COURSE

OBJECTIVES
A. Learn about basic chemical process units and how to do balances around them
B. Learn to analyze and solve material balance problems
C. Learn to analyze and solve energy balance problems
D. Learn to analyze more complex balance problems involving coupling of material and energy balances for multiple units

REQUIRED TEXT
R.L. Rowley, Course Web Site
http://www.et.byu.edu/~rowley/ChEn273/index.html

ADDITIONAL SOURCES

LECTURES
MWF 10:00 am - 10:50 am
254 CB

INSTRUCTOR
Ronald E. Terry, Professor
350H CB 422-4297 ron_terry@byu.edu
http://www.et.byu.edu:8080/~terryr/

OFFICE HOURS
MWF: 9 – 9:50 am; 11 – 12 noon

TEACHING ASSISTANTS
Richard James Greg Gardner

WEB SITE
The www home page for this class is located at:
http://www.et.byu.edu/~rowley/ChEn273/index.html

GRADES
Grades will be determined using a straight scale. You are NOT in competition with the rest of the class; your goal should be to learn the material thoroughly.
Major grade division will be based on your final percentage score (as calculated below) in accordance with the following scale (the bottom ends of each range may be lowered up to 3% points):

- 100% - 90% . . . . . . A
- 90% - 80% . . . . . . B
- 80% - 70% . . . . . . C
- 70% - 60% . . . . . . D
- <60% . . . . . . . . . . E

The +/- designations, or 1/3 letter grades will be determined by the instructor. Generally, these 1/3 letter grades will be assigned within the major grade division, but the instructor may also raise [or lower] a student's grade by 1/3 if evidence suggests that a single score lowered [or raised] the student's final score relative to the bulk of the other scores. Thus, if a student had one "bad" exam, but the other exams, including the final, suggest that the student mastered the material, the instructor might elevate that student's final grade by 1/3.

Scores will be determined from three exams, homework problems, a case study project and the comprehensive final exam. Weights used to determine the final percentage score will be:

1. Three exams . . . . . . . . . . . . . 36%
2. Homework problems . . . . . . . . 30%
3. Case study . . . . . . . . . . . . . . 14%
4. Final Exam . . . . . . . . . . . . . . 20%

Additionally, your grade as determined by the method above will be dropped one third letter grade (e.g., A to A-) if the Dean’s lectures requirement is not met. See the requirements below.

**UNIVERSITY MISSION**

The following is quoted from the General Catalog. "The mission of Brigham Young University - founded, supported, and guided by The Church of Jesus Christ of Latter-day Saints - is to assist individuals in their quest for perfection and eternal life. That assistance should provide a period of intensive learning in a stimulating setting where a commitment to excellence is expected and the full realization of human potential is pursued . . . To succeed in this mission the university must provide an environment enlightened by living prophets and sustained by those moral virtues which characterize the life and teachings of the Son of God."

**DRESS AND HONOR**

All of us have been instructed on the Dress and Honor Codes of the university. We have all committed to obey and sustain these codes. It will be expected in this class that each of us will honor the commitments that we have made. The teacher reserves the right to withhold an exam from an individual who is failing to abide by his or her commitment to the Dress Code.

The Honor Code suggests that there will be no plagiarizing on written work and no cheating on exams. If a student is caught cheating on an exam, he or she will be given a zero for the exam. If a student is caught cheating on two exams, the student will be referred to the Honor Code Office and be given an E in the course.

These codes will be strictly enforced in the classroom. Appropriate attire and behavior is expected.
SEXUAL HARASSMENT
BYU’s policy against sexual harassment protects both employees of the University as well as students. Under Title IX of the Education Amendments of 1972, students who encounter sexual harassment from other students are protected. If you encounter unlawful sexual harassment or gender based discrimination, please talk to your professor; contact EEO office (422-5895); or contact the Honor Code Office (422-2847).

STUDENTS WITH DISABILITIES
BYU is committed to providing a working and learning atmosphere that reasonably accommodates qualified persons with disabilities. If you have any disability, which may impair your ability to complete this course successfully, please contact the Services for Students with Disabilities Office (422-2767). Reasonable academic accommodations are reviewed for all students who have qualified documented disabilities. Services are coordinated with the student and instructor by the SSD office. If you need assistance or if you feel you have been unlawfully discriminated against on the basis of disability, you may seek resolution through established grievance policy and procedures. You should contact the Equal Employment Office at 422-5895, D-282 ASB.

PROFESSIONAL CODE
All chemical engineering students are expected to develop a professional attitude in keeping with the AIChE code of ethics (see item VI in this syllabus or http://www.et.byu.edu/~rowley/ChEn273/Toolchest/ethics.htm). It is expected that students will understand the AIChE code of ethics and will uphold its principles in their actions, exhibiting integrity and advancing the honor and dignity of the profession.

