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Fall 2019

CHE 342-003: Chemical Engineering Thermodynamics II

Richard T. Cimino

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1. **ChE 342 - Chemical Engineering Thermodynamics II**
2. **Credits and contact hours:** 3-0-3 (3 lecture hr/wk - 0 lab hr/wk - 3 course credits)
3. **Course Coordinator:** Dr. Gennady Gor
4. **Course Instructor:** Dr. Richard T. Cimino
5. **Textbook:** Fundamentals of Chemical Engineering Thermodynamics, Kevin D. Dahm, Donald P. Visco, Cengage Learning, (2014). ISBN: 1111580707
6. **Specific course information**
    a. **Description:** The principles and methods developed in Chemical Engineering Thermodynamics I are extended to multicomponent systems, and used to treat phase and chemical equilibrium as well as such applications as chemical reactors and refrigeration systems.
    b. **Prerequisites:** ChE 230, Math 211 (or Math 213), Chem 236
    c. **Required, Elective, or Selective Elective** - Required
7. **Specific goals for the course**
    a. A student should be able to:
        1. Calculate efficiencies for reversible and practical cycles, such as Carnot, Rankine & Brayton
        2. Calculate heat absorption and heat rejection rates for cycles
        3. Calculate work of turbines & pumps
        4. Analyze internal combustion engines & gas turbine engines
        5. Analyze refrigeration cycles & liquefaction processes
        6. Apply Raoult's law and Henry's law to solve thermodynamics problems
        7. Predict behavior from liquid/vapor phase diagrams including azeotropes
        8. Carry out bubble and dew point calculations for a given mixture
        9. Calculate partial properties of binary solutions, such as partial molar volumes
        10. Calculate activity coefficients using correlating equations such as Margules and Lan Laar
        11. Determine VLE using ideal gas and ideal solution models
        12. Analyze appropriate models for calculating phase equilibrium
        13. Interpret phase diagrams of binary systems
        14. Calculate vapor-liquid equilibria for non-electrolyte systems
        15. Predict equilibrium compositions of mixtures under phase equilibria
        16. Apply concepts of equilibria of multi-component, multi-phase systems to the evaluation and design of separation processes, such as distillation
        17. Estimate the fugacity coefficients for given mixtures
        18. Analyze ideal gas/solution models that reflect behavior of real mixtures based on concepts of excess free energy and chemical potential
    b. This course explicitly addresses the following ABET student outcomes:
        1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
8. **Topics**
    1. Heat Engines
    2. Refrigeration Processes
    3. Vapor-Liquid Equilibrium
    4. Solution Thermodynamics

5. Solution Thermodynamics Applications
6. Chemical Reaction Equilibria

ChE 342: Chemical Engineering Thermodynamics II
Fall 2019

Instructor: Dr. Richard T. Cimino, Senior Lecturer
Office: 387 Tiernan Hall, Phone: 973-596-5729, E-mail: cimino@njit.edu
Class: Tuesday, Thursday, 8:30-9:50 PM; Room: Tiernan 114
Office Hours: TBA

Course Description and Requirements

This course will cover heat engines, refrigeration, thermodynamics of mixtures, phase equilibrium and chemical-reaction equilibrium. Solid knowledge of chemical engineering thermodynamics including these topics is necessary to succeed in more advanced chemical engineering courses. In particular, the current course is a pre-requisite for ChE 349 Kinetics and Reactor Design and ChE 360 Separation Processes I.
Pre-Requisites: ChE 230, Math 211 (or Math 213), Chem 236

Course Objectives

Taking this course, a motivated student will learn to:

- Use the laws of thermodynamics to analyze basic power and refrigeration cycles.
- Apply both fundamental and practical knowledge of thermodynamics to the design of basic power and cooling cycles.
- Apply concepts of thermodynamic to solutions.
- Determine equilibrium compositions of chemical reaction products and two-phase liquid/vapor mixtures.

