems.
  - Understand that a control volume is an engineering artifice used to focus
  - Understand that it can be drawn around any subset of an engineering process
  - Understand that the important terms are those that cross the boundary and those inside the boundary

Students will understand the language of flowsheets.
- Students will:
  - Learn the semi-industrial standard symbology
  - Recognize the likeness of the symbology to the actual equipment
  - Learn the proper flowsheet organization
  - Learn use of templates for proper communication

Material Balances

Students will learn conservation of mass.
- Students will:
  - Learn the general material balance equation
  - Learn that the control volume sets the context of the general material balance
  - Learn the significance of the accumulation term
  - Learn the significance of the input term
  - Learn the significance of the output term
  - Learn the significance of the generation term
  - Learn the significance of the consumption term
  - Formulate reaction specifics as consumption or generation

Energy Balances

Students will learn conservation of energy.

Student will:

- Learn the simplified first law focusing only on internal energy, enthalpy, heat and work
- Recognize that there is only one energy balance per control volume
- Learn the significance of the accumulation term
- Learn the significance of input terms due to flow
- Learn the significance of the output terms due to flow
- Learn the significance of the input terms of heat and work
- Learn that for conventional chemical engineering situations there are no generation or consumption terms
- Learn the convention of heat and work added to the control volume are positive.
- Learn the alternative convention that work added to the control volume is negative.
  - Learn that heat is energy flow due to a temperature difference
- Learn that enthalpy values are relative to a basis
- Learn that internal energy values are relative to a basis
- Learn that there are enthalpy/internal energy changes due to a phase change
- Learn that there are enthalpy/internal energy changes due to chemical reactions
- Learn that there are enthalpy/internal energy changes due to mixing
- Learn that it is poor practice to consider reaction and mixing terms to be 'heats', 'generation' and/or 'consumption

<u>Skills</u>

Students will develop good organizational and documentation skills.

Students will:

- Organize their work to professional standards
- Practice developing organized solutions with work flowing sequentially down the page
- Write all units and unit conversions on the solution
- Include all units in the solution
- Use engineering paper for all hand calculations
- Use appropriate graph paper for all hand generated plots
- Label axes and figures
- Document the evolving solution stating all assumptions, units and nomenclature
- Document all observations
- Document all conclusions

Students will develop good problem solving skills.

Students will:

- Recognize that problem solving involves the six steps of engage, define, explore, plan, do and evaluate.
- Recognize that these six steps are iterative, not sequential.
- Accept and practice this strategy
- Recognize that this skill is required for complex problems
- Translate a problem statement or question into a definition
- Write the definition as part of the problem solution
- Estimate the solution form and values as part of the definition
- Identify what is known and what needs to be known
- Gather information to prepare the foundation for the solution
- Plan efficiently the solution strategy prior to beginning

- Will not begin the execution (do step) until appropriate definition, exploration and planning have been completed.
- Accept that the exploration and plan will change
- Evaluate the evolving solution
- Evaluate their plan to ensure that effort is only being placed on the defined problem.
- Evaluate their solution in the context of the definition

Students will develop effective control volume usage.

- Students will:
  - Identify all control volumes on a flowsheet
  - Select effective control volumes based on the problem definition
  - Identify all inputs due to material flow
  - Identify all output due to material flow
  - Identify all inputs due to heat
  - Identify all inputs due to work

Students will develop effective material balance solution methods

- Students will:
  - Draw a flowsheet of every problem
  - Label all equipment
  - Number all streams
  - Identify knowns
  - Identify unknowns
  - Identify specifications
  - Calculate total number of equations required
  - Identify and document all control volumes
  - Simplify the general material balance equation for the problem
  - Write material balance equations
  - Write definition equations
  - Write specification equations
  - Simplify the problem, if necessary
  - Solve the problem for all unknowns
  - Document the significant results with respect to the definition
  - Refrain from algebraically combining material balances as part of the set up

Students will develop effective energy balance solution methods.

- Students will:
  - Write the energy balance for the identified control volumes
  - Select an appropriate basis for enthalpy and internal energy
  - Select heats of formation for an enthalpy basis where appropriate
  - Calculate appropriate values for enthalpy and internal energy, as needed
  - Use a consistent convention for heat
  - Use a consistent convention for work

Students will develop the ability to recognize and develop specifications

- Students will:
  - Identify the number of specifications required with multiple streams leaving a control volume
  - Use mole fraction and mole percent specifications
  - Use weight fraction and weight percent specifications
  - Use vapor pressure and partial pressure of a single condensable component to tie two streams
  - Use percentage recovery specifications

Students will use appropriate computational tools.

- Students will:
  - Practice estimation
  - Practice using unprogrammed calculators
  - Practice using self-developed computer code
  - Practice using sequential modular spreadsheet solution approaches
  - Practice using equation oriented spreadsheet solution approaches
  - Be introduced to process simulation solution approaches
  - Select the appropriate tool for the problem definition