DEAN’S LECTURES
All ChEn 273 students are required to attend two Dean’s Lectures during winter semester. Each student must keep his own attendance records on the seminar card provided (attendance card available from the department secretaries). Attendance cards must be turned in at the department office by the last day of class.

The dates for the Dean’s Lectures will be announced.
I. CLASS MECHANICS

A. Homework Problems

Homework is an essential, integral part of this course because problem solving skills are obtained only by solving problems— lots of problems. Do not assume that you have learned the material just because you can follow the instructor's solutions. Starting from scratch on a problem is a higher level of understanding than simply understanding how someone else worked the problem.

The following rules govern the problem sets:
1. Homework problems are due at the beginning of class on the assigned day.
2. Each day's homework will be scaled to 100 points and the lowest three scores will be dropped.
3. Late homework will only be accepted up to one class period after the due date. Assignments due on Monday may be turned in on Wednesday without any late penalty. This is to accommodate you over the weekend so that you won't feel pressured to do homework on Sunday. Homework due on Wednesday and Friday will be accepted on Friday and Monday, respectively, but you will lose 20 points as a late penalty. Homework will not be accepted beyond one class period after the due date for any of the homework. Remember, it is only the Monday assignments that can be turned in late without penalty. If you do not turn in a homework due to an absence or sickness, it will be one of the three scores that are dropped. Do not ask for excused absences so that you can drop your lower scores; the purpose of the three dropped scores is to accommodate absences without you being required to get them excused. If something drastic happens so that you must be absent for more than three assignments, please talk to me on an individual basis and we will work something out.
4. Answer keys will be posted on the class web site. Answer keys will be in MATHCAD format. You may download these answer keys for your own use.
5. You may discuss with others how to begin working problems—in fact this is encouraged—but you must work the problem entirely yourself to hand in. Working together does not mean that you do one assignment between two or more people. It is unethical to turn in a homework sheet with only your name on it if others have been involved in working out the solution. The actual working out of the problem and the number crunching must be done by you as an individual, but you may discuss with others your approach, methodology and reasoning. You must not work together in MATHCAD and then print out a solution for each of you. Rather, each student must work the problem independently in MATHCAD and turn in their own solution. Two MATHCAD sheets that are similar enough to indicate a joint solution will be considered plagiarized and subject to honor code violation procedures.
6. Homework should be written on one side only of 8.5" x 11" paper. Neatness is essential in developing good problem solving techniques. Points may be taken off for sloppiness.

B. Computer Problems

The computer is a valuable tool in this class and you are free to use spreadsheets, graphics packages, and programming languages. I recommend that you become very conversant in MATHCAD as it will be a great tool for you throughout the chemical engineering curriculum. It is expected that you already know how to use MATHCAD because you should have taken ChEn 263. If you are a transfer student and are not familiar with MATHCAD, the teaching assistants will be glad to help you get started. Some of the homework will specifically require MATHCAD, but you are free to use MATHCAD on any of the other problems. All answer keys posted to the web will be live MATHCAD documents. This way you can change numbers in them if you want and see where you might have made mistakes.

C. Exams

Unless otherwise specified, the three exams will be open-book exams given in the testing center on the days shown on the attached schedule.

D. Final Exam

The final exam for the course will be given on Tuesday, April 22, 2002, from 3:00 pm to 6:00 pm in the regular classroom. It will be a comprehensive, open-book, open-notes final. All students must take the final exam to pass the course. Finals will not be given at any other time.
E. **Reading Assignments**
   You are expected to keep up with the reading assignments on your own initiative. Assignments for each day of the entire semester are listed on the attached schedule. You should read the assigned material before class. I will not remind you in class to do the reading. That does not mean it is not important. Generally, poor performance on exams is a result of not doing the reading.

F. **Case Study**
   Midway through the course you will be divided into smaller groups. Your group will be assigned a case study to work on as a group. The case study involves balances on a process involving multiple units and is a good capstone problem for the course. Your group will interact with a consultant, either myself or one of the TA's. I will introduce the case study and talk about the process in general, but then your groups will need to be self-motivated to meet regularly to discuss the problems and prepare a design for the project.

   Your group will be given $30,000 (but it will not be negotiable US currency - sorry) in start-up funds with which to complete the project. You may use these funds to buy consulting services. Consultations with Dr. Terry will cost $15,000; consultations with the TAs are a real bargain and will only cost $5,000 per session. Your consultants are willing to check over your flow diagram and point out any errors to you for a fee of $5,000. Consultants are also willing to consult with you concerning the approach your group is taking to particular problems. Once the money has been expended, no additional questions will be answered.