Learning Materials

Textbook Required: Fundamentals of Chemical Engineering Thermodynamics, Kevin D. Dahm, Donald P. Visco (2014). ISBN: 1111580707
Additional: Introduction to Chemical Engineering Thermodynamics, Seventh Edition, J.M. Smith, H.C. Van Ness and M.M. Abbott, McGraw-Hill (2005). ISBN: 0-07-310445-0

Other Learning Material: The textbook is the main source for preparing for classes and reading the textbook before each class is necessary. Additional materials will be posted on Canvas.
Calculator: A high-end calculator (TI-83, TI-84 or TI-84SE) is required for solving exam problems.
Software: Use of Matlab, Python or other computational software is strongly recommended for working on homework assignments.

Course Outline

	Date	**Topic** (preliminary, subject to minor changes)
1.	Sep. 3	Recollection of Thermo I and PChem.
2.	Sep. 5	Carnot Cycle (PV and TS diagram).
3.	Sep. 10	Rankine Cycle.
4.	Sep. 12	Vapor Compression Refrigeration Cycle.
5.	Sep. 17	PH-diagrams. Examples.
6.	Sep. 19	Examples on Refrigeration.
7.	Sep. 24	Basics of Liquefaction. Joule-Thomson Process.
8.	Sep. 26	Liquefaction. Linde and Claude Processes.
9.	Oct. 1	Midterm 1.
10.	Oct. 3	Phase Equilibrium for Pure Components: Gibbs Free Energy.
11.	Oct. 8	Phase Equilibrium for Pure Components: Vapor Pressure.
12.	Oct. 10	Chemical Potential and Fugacity.
13.	Oct. 15	Fugacity from EOS. Poynting Method.
14.	Oct. 17	Introduction to Mixtures.
15.	Oct. 22	Properties of Mixing. Partial Molar Properties.
16.	Oct. 24	Partial Molar Properties of Binary Mixtures.
17.	Oct. 29	Pxy and Txy Diagrams. Raoult's law. Bubble and Dew Points Calculations.
18.	Oct. 31	Dew T calculation. Two-component PT Flash. Lever Rule.
19.	Nov. 5	Midterm 2.
20.	Nov. 7	Three-component Flash. Modified Raoult's Law. VLE Calculation Based on it.
21.	Nov. 12	Phase Equilibrium for Mixtures. Mixture Fugacity.
22.	Nov. 14	Raoult's and Henry's Laws from Mixture Fugacities.
23.	Nov. 19	Fugacity from Generalized Correlations and Virial EOS.
24.	Nov. 21	Gibbs Free Energy Models. One- and Two-parameter Margules Equation.
25.	Nov. 26	Data Reduction Procedure Using Margules Equation.
26.	Dec. 3	Wilson and Van Laar Equations. Thermodynamic Consistency. Integral Test.
27.	Dec. 5	Basics of Chemical Reactions Equilibrium.
28.	Dec. 10	P and T Effects on Reaction Equilibrium. Van't Hoff Equation.

Assessment and Grading

Homework: Homework assignments will be given regularly, at least ten assignments per semester. The assignments will be posted on Canvas. The homework (including both reading and problems assignments) must be completed by Tuesday's class of the week following the assignment, unless otherwise is explicitly stated. No late homework will be accepted. The homework assignment will be of two types, as detailed below.

Individual Assignments: Several assignments will be individual assignments. On these assignments, your work will be graded for completion.

Team Assignments: Other assignments will require you to work in teams of 4-5 students, handing in one team solution per assignment. These assignments will be graded for correctness. The instructor will designate the teams near the beginning of the semester. If a student's name appears on a solution, it certifies that they have participated in solving the problems.

Individual Accountability on Team Assignments. Solution outlines - Each team member

must set up the homework problems individually before the team gets together to work out the details. Solution outlines will be required to be turned in to the instructor on team assignments, and will be checked for completion.

