MIDDLE EAST TECHNICAL UNIVERSITY - Northern Cyprus Campus
Department of Chemical Engineering
CHME 204 - Thermodynamics I

Course Syllabus and Schedule for Spring 2013

Instructor

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If you have any questions about the course or need assistance, please contact me via e-mail at any time.

Teaching Assistant

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Ms. Esat will held two-hour (15.40-17.30) tutorial on Thursdays in Room TZ-13.

Course Objectives

At the conclusion of this course, you should be able to

1. Visualize different thermodynamic properties and distinguish between them.
2. Differentiate reversible processes from irreversible ones.
3. Carry out an energy balance on a given process.
4. Calculate the amount of heat transferred and work done to carry out a given process.
5. Estimate thermodynamic properties either by using equations of state or from charts and tables.
6. Write the entropy balance for a given process and calculate the change in entropy.
7. Determine whether a given process is thermodynamically feasible or not.
8. Calculate the thermal efficiency for a heat engine cycle.
9. Calculate the coefficient of performance and determine the heating and cooling load requirements.

Classroom Hours

F 09.40-12.30 (T-111)

Course Website

The course syllabus, homework assignments, and all handouts will be posted on **METU Online**. For additional information you may also visit my webpage:

http://www.metu.edu.tr/~itosun/courses.html

Textbook

M.D. Koretsky, *Engineering and Chemical Thermodynamics*, Wiley, 2004.

Recommended Textbooks

▶ S.I. Sandler, *Chemical, Biochemical, and Engineering Thermodynamics*, 4^{th} Ed., Wiley, 2006.

▶ J.M. Smith, H.C. Van Ness, M.M. Abbott, *Introduction to Chemical Engineering Thermodynamics,* 7^{th} Ed., McGraw-Hill, 2004.

▶ G.J. Van Wylen, R.E. Sonntag, C. Borgnakke, *Fundamentals of Classical Thermodynamics*, 4^{th} Ed., Wiley, 1994.

▶ Y.A. Cengel, M.A. Boles, *Thermodynamics - An Engineering Approach*, 7^{th} Ed., McGraw-Hill, 2010.

Exams

Two midterm exams will be given on the following dates:

Midterm Exam # 1: April 5, 2013
Midterm Exam # 2: May 10, 2013

If you miss an exam with a certified medical excuse, you may take a make-up exam at a designated time during the final exams (May 27 - June 8, 2013). It will be **CHALLENGING**.

All exams will be open-book (Koretsky's **original** book only) and open-notes (class handouts and your own handwritten notes, **NOT** homework solutions). It is your responsibility to understand the exam questions. If you have difficulty with English, you may bring a dictionary with you.

Grading

To get an **AA** in this course, you must attempt and do satisfactory work on all homework problems in addition to getting the necessary weighted average grade on tests.

A weighted average grade will be calculated as follows:

Midterm exams: 50% (25% each)
Homework: 15%
Final exam: 35%

There will be a **gray area** between each two letter grades in the final distribution, so that two students getting the same weighted average could get different letter grades. If you are in one of these gray areas, whether you get the higher or lower grade depends on three factors: (*i*) Class attendance and participation in class, (*ii*) Your performance on homework problems, (*iii*) Whether your midterm exams and homework performance has been improving (your grade goes up) or declining (it goes down).

Homeworks

You are encouraged to collaborate on the homework assignments, but you should write your answers **independently**. You should not copy solutions from a classmate or from solution sets from previous years to which you might have access. Presenting someone else's work as your own is **plagiarism** (or cheating) and will be dealt accordingly.

The homework format described below is intended to familiarize you with the way practicing engineers actually do their work. The format includes most of the elements required by professional engineering offices, and it includes common standards for the presentation of computations, tables, and graphs.

In professional practice, all written work is kept as a record of the engineering/design/construction process. Such records are needed to show that accepted engineering and design methodologies were employed, to establish professional responsibility for the work, to justify time sheets, to justify client billings, to permit error checking, and to provide a record of the as-built facility.

For these reasons, actual engineering worksheets contain information that identifies the responsible worker and checker, the date the work was done, the project name and account number, task name and account number, and page numbers, including the total number of pages in the task, so that missing pages can be detected. All work must be checked by others and must be filed for future retrieval and reference.