   On the last day of class, you are to turn in the following items for grading of the case study:
   
   (a) A completed case study report from your group showing the overall design of the process with appropriate stream tables etc. and answers to questions. This should be done neatly and professionally. Only one report should be turned in for each group.

   (b) Each individual should turn in a single page table that provides his/her confidential evaluation of the contribution of each group member.

   An overall score will be assigned to each group's case study. Additional points will be added or subtracted depending on any clear evidence from the contribution evaluations that particular individuals made extraordinary or sub-standard contributions. Thus, individual scores may vary slightly within any one group.

G. **TA Help Sessions**
   During the first week of class, we will schedule hours that the TA's will be in a help room. You are free to come by during those hours and seek help on problem assignments.
## II. READING AND ASSIGNMENT SCHEDULE

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Web Study Assignment</th>
<th>Text Reading Assignment</th>
<th>Assignment Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 6</td>
<td>M</td>
<td>Stream Variables in Balances; Stream Variables Require Units; Unit Conversions; Dimensional Consistency</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Jan 8</td>
<td>W</td>
<td>Data at Desired Conditions; Interpolation: Unknown Model; Interpolation: Known Model; Extrapolation; Least Squares Method</td>
<td>Chapter 2</td>
<td>HW #1: RLR0, 2.2, 2.4, 2.24</td>
</tr>
<tr>
<td>Jan 10</td>
<td>F</td>
<td>Composition Units; Using a Basis; Temperature</td>
<td>3.0 - 3.3; 3.5</td>
<td>HW #2: 2.15, 2.29*, 2.31</td>
</tr>
<tr>
<td>Jan 13</td>
<td>M</td>
<td>Pressure</td>
<td>3.4, 3.6</td>
<td>HW #3: 2.44, 2.43*, 3.7</td>
</tr>
<tr>
<td>Jan 15</td>
<td>W</td>
<td>General Equations; General Simplifications; Independent Mass Balances; Problem Solving</td>
<td>4.0 - 4.2</td>
<td>HW #4: 3.39, 3.42, 3.43</td>
</tr>
<tr>
<td>Jan 17</td>
<td>F</td>
<td>Deg. of Freedom: Introduction; D of F Single w/o Reaction</td>
<td>4.3</td>
<td>HW #5: 3.23, 4.8</td>
</tr>
<tr>
<td>Jan 20</td>
<td>M</td>
<td><strong>Martin Luther King Holiday - NO CLASS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan 22</td>
<td>W</td>
<td>Mass Balance Nonreacting; Review of Ind Mass Balances</td>
<td>4.5</td>
<td>HW #6: 4.17, 4.18*</td>
</tr>
<tr>
<td>Jan 24</td>
<td>F</td>
<td>Multi-Unit Processes; Independent Systems; Deg Freedom on Multi-Unit</td>
<td>4.4</td>
<td>HW #7: 4.22*, 4.25*</td>
</tr>
<tr>
<td>Jan 27</td>
<td>M</td>
<td>Recycle and Purge; Cautions</td>
<td>4.5</td>
<td>HW #8: 4.29*, 4.31</td>
</tr>
<tr>
<td>Jan 29</td>
<td>W</td>
<td>Differences; Nomenclature; Multiple Reactions</td>
<td>4.6</td>
<td>HW #9: 4.32*, 4.34</td>
</tr>
<tr>
<td>Jan 31</td>
<td>F</td>
<td>exam 1</td>
<td></td>
<td>NO CLASS - USE THIS TIME TO TAKE EXAM #1</td>
</tr>
<tr>
<td>Feb 3</td>
<td>M</td>
<td>Examples: Reacting systems</td>
<td>4.7</td>
<td>HW #10: 4.42, 4.49</td>
</tr>
<tr>
<td>Feb 5</td>
<td>W</td>
<td>Examples: Reacting systems</td>
<td>4.7</td>
<td>HW #11: 4.45, 4.47</td>
</tr>
<tr>
<td>Feb 7</td>
<td>F</td>
<td>Combustion</td>
<td>4.8 - 4.10</td>
<td>HW #12: 4.57, 4.50</td>
</tr>
<tr>
<td>Feb 10</td>
<td>M</td>
<td>Ideal Systems; Liquid &amp; Solid; Ideal Systems; Pure Gas; Ideal Gas Mixtures</td>
<td>5.0 - 5.2</td>
<td>HW #13: 4.70, RLR1†</td>
</tr>
<tr>
<td>Feb 12</td>
<td>W</td>
<td>Van der Waals Equation of State; Other Equations of State; Compressibility; Corresponding States</td>
<td>5.3-5.5</td>