Peer Evaluation: You will use the Comprehensive Assessment of Team Effectiveness (CATME, `www.catme.org`) to evaluate the teaming behaviors of yourself and your teammates. These evaluations will be incorporated into the assignment of final homework grades.

Upon evaluation, each student is assigned a multiplier related to how you and your teammates rated your performance. Your multiplier ranges from 0 to 1.05 and is related to the team's average evaluation score. If your multiplier $= 1 \Rightarrow$, your rating is the same as the team average; $< 1 \Rightarrow$ your rating is less than the team average; $> 1 \Rightarrow$ your rating is greater than the team average. Your final team homework score is then weighted by this multiplier:
e.g. 90% total Team Homework score $\times$ (1.05) = 94.5%

Conflict Resolution: Consult with your instructor immediately if a conflict arises that cannot be worked through by the team.

Firing: If a team member refuses to cooperate on an assignment, their name should not be included on the solution. If the non-cooperation continues, the team should meet with the instructor so that the problem can be resolved, if possible. If no resolution is achieved the cooperating team members may notify the uncooperative team member in writing (by email, cc the instructor) that they are in danger of being fired. If there is no subsequent improvement on the next assignment, the team should notify the uncooperative team member in writing (by email, cc the instructor) that they are no longer with the team.

Quitting: Students who are consistently doing all the work for their team may issue a warning (by email, cc the instructor) that they will quit unless they start getting cooperation and a second memo (by email, cc the instructor) quitting the team if things do not improve.

Students who are fired or quit must meet with the instructor immediately, or they will get zeros for the remaining assignments. Students who quit will be allowed to join another team (cannot exceed 5 members) or to work the homework problems alone, by their own choice. If a student decides to work alone, they may not later ask to join a team. Students who are fired may work together (if there is more than one at any time). Otherwise, they must work alone.

Quizzes: Regular quizzes will be given based on the homework material, including both concepts and problems. The quizzes will not be announced in advance, so please be prepared to have a quiz during every class. No make-up quizzes will be allowed. All quizzes will be closed book with no material allowed. The quizzes will often take place at the beginning of the class, so being on time is strongly encouraged.

Exams: There will be two midterm exams (1.5 hours long) and one final exam (2.5 hours long). All exams will be closed book, however a handwritten sheet (double-sided, letter size) with materials used to prepare for midterm exams will be allowed. For the final exam two sheets are allowed. Shared or copied preparation sheets, as well as use of any electronic materials will be considered as a violation of academic integrity.

Homeworks (team)	10%
Homeworks (individual)	5%
Quizzes	10%
Midterm #1	20%
Midterm #2	25%
Final Exam	30%
	100%

Percent	Grades
above 85%	A
above 80%	B+
above 75%	B
above 70%	C+
above 65%	C
above 55%	D
below 55%	F

Important Dates

- Midterm exam #1: October 1, 2019
- Midterm exam #2: November 5, 2019
- Final exam: between December 14 and 20, 2019
- Withdraw Deadline: November 11, 2019

Policies

NJIT Honor Code: The NJIT Honor Code will be upheld and any violations will be brought to the immediate attention of the Dean of Students.
Special Needs: If you need accommodations due to a disability please contact Chantonette Lyles, Associate Director of Disability Support Services, Fenster Hall Room 260 to discuss your specific needs. A Letter of Accommodation Eligibility from the Disability Support Services office authorizing your accommodations will be required.
Lectures

- Attendance is strongly recommended. Attendance sheet has to be signed at the beginning of each class. The examples discussed in the class are not necessarily from the main textbook and therefore missing a class will have consequences for preparation to quizzes and exams.
- The classes start at 8:30, and the students must be in class by that time. Being late to class may have consequences for the grade, since many of the classes will start from quizzes.
- Electronic devices other than calculators (laptops, tablets, cell-phones etc.) are not permitted during the classes. No audio or video recording is allowed.
- Cellphones should be turned off during both lectures and exams and not allowed under any circumstances.
- Laptops will be permitted only if necessary for class activities.
- No eating any time during the classes.