Therefore, it is essential that work results and records be presented in prescribed formats that are familiar to their users. The use of familiar formats makes data recovery and checking faster and more accurate, which enhances the productivity of the company. The details of the prescribed formats vary from company to company, but these variations do not mean that formats are unimportant.

Below are those format elements that should be used in submitting homework assignments. These same standards apply to examinations as appropriate. **WORK WHICH DOES NOT ADHERE TO THESE STANDARDS WILL BE RETURNED UNGRADED.**

1. Paper

- A-4 size MUST be used.
- Draw a margin of 2.5 cm on the left-hand side.
- Use one side of each page.
- Each problem should start on a new page.
- At the top of the page, indicate the course, student name, and problem number as the page sequencing information as shown below:

CHME 204	Binbirgece, Şehrazat	Homework # 1/4	3/18
Problem 4	Your work goes here		

2. Sample Solution

Problem 4 - One kilogram of steam is contained in a piston-cylinder device at 800 kPa and 250 °C. If it undergoes a mechanically reversible, isothermal expansion to 200 kPa, how much heat does it absorb? Also calculate the work done by the system.

SOLUTION

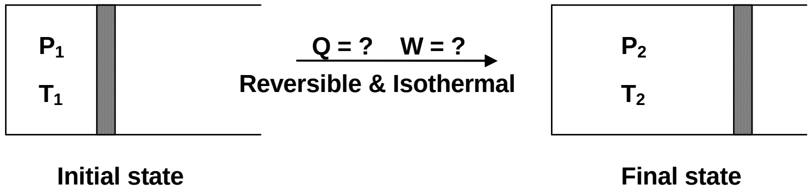
Given: 1 kg of steam in a piston-cylinder device

Initial state (State1): $P_1 = 800\,\text{kPa}$ $\quad T_1 = 250\,°\text{C}$

Final state (State2): $P_2 = 200\,\text{kPa}$ $\quad T_2 = 250\,°\text{C}$

Find: $Q = ?$ $\quad W = ?$

Schematic



System: Steam in the cylinder (closed system)

Thermodynamic properties: From Table B.4 in Appendix B

$$\widehat{U}_1 = 2715.5\,\mathrm{kJ/kg} \qquad \widehat{S}_1 = 7.0384\,\mathrm{kJ/kg.K}$$
$$\widehat{U}_2 = 2731.2\,\mathrm{kJ/kg} \qquad \widehat{S}_2 = 7.7085\,\mathrm{kJ/kg.K}$$

Analysis

The process is reversible and isothermal. Thus,

$$\widehat{Q} = T\,\Delta\widehat{S}$$
$$= (250 + 273)(7.7085 - 7.0384) = 350.5\,\mathrm{kJ/kg}$$

From the first law of thermodynamics for a closed system

$$\widehat{W} = \Delta\widehat{U} - \widehat{Q}$$
$$= (2731.2 - 2715.5) - 350.5 = -334.8\,\mathrm{kJ/kg}$$

$$\boxed{\widehat{Q} = 350.5\,\mathrm{kJ/kg}} \qquad \boxed{\widehat{W} = -334.8\,\mathrm{kJ/kg}}$$

3. Cover Page

Print the following information on the cover page of all assignments:

- CHME 204 - Thermodynamics I
- Last Name, First Name
- Assignment number
- Date
- Names of your collaborators

4. Instruments

All writing must be done in pencil and be easily readable, i.e., neatly printed or cursive letters of sufficient darkness. It is suggested a mechanical drafting pencil with grade 2B or softer lead be used. All straight lines are to be drawn with a ruler. It is suggested a 30 cm clear plastic ruler be purchased. This is also an aid in reading tables and figures. A template of common drawing shapes (squares, circles, etc.) and a "french" curve are also recommended.

FREEHAND CURVES AND FREEHAND STRAIGHT LINES ARE NOT ACCEPTABLE.

WORKING IN PEN (INK) IS NOT ACCEPTABLE.

5. Answers

Answers are to be clearly identified. A single answer must be submitted for each part of each question. The answer should be boxed.