<td>HW #14: 5.19, 5.24, 5.46</td>
</tr>
<tr>
<td>Feb 14</td>
<td>F</td>
<td>Single Component VL Boundaries; Cla-Clapeyron; VL Boundaries; Antoine 1 Component Liquid</td>
<td>6.0 - 6.2</td>
<td>HW #15: RLR2†</td>
</tr>
<tr>
<td>Feb 17</td>
<td>M</td>
<td><strong>President’s Day Holiday</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb 18</td>
<td>Tu</td>
<td>VLE; Data; Raoult’s Law</td>
<td>6.3 - 6.4</td>
<td>HW #16: 6.6, RLR3†</td>
</tr>
<tr>
<td>Feb 19</td>
<td>W</td>
<td>Raoult’s Law; Mathcad</td>
<td>6.3 - 6.4</td>
<td>HW #17: 6.60, 6.61</td>
</tr>
<tr>
<td>Feb 21</td>
<td>F</td>
<td>Solid-Liquid Eq.; Liquid-Liquid Eq.</td>
<td>6.5 - 6.8</td>
<td>HW #18: RLR4†</td>
</tr>
<tr>
<td>Feb 24</td>
<td>M</td>
<td>Forms of Energy; 1st Law of Thermodynamics; Pressure Volume Work</td>
<td>7.0 - 7.3</td>
<td>HW #19: 6.77, 6.75, 6.95</td>
</tr>
<tr>
<td>Feb 26</td>
<td>W</td>
<td>exam 2</td>
<td></td>
<td>NO CLASS - USE THIS TIME TO TAKE EXAM #2</td>
</tr>
<tr>
<td>Feb 28</td>
<td>F</td>
<td>Open Systems; 1st Law of Thermodynamics</td>
<td>7.4 - 7.5</td>
<td>HW #20: 7.8, 7.11</td>
</tr>
<tr>
<td>Mar 3</td>
<td>M</td>
<td>Open Systems: Examples</td>
<td>7.6</td>
<td>HW #21: 7.28, 7.35</td>
</tr>
<tr>
<td>Mar 5</td>
<td>W</td>
<td>Mechanical Energy Balances; Incompressible Flow</td>
<td>7.7</td>
<td>HW #22: 7.42, 7.46</td>
</tr>
<tr>
<td>Date</td>
<td>Day</td>
<td>Topic</td>
<td>Sections</td>
<td>HW #</td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Mar 7</td>
<td>F</td>
<td>Heat capacities: Constant Volume; Heat Capacity: Constant Pressure;</td>
<td>8.1 - 8.3, 8.4a-c</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat Capacity: Data; Choice of Path; Changes in Enthalpy; Obtaining</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hvap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar 10</td>
<td>M</td>
<td>Psychrometric Charts</td>
<td>8.4d-e</td>
<td></td>
</tr>
<tr>
<td>Mar 12</td>
<td>W</td>
<td>Heat of Mixing; Mixing Process</td>
<td>8.5a-b</td>
<td></td>
</tr>
<tr>
<td>Mar 14</td>
<td>F</td>
<td>Enthalpy Conc. Diag: Balances Enth. CD</td>
<td>8.5c</td>
<td></td>
</tr>
<tr>
<td>Mar 17</td>
<td>M</td>
<td>Heat of Reaction</td>
<td>9.1 - 9.2</td>
<td></td>
</tr>
<tr>
<td>Mar 19</td>
<td>W</td>
<td>Component Energy Bal Heat of Rxn at other Temp</td>
<td>9.3 - 9.4</td>
<td></td>
</tr>
<tr>
<td>Mar 21</td>
<td>F</td>
<td>Element Balances Alternative Approaches</td>
<td>9.5a-b</td>
<td></td>
</tr>
<tr>
<td>Mar 24</td>
<td>M</td>
<td>Differential Mass Balances</td>
<td>11.0 - 11.2</td>
<td></td>
</tr>
<tr>
<td>Mar 26</td>
<td>W</td>
<td>Differential Mass Balances</td>
<td>11.0 - 11.2</td>
<td></td>
</tr>
<tr>
<td>Mar 28</td>
<td>F</td>
<td>Differential Energy Balances</td>
<td>11.3 - 11.4</td>
<td></td>
</tr>
<tr>
<td>Mar 31</td>
<td>M</td>
<td>case study</td>
<td>No class – Work on case study</td>
<td></td>
</tr>
<tr>
<td>Apr 2</td>
<td>W</td>
<td>exam 3</td>
<td>NO CLASS – TAKE EXAM #3</td>
<td></td>
</tr>
<tr>
<td>Apr 4</td>
<td>F</td>
<td>case study</td>
<td>NO CLASS - WORK ON CASE STUDY</td>
<td></td>
</tr>
<tr>
<td>Apr 7</td>
<td>M</td>
<td>case study</td>
<td>NO CLASS - WORK ON CASE STUDY</td>
<td></td>
</tr>
<tr>
<td>Apr 9</td>
<td>W</td>
<td>case study</td>
<td>NO CLASS - WORK ON CASE STUDY</td>
<td></td>
</tr>
<tr>
<td>Apr 11</td>
<td>F</td>
<td>case study</td>
<td>NO CLASS - WORK ON CASE STUDY</td>
<td></td>
</tr>
<tr>
<td>Apr 14</td>
<td>M</td>
<td>Review for Final</td>
<td>In-class review for final</td>
<td>Case Study Due by 5 pm</td>
</tr>
<tr>
<td>Apr 22</td>
<td>Tues</td>
<td>Final Exam (3 pm – 6 pm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
III. ADDENDUM TO HOMEWORK PROBLEMS