Course materials, office hours and correspondence

- The course Canvas page is the main platform for delivering information about the course. All relevant course materials and assignments will be posted on Canvas, so a student should check it regularly.
- The students have to upload a professional-looking head shot for their Canvas profile.
- The students are strongly encouraged to attend Office Hours. Long questions, which require derivations will be discussed only during the Office Hours and will not be answered by email. Questions regarding grades can be discussed only during the Office Hours.
- E-mail and Canvas correspondence is intended only for quick questions. Questions which require a detailed discussion should be discussed in person during the Office Hours.

- All correspondence should be conducted in a professional style, using formal English.
- To assure quick response to your emails, please add "ChE342" in the subject of your emails.
- The instructor reserves the right not to respond to emails if the email does not have a greeting or a signature.

Exams, Quizzes, Homeworks and Grades

- A letter grade is based on the final score, calculated using an Excel spreadsheet in accordance with the Tables given in this syllabus. The assigned letter grade is final and cannot be negotiated.
- A student can dispute the exam scores within a week after the announcement of the score. Exam scores can be disputed during the official Office Hours, not during class time or via email.
- The graded exams must be returned within a week to be saved for the department course assessment initiative. If a student does not return the exam, the grade for this exam is zeroed.
- Students will get zero for not coming to quizzes, exams, or any other course activity. If students miss an exam due to extreme circumstances (such as a medical problem), they need to notify the instructor via email before the beginning of the exam, and bring proof of the circumstance to the Dean of Student's office. Only in the case of official approval from the Dean of Student's office, may a make-up be given at the discretion of the instructor.
- A student must show as many details when solving a problem during an exam of a quiz. Not showing the work will cause losing points even if the final answer is correct.
- Partial credits can be given for solving the exams problems.
- No partial credit will be given if there is not enough details to follow.
- The final answer should be always evaluated with respect to its reasonability. No partial credit will be given if the final answer is wrong and unreasonable, and it is not stated.
- There will be no partial credits for the questions/problems on quizzes.
- Each quiz or team homework is worth 2% of the overall grade. Each individual homework is worth 1%.
- If a student misses a quiz due to a legitimate reason (absence approved by the Dean of Students), this quiz is excluded from the calculation, and the weights of the quizzes are scaled proportionally.
- Student handwriting must be legible in order to receive points.
- A student coming to dispute a grade has to bring completed homework sheets. No discussion of grades will be held without completed homework.

Homework Format

- Staple a cover sheet (does not need to be engineering paper) with your group's names, the date and the homework assignment number as the first page of each homework set.
- Headers - The five boxes at the top of each sheet of a homework assignment must contain the following printed information from left to right:

Staple	Name	Course & Section No.	Date Due	Page number/total pages

- Writing Mechanics - All homework should be carefully and legibly printed in pencil. If it can't be read, it can't be graded.
- Calculations - All homework calculations should be consistent with the following.
  - Include complete calculations for every calculation presented to demonstrate how results were obtained.

  - Include all units for each term in each equation. The units must balance.
  - Use the appropriate number of significant figures (often two or three) for all results (but use at least two extra significant figures in calculations).
  - Clearly indicate the final solution by boxing it in with a rectangle.
- Problem Order - Problems should clearly labeled, and presented in the order assigned (one, two, three, etc.).
- Problem Essentials - Problem solutions should include the following items in order.
  - Homework problem number listed at the beginning of the problem.
  - Brief problem statement. Provide bullet points of key aspects of the problem if it is longer than a few sentences.
  - The required information - the information or solution that we are looking for.
  - A straight-edge or carefully drawn diagram(s) that clearly illustrates the problem. Optional, but often needed.
  - The boxed solution of the problem including all required steps and calculations.