6. Abbreviations

Use standard abbreviations. Use standard engineering notation. Do not invent abbreviations.

7. Accuracy

Avoid writing down excessive digits from calculations. Most data items should be written down to 2 significant decimal digits, i.e., molecular weights, constants, etc. Final answers should reflect no greater than 0.1% accuracy, i.e., 3 significant decimal digits.

8. Units

Much credit is lost in failing to use units in calculations. This does not just include writing down the units but "using them", i.e., cancelling units to determine the final units.

9. References

The source of all data and information used in your solution except that contained in the problem statement should be referenced. References must contain enough information so that your referenced data could be easily checked. Web references should contain a complete URL.

10. Sketches and Graphical Information

Provide a neat, labeled definition sketch of the problem.

If the solution is graphical, use the appropriate graph axes, i.e., arithmetic, semilog, log-log, to aid the reader in obtaining accurate data from the graph. Usually this will be obtained by selecting axes which "straighten out" curves as much as possible.

Whenever possible, use the built-in graphing/drawing capabilities in MS Word®, Excel® or MATHCAD®. If hand drawing is unavoidable, linework should be drawn neatly using straight edges and curve guides on an appropriate GRAPH PAPER[1].

Each sketch or graph must have a descriptive title and a figure number, and the number and title must be placed beneath the art work.

[1] You can download graph papers either from *http://www.printfreegraphpaper.com/* or *http://incompetech.com/graphpaper/*.

CLASSROOM RULES AND BEHAVIOR

• Attendance at every class meeting is strongly recommended. If you are one of those students with unexcused absences, do not expect me to spend time outside of the class to answer your questions related to the material covered during these absences.
• Always bring your downloaded notes and textbook to class since I will be referring to them often.
• Do not chat with friends during class meetings. Show respect for your instructor, yourself, and your classmates by paying attention in class and participating in class discussions.
• Do not arrive late to class and do not leave the classroom during class meetings. Exceptions may occur for medical emergency or situations where prior instructor approval has been granted.
• Cell phones should be turned off in the classroom and cell phone usage during class meetings is prohibited. If an unusual family situation requires you to be available, set your phone to vibrate and sit near the exit.
• Do not read other unassigned materials (newspapers, magazines, etc.) during class meetings.
• The consumption of food and drink (except water) during class meetings is prohibited.
• Sleeping in class or resting your head on furniture is not tolerated.

HOW TO SUCCEED IN THIS COURSE

> Thermodynamics is a funny subject. The first time you go through the subject, you don't understand it at all. The second time you go through it, you think you understand it, except for one or two small points. The third time you go through it, you know you DON'T understand it, but by that time you are so used to the subject that it doesn't bother you any more.
>
> Arnold Sommerfeld

As stated by Sommerfeld, thermodynamics can be difficult to grasp. A number of healthy habits will make it clear and coherent:

• **Believe that you, not me, are responsible for your learning.** As a mature and a responsible student, you are expected to take charge of your learning. You should **thoroughly** read up before the lecture, attend the lecture, then re-read. In addition, you should work through the problems in detail and seek out other resources as necessary to aid your understanding. The help you seek should not be on a problem-by-problem, piecemeal basis, but rather for clarification of main issues and ideas that emerge from your reading and problem sets.

• **Take note of concepts and statements that you do not understand.** Write down the things that are a source of difficulty and confusion for you. Then, seek out answers. Work through problems a second time. Consult a different textbook. Ask a peer. Avoid memorizing problem solutions.

• **Learn to be an independent learner.** The homework assignments help to develop and to strengthen your problem solving skills. Therefore, it is strongly suggested that you first try to solve the problems by yourself. Try to resolve difficulties by taking different approaches, working on different but related examples, or reading other texts. Then, discuss challenges in groups or in office hours if necessary (start early to allow time to discuss challenges and questions).

• **Pose yourself questions.** After working through a problem, ask yourself, "*What would happen in that problem if X were given instead of Y?*" Challenge yourself to think of possible variations beyond the examples in the lecture notes and homework problems.