Note: Whenever you have a problem in the textbook that says “write a program” you need NOT write a program. You may do the problem in Mathcad, Excel or VisualBasic.

RLR0. For this problem, you are to go to the course web site and find two images of a cartoon waving hand that looks like the one at the right. When you find each of these two images, you are to click on the image and fill in the requested material. When you do so, I will automatically receive an email of the information that you have filled in and you will be given credit for this problem. One of the hand images will be found in the web reading assignment for the first day of class; and the other will be found in the AIChE Code of Ethics page that is accessed through the toolbox utilities (the Swiss army knife).

2.29. Rather than doing the problem in the book, use the data in problem #2.29 to determine the vapor pressure in mm Hg at T = 185°C by (a) linear interpolation and (b) graphical estimation using MATHCAD.

2.43. Derive the requested expression and then use it to fit a straight line through the origin and the points given below. Then use MATHCAD to perform the regression and plot the points and the fitted line on the same graph.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>1.9</td>
<td>2.1</td>
</tr>
<tr>
<td>3.2</td>
<td>3.1</td>
</tr>
</tbody>
</table>

4.18. Include a degree-of-freedom analysis.

4.22. In place of part (c), use MATHCAD to set up the mass balance as a function. Then use this function to complete the mass balances for the data given in the problem. If the mass balance is impossible for some conditions, indicate that the mass balance cannot be closed.

4.25. Include a degree-of-freedom analysis.

4.29. Include a degree-of-freedom analysis.

4.32. Include a degree-of-freedom analysis.

4.35. Do only part (a), but do it twice. Do it once by "hand" and once using MATHCAD to solve simultaneous equations. Include a degree-of-freedom analysis for the "hand" version.

RLR.1. Methanol can be formed from carbon monoxide and hydrogen in the gas-phase reaction

\[ CO + 2H_2 \rightarrow CH_3OH \]  

(a) (b) (c)

and the mole fractions exiting the reactor are in equilibrium according to the equilibrium relation

\[ \frac{x_c}{x_a x_b} = 4.79(10)^{73} P^2 \exp\left(\frac{11458}{T}\right) \]

where \( P \) is in atm and \( T \) is in Kelvin.

(a) Write down the component balance expressions in terms of the extent of reaction. \[ \]

\[ \]
(b) Write down the mole fractions which exit the reactor in terms of \( x \).

(c) Use MATHCAD to calculate \( x \) and solve for the equilibrium mole fractions that result when 3 moles of CO, 5 moles of \( \text{H}_2 \) and 0.2 mole of \( \text{CH}_3\text{OH} \) are fed to the reactor and the temperature and pressure are 423 K and 4.0 atm, respectively. Redo the problem at several temperatures and plot \( x \) versus T over the range 350 K to 600 K.

RLR.2. This problem involves computation and comparison of vapor phase densities using three techniques:

1. the ideal gas law,
2. the generalized compressibility charts, and
3. the Soave equation of state (MATHCAD problem)

Please use the above three techniques to determine the density of 30 mol% mixture of chloroform in carbon disulfide at 334°C and 915 psia. Your results should all be in SI units. While the first two methods are to be done by hand, the third method must be done on a computer using Mathcad. The acentric factors for chloroform and carbon disulfide are 0.216 and 0.115, respectively. Which answer do you believe is more correct? Why?

RLR.3. Use MATHCAD to compare the DIPPR, Antoine, and Clausius-Clapeyron equations for ethanol over the range -32°C to 80°C. Use Table Table B.4, pg 640, to obtain Antoine constants and Appendix B to obtain the normal boiling point and heat of vaporization. Use the CRC Handbook or Perry's to put experimental data on a plot with the two calculated lines. Which equation works best over this range?

RLR.4. Use MATHCAD to set up a bubble-point calculation for the case of known pressure and liquid compositions. You will perform the calculations to determine the temperature and the vapor mole fractions that are in equilibrium. You should use this method to generate a \( Txy \) diagram for the acetone-ethanol mixtures of problem #6.68 at 1 atm pressure. A convenient way to do this is to set up a vector of liquid mole fractions at intervals of 0.1 and solving for a vector of \( T \) and \( y \) values. Compare the calculations with experimental data by plotting the values your program generates for \( Txy \) on the same plot with the experimental data used in problem #6.68 above. Discrepancies between the two are primarily due to nonidealities in the liquid phase not accounted for by Raoult's law.

8.66.

- Use MATHCAD instead of a program for part c. You do not have to do part b.
- Because of this problem's similarity to your previous MATHCAD problem, you may save time if you start with a copy of the previous file and modify it.
- Enthalpies for all streams must of course be relative to the same temperature. I suggest you calculate all enthalpies relative to 25 °C. Use the heat capacities to do this. Note, however, that the vapor enthalpies must include the heat of vaporization. Recall that the way to do this is heat the liquid from 25 °C to the normal boiling point, vaporize it at the boiling point, and then heat the vapor from the boiling point to the final temperature. You must therefore supply normal boiling points and heat of vaporization data to the program.
- Good Luck! I get 52.5°C as the operating temperature of the flash drum with 55.2 mol% in the liquid phase.

9.7. Do parts a-c only! Use the DIPPR database instead of the appendix of the text.

9.21. Please use a compound balance with extent of reaction on this problem.


9.68. Use MATHCAD to find the adiabatic flame temperature of part (c).
IV. SYMBOLS USED IN CLASS

A. Symbols for Different Properties
   - \( a \): acceleration
   - \( A \): area
   - \( C \): molarity
   - \( C_p \): constant pressure heat capacity
   - \( C_v \): constant volume heat capacity
   - \( f, F \): degrees of freedom
   - \( f \): fractional conversion
   - \( g \): acceleration due to gravity
   - \( g_c \): force conversion constant
   - \( h \): height; head
   - \( H \): enthalpy
   - \( m \): mass; number of independent stream variables
   - \( M \): molecular weight
   - \( n \): moles; number of components; number of independent balance eqns.
   - \( N \): ratio of moles of solvent to moles of solute
   - \( p \): number of specified stream variables; number of phases
   - \( P \): pressure
   - \( P^* \): vapor pressure
   - \( Q \): heat; represents generalized chemical symbol in reaction
   - \( s \): number of subsidiary relations
   - \( S_{J,h} \): selectivity of \( J \) over \( h \)
   - \( S_{r,(h_r)} \): relative saturation (humidity)
   - \( S_{m,(h_m)} \): molal saturation (humidity)
   - \( S_{a,(h_a)} \): absolute saturation (humidity)
   - \( T \): temperature
   - \( U \): internal energy
   - \( V \): volume
   - \( v \): velocity
   - \( w \): mass fraction
   - \( W \): work
   - \( W_s \): shaft work
   - \( x \): mole fraction generally; mole fraction of liquid phase specifically
   - \( y \): mole fraction of vapor phase specifically
   - \( Y \): yield
   - \( Z \): compressibility factor
   - \( \Delta \): stoichiometric coefficient with appropriate sign
   - \( \bullet \): extent of reaction

B. Subscripts, Superscripts and Other Adornments
   - \( J \): extensive property \( J \) for system
   - \( J_i \): extensive property \( J \) for component \( i \)
   - \( J_i^e \): \( J \) for pure component; \( J \) entering reactor
   - \( J_{i,j}^l \): \( J \) for component \( i \) in stream \( j \)
   - \( J' \): \( J \) on dry basis; \( J \) leaving reactor
   - \( \hat{j} \): specific property (\( J \) per unit mass)
   - \( \tilde{j} \): molar property (\( J \) per mole)
   - \( J_c \): value of \( J \) at critical point
   - \( J_r \): reduced value of \( J \), i.e., \( J/J_c \)
\( j \) flow rate of \( J \)
\( J_l \) value of \( J \) in liquid phase
\( J_v \) value of \( J \) in vapor phase
\( \Delta J_v \) change in \( J \) upon vaporization, i.e., latent \( J \)
\( \Delta J_f \) change in \( J \) upon melting, i.e., fusion
\( \Delta J_{\text{mix}} \) change in \( J \) upon mixing
V. STANDARD HOMEWORK FORMAT

1. Organize work carefully and logically. Write legibly and neatly.
2. Carry units all the way through to the final answer. Units should appear on all numbers.
3. Carry algebraic expressions analytically as far as possible before substituting numbers.
4. Underline, box or otherwise mark results and answers.
5. Label your first page with a heading containing ChEn 273, your name, assignment number, date and page. Subsequent pages should contain at least the page number and your name or initials.
6. Write on only one side of the paper——— engineering paper is preferred.
7. Before turning in your assignment, staple all sheets together in upper left-hand corner, fold the paper lengthwise with the writing on the inside, and write ChEn 273, your name, assignment number and date on the outside with the fold to the left.