• **Invest some time.** We all like to maximize the work-to-time ratio, but thermodynamics requires some quality practice to get familiar with the concepts, calculus, and mathematical manipulations involved. Don't be afraid to work extra examples in the notes, or find new books to consult. Your goal should not be to master the homework problems, but to master the subject material as a whole.

• **Know that it's normal to struggle.** Thermodynamics might be more challenging to you than you're used to in other courses. It should be that way. Avoid feeling competitive with other students. Your job is to learn. Others might have different backgrounds or understand things before you. If that's the case, seek them out for help. Never be too proud to ask questions or get help from students or the instructor. A little bit of struggle is expected, but you can always address that by seeking out the appropriate help.

PROBLEM SOLVING METHODOLOGY

A standardized approach to solving problems often is the best way to develop a problem's solution. These steps constitute a rational approach toward the completion of any engineering problem.

- Ask yourself what physically is happening in the problem you are trying to solve. Take notes when you explain to yourself what the problem is about. Indicate the given and required quantities.
- Draw a simple sketch and label its important components to help you understand the physical situation. Use a nomenclature that is convenient and well accepted. Define the boundaries of your system. Sometimes it is extremely helpful to use thermodynamic coordinates - try to draw the processes in an appropriate diagram (P-V, T-S, etc.) and label the states consistently with your sketch. This helps you visualize the processes and apply the basic concepts.
- List the simplifying assumptions. Make sure that your assumptions are justified and **REASONABLE**.
- Simplify the general equations describing the physical situation.
- If possible, express the equations in dimensionless form by defining appropriate dimensionless variables.
- Solve the equations analytically if this is easy or desirable, or numerically if analytical solutions are tedious or not possible.
- Substitute any numerical values required for quantification of the solution.
- **THINK!!** What do your solutions indicate, are they reasonable? Indicate limitations of your solution and revisit your assumptions and modeling simplifications.

In completing this procedure, the following additional considerations will help you to develop a good engineering approach. These will provide you with a better understanding of why you are using a particular procedure, not just what the steps are for a solution.

- Write legibly (illegible assignments will not be graded).
- Always use and keep track of units. Mistakes can frequently be identified through inconsistencies in the units.
- Number your equations, refer to them by number, and insert a few words here and there so that the reader can follow your analysis without having to guess what you are doing.
- If your solution involves the use of MATHCAD®, explain each step in the calculations by inserting comments. Do not just provide a series of equations.
- Any tables or figures used to present results should be described with text as well. These figures do not speak for themselves.

COURSE OUTLINE

1. Introduction

2. Definitions System (isolated, closed, open), State, Equation of state, Process, Intensive and extensive properties, Steady-state, Uniform, Equilibrium

3. Force and Pressure Constant pressure (isobaric) processes

4. Thermal Equilibrium and Zeroth Law Measurement of temperature, Constant temperature (isothermal) processes

5. Work The concept of work in mechanics, Kinetic energy and work, Classification of forces, Conservation of mechanical energy, Non-conservative forces, Internal energy

6. Heat

7. The Concept of Reversibility

8. Reversible and Irreversible Work

9. Properties of Pure Substances Pure substance, Vapor-liquid-solid equilibrium in pure substances, Property diagrams (temperature-volume, pressure-volume, pressure-temperature) for phase-change processes, Phase rule, Enthalpy, The use of steam tables

10. The First Law of Thermodynamics Unsteady-state energy balance

11. The Energy Balance for Closed systems Reversible processes (constant volume, isobaric, isothermal, adiabatic, polytropic) involving ideal and real gases

12. The Energy Balance for Steady-State Flow Systems Compressors and expanders, Throttling devices, Nozzles

13. Unsteady-State Applications of the Energy Balance

14. The Second Law of Thermodynamics Clausius statement, Kelvin-Planck statement, Heat engine, Carnot engine, Theorem of Clausius, Entropy

15. Calculation of Entropy Changes Property diagrams (temperature-entropy, enthalpy-entropy) involving entropy, Entropy change of pure substances, Entropy change of solids and liquids, Entropy change

16. The Steam Power Plant Rankine cycle, Deviations from ideal cycles

17. Refrigeration and Liquefaction Vapor-compression refrigeration cycle, Carnot refrigeration cycle, Liquefaction processes