VI. AIChE CODE OF ETHICS

Chemical engineering is the profession in which a knowledge of mathematics, chemistry and other natural sciences gained by study, experience, and practice is applied with judgment to develop economic ways of using materials and energy for the benefit of mankind.

Goals:

Members of the American Institute of Chemical Engineers shall uphold and advance the integrity, honor, and dignity of the engineering profession by:

• Being honest and impartial and serving with fidelity their employers, their clients, and the public;
• Striving to increase the competence and prestige of the engineering profession;
• Using their knowledge and skill for the enhancement of human welfare.

Responsibilities:

To achieve these goals, members shall:

• Hold paramount the safety, health, and welfare of the public in performance of their professional duties;
• Formally advise their employers or clients (and consider further disclosure, if warranted) if they perceive that a consequence of their duties will adversely affect the present or future health or safety of their colleagues or the public;
• Accept responsibility for their actions and recognize the contributions of others; seek critical review of their work and offer objective criticism of the work of others;
• Issue statements or present information only in an objective and truthful manner;
• Act in professional matters for each employer or client as faithful agents or trustees, and avoid conflicts of interest;
• Treat fairly all colleagues and co-workers, recognizing their unique contributions and capabilities;
• Perform professional services only in areas of their competence;
• Build their professional reputations on the merits of their services;
• Continue their professional development throughout their careers, and provide opportunities for the professional development of those under their supervision.

1 http://www.aiche.org/about/ethicscode.htm
VII. PROBLEM SOLVING PROCEDURES

Have you ever been trying to solve a problem (not necessarily a chemical engineering problem) and become totally lost in the middle of it, not really knowing where you've been or possibly not even remembering what it was that you were trying to solve for in the first place. ChEn 273 is a problem solving course and learning to attack a problem in an organized fashion is an important step in an engineer's education. To avoid the onset of panic caused when you get lost in the middle of a problem and to provide you with a generalized decision making scheme, I have outlined below the typical sort of procedures that might be used in attacking a problem. While I don't require you to memorize this procedure, I do expect that you will consistently set your problems up in the general fashion described below. You should begin to use this approach immediately in this class. As this approach becomes second nature to you, your problem solving capabilities will be greatly enlarged and (importantly) you will be able to attack material and energy balance problems with a great deal of self confidence.

General Problem Solving Approach

A. DEFINE
   1. Draw a sketch of the problem.
   2. Label the sketch with flows and composition for each steam.
   3. Put all known values of compositions and flows on the sketch.
   4. Select a basis of calculation.
   5. List the unknown stream quantities with symbols.
   6. Identify exactly what you are being asked to calculate.

B. EXPLORE
   1. Select the system boundaries.
   2. Determine the degrees of freedom and the number of equations to be solved.
   3. Obtain the necessary data and physical properties.
   4. Identify possible attacks.
      i. Use equations with fewest unknowns first.
      ii. Use tie-components if appropriate.
      iii. The overall balance should generally be used.
      iv. Relocate the basis if necessary.
      v. For multiple units, start with the unit which has the lowest degree of freedom.
   5. Write down independent balance equations for the chosen attack.

C. SOLVE
   1. Solve simultaneous equations.
   2. Scale-up from the chosen basis.

D. CHECK
   1. Check your answers by direct substitution.
VIII. Competencies.

Students should gain the following competencies in this course. A level 3 competency (mandatory) is one that all students in the class are expected to master or they must repeat their study of the topic; a level 2 competency (measured) is one that is expected of all students and their level of competency is measured, but no repeat is required if the minimum competency is not achieved; a level 3 competency (exposure) means that students are exposed to the material, but there is no minimum performance expectation.

You will be asked at the end of the course to evaluate how well this class contributed to your developing the written expectation and how proficient you believe you are with respect to that expectation. Level 3 competencies must be mastered before graduation and will be tested on the Level-3 Competency Exam in your senior year, so you will want to pay special attention to those topics.

<table>
<thead>
<tr>
<th>Competency</th>
<th>Level</th>
<th>I/X/R</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>2</td>
<td>X</td>
<td>Students will learn about chemical processes, units, and corresponding equipment</td>
</tr>
<tr>
<td>3.1.1</td>
<td>3</td>
<td>X</td>
<td>Students will be able to use basic engineering units in both SI and AES systems in solving problems, and be able to interconvert between unit systems both by hand and with an equation solver.</td>
</tr>
<tr>
<td>3.1.2</td>
<td>3</td>
<td>X</td>
<td>Students will be able to solve steady-state, overall, material and energy balances for systems which include one or more of the following: recycle, multiple units, chemical reactions.</td>
</tr>
<tr>
<td>3.1.3</td>
<td>2</td>
<td>X</td>
<td>Students will be able to set up and solve simple transient material balances.</td>
</tr>
<tr>
<td>3.1.4</td>
<td>2</td>
<td>X</td>
<td>Students will be able to use a degree-of-freedom approach to assist in the solution of material and energy balances.</td>
</tr>
<tr>
<td>3.1.5</td>
<td>2</td>
<td>X</td>
<td>Students will be able to read mixture phase diagrams (solid solubility, liquid-liquid, VLE) and construct mass balances from them using the lever rule, tie lines, etc.</td>
</tr>
<tr>
<td>3.1.6</td>
<td>1</td>
<td>I</td>
<td>Students will be introduced to the solution of transient energy balances.</td>
</tr>
<tr>
<td>3.2.1</td>
<td>3</td>
<td>X</td>
<td>Students will understand the phase behavior of pure substances in relationship to the variables T, P, and $\mu$ (including vapor pressure, critical point, freezing line, triple point, etc.)</td>
</tr>
<tr>
<td>3.3.1</td>
<td>3</td>
<td>X</td>
<td>Students will be able to use the mechanical energy balance equation to solve fluid flow problems both with and without friction.</td>
</tr>
<tr>
<td>3.3.3</td>
<td>2</td>
<td>X</td>
<td>Students will be able to solve simple fluid statics problems.</td>
</tr>
<tr>
<td>3.7.1</td>
<td>3</td>
<td>I</td>
<td>Students will be introduced to the first law of thermodynamics for closed and open systems.</td>
</tr>
<tr>
<td>3.7.2</td>
<td>3</td>
<td>I</td>
<td>Students will be introduced to solution thermodynamics fundamentals.</td>
</tr>
<tr>
<td>3.7.3</td>
<td>3</td>
<td>I</td>
<td>Students will understand the fundamental principles of chemical reaction equilibria including extent of reaction, equilibrium constant and its temperature-dependence, and equilibrium conversion.</td>
</tr>
<tr>
<td>3.7.4</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to equations of state and corresponding states correlations.</td>
</tr>
<tr>
<td>3.7.5</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation.</td>
</tr>
<tr>
<td>4.1</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to process variables (e.g., P, T, flow rate, conc.) and their measurement.</td>
</tr>
<tr>
<td>5.3</td>
<td>2</td>
<td>R</td>
<td>Students will be able to solve numerical and symbolic problems with use of advanced math software (e.g. Mathcad).</td>
</tr>
<tr>
<td>5.5</td>
<td>1</td>
<td>I</td>
<td>Students will be introduced to the use of appropriate information skills, standard office applications, and tools (e.g. WWW, electronic and reference book library searches, modern property databases) to assist in problem solving.</td>
</tr>
<tr>
<td>6.1</td>
<td>3</td>
<td>X</td>
<td>Students will demonstrate an ability to solve engineering problems.</td>
</tr>
<tr>
<td>-----</td>
<td>---</td>
<td>---</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>6.2</td>
<td>2</td>
<td>X</td>
<td>Students will be able to use a problem solving strategy to define and solve engineering problems.</td>
</tr>
<tr>
<td>6.4</td>
<td>2</td>
<td>X</td>
<td>Students will exhibit critical and creative thinking skills for analysis and evaluation of problems and cause-effect relationships.</td>
</tr>
<tr>
<td>6.5</td>
<td>2</td>
<td>X</td>
<td>Students will be able to obtain and evaluate appropriate input information/data from databases, handbooks, correlations, experiments, literature, etc.</td>
</tr>
<tr>
<td>6.6</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to the notions of rationalizing units, making order of magnitude estimates, assessing reasonableness of solutions, and selecting appropriate levels of solution sophistication.</td>
</tr>
<tr>
<td>7.2</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to how safety and environmental considerations are incorporated into engineering problem solving.</td>
</tr>
<tr>
<td>8.3</td>
<td>1</td>
<td>I</td>
<td>Students will demonstrate effective reading of technical material.</td>
</tr>
<tr>
<td>8.4</td>
<td>1</td>
<td>X</td>
<td>Students will demonstrate effective interpretation of graphical data.</td>
</tr>
<tr>
<td>9.1</td>
<td>2</td>
<td>R</td>
<td>Students will practice good teamwork principles.</td>
</tr>
<tr>
<td>9.2</td>
<td>2</td>
<td>X</td>
<td>Students will demonstrate experience working together in teams.</td>
</tr>
<tr>
<td>10.4.2</td>
<td>3</td>
<td>I</td>
<td>Students will be introduced to single-stage flash calculations.</td>
</tr>
<tr>
<td>10.6.1</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to calculations involving work in turbines and compressors.</td>
</tr>
<tr>
<td>11.2</td>
<td>2</td>
<td>I</td>
<td>Students will be introduced to the AIChE code of ethics.</td>
</tr>
</tbody>
